

A Qualitative Content Analysis Examining the Biomechanical Implications of “Curling” and
“Keybedding” in the Taubman Approach

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Abstract

Many pianists are impacted by playing-related pain and injury, but a great deal is still unknown about the development and prevention of these problems. Several approaches to piano technique have been developed to provide technical recommendations based on scientific ideas. The anecdotal success of some approaches suggests that understanding the biomechanical concepts underlying them may be beneficial. However, these approaches are rarely discussed in the literature, in part due to linguistic inconsistencies among pedagogical and scientific disciplines. This has created obstacles to scientific evaluation of the claims made by pedagogues, and it has limited the degree to which knowledge transfer can occur among different fields. One approach that has been anecdotally successful in alleviating and preventing playing-related problems is the Taubman Approach, which aims in part to identify certain “sources of tension” that may increase the likelihood of developing physical problems.

This study used Qualitative Content Analysis (QCA) to examine sources on the Taubman Approach in order to identify claims about biomechanics underlying two different “Sources of tension:” “Curling” and “Keybedding.” The results from each QCA were then used to propose a biomechanical explanation of these concepts in language that is consistent with current scientific literature. The results of the analysis on “Curling” suggest that actively flexing the DIP/PIP joints requires activating multiarticular muscles, which can lead to increased muscle contraction, forces, and stiffness across multiple degrees of freedom when playing. Motions and positions proposed by the Taubman Approach as alternatives to “Curling” were also examined. The results of the analysis on “Keybedding” indicated that using excess fingertip force once the key is depressed may be problematic. Relevant aspects of the piano mechanism were identified, as well as recommendations for the proper setup at the keyboard that may impact muscle contraction,

forces, and stiffness once playing begins. Subjective terms were analyzed to differentiate biomechanical aspects of the recommended way to keep the key depressed from other ways that may be problematic. The hand and forearm were said to have an important role in generating the necessary fingertip force to keep the key depressed without using excessive muscle contraction across the finger joints. Both analyses also identified technical and physical problems that may be relevant to each concept. The findings in this study yielded insights into important issues related to the terminology used to describe piano technique in different contexts. These insights included the need for clear differentiation between subjective and objective language, as well as the need for understanding pedagogical language in context before knowledge transfer can occur.

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Table of Contents

Abstract	ii
Acknowledgements	iv
Table of Contents	v
List of Tables	ix
List of Figures	x
Chapter 1: Review of Literature	1
1.1 Pianists’ Injuries	2
1.1.1 Prevalence and Impact of Injuries	2
1.1.2 Types of Injuries	3
1.1.3 Potential Risk Factors in the Development of Injuries	5
1.1.4 Individual Factors	5
1.1.5 Psychological and Cultural Factors	6
1.1.6 “Overuse” vs. “Misuse” and Injury Prevention	6
1.1.7 Treatment of Injuries	8
1.2 Dorothy Taubman (1917-2013) and the Development of the Taubman Approach	8
1.2.1 Taubman’s beliefs about injury - Causes, Prevention, and Treatment	10
1.3 Historical Overview of Piano Technique - Taubman’s Approach in Context	11
1.3.1 The “Finger School”	13
1.3.2 The “Arm Weight” and “Relaxation” schools	13
1.3.3 Tobias Matthay (1858-1949)	14
1.3.4 Otto Ortmann (1889-1979)	15
1.3.5 Dorothy Taubman’s approach in context	16
1.3.6 Edna Golandsky and wider dissemination of the Taubman Approach	20
1.3.7 Sources on the Taubman Approach	21
1.3.8 Criticisms of the Taubman Approach	23
1.3.9 Criticisms from musicians	24
1.3.10 Criticisms from medical professionals	25
1.4 Conclusion: Taubman’s impact on the field	25
Chapter 2: Research Problem	27
2.1 Previous Research on the Taubman Approach	28
2.2 Research Questions	33
2.3 Research Aims	33
Chapter 3: Methodology	35
3.1 Choice of Method	35
3.2 Justification of Method	36
3.3 Sources analyzed	37
3.3.1 Taubman Approach Sources	37
3.3.2 Scientific Sources	39

3.4 QCA Methodology	40
3.5 Presentation of Analyses	44
3.6 Limitation of Analyses	45
Chapter 4: “Curling”	47
4.1 “What is “Curling?”	47
4.1.1 “Curling” is pulling fingers in from the nail joint	47
4.1.2 Fixating causes dual muscular pulls	50
4.1.3 “Curling” uses the long flexor muscle that pulls tightly under the wrist/fingers	56
4.1.4 “Curling” restricts up and down hand/finger motion	63
4.1.5 “Curling” prevents opening the hand	69
4.1.6 “Curling” and Stretching together creates dual muscular pulls	70
4.1.7 Don’t “curl” the thumb	76
4.1.8 Conclusion: What is “Curling?”	80
4.2 “Curling” in Context	81
4.2.1 Don’t line up all fingers to be the same length as a starting position	82
4.2.2 Don’t play in horizontal key spots/key spots must have an in/out relationship	83
4.2.3 “Curling” occurs when you pull the finger out instead of the arm	86
4.2.4 Don’t “curl” longer fingers to play white keys/to avoid the black key area	88
4.2.5 “Curling” can cause finger(s) to feel(s) too long	93
4.2.6 Don’t “curl” to prevent broken nail joints	93
4.2.7 Don’t “curl” when plucking in octave playing	95
4.2.8 “Curling” can occur because the wrist is too low	97
4.2.9 Conclusion: “Curling” in context	98
4.3 “Curling” leads to physical/musical problems	99
4.3.1 “Curling” can lead to pain/injury	100
4.3.2 “Curling”/fixating creates tension/tightness	100
4.3.3 “Curling” can cause fingers to stay curled/dystonia	107
4.3.4 Miscellaneous - problems associated with “Curling”	109
4.3.5 Conclusion: “Curling” leads to physical/musical problems	110
4.4 Miscellaneous - “Curling”	111
4.5 Fingers/hand should have natural curve/position	114
4.5.1 Natural curve position is the same as when the hand is at one’s side	114
4.5.2 Fingers should stay in the same relationship to each other	115
4.5.3 Nail joint should be relatively straight	115
4.5.4 Miscellaneous - Natural curve position	116
4.5.5 Conclusion: The “natural curve” position	124
4.6 Motions that prevent “Curling”	125
4.6.1 Fingers should only move from the main knuckle	126
4.6.2 Finger motions should use short flexors that don’t cross/pull tightly over the wrist	127
4.6.3 Natural curve allows fingers/hand to move freely	129
4.6.4 Correct in/out movements can prevent “Curling”	132
4.6.5 Playing in the black key area can prevent “Curling”	137
4.6.6 Conclusion: Taubman’s proposed alternative movements to prevent “Curling”	139
4.7 Conclusion: “Curling”	140

Chapter 5: “Keybedding”	153
5.1 Characteristics of the piano	153
5.1.1 The piano is a speed tool	154
5.1.2 The point of sound is where the hammer hits the string	158
5.1.3 There is no sound on the bottom of the key	160
5.1.4 The keys are weighted	161
5.1.5 The keys hit back with equal force	163
5.1.6 Miscellaneous - Piano characteristics	164
5.1.7 Conclusion: Piano characteristics	165
5.2 Before playing	166
5.2.1 The fingers should rest down on the keys before playing	167
5.2.2 Don’t hover/relax before playing	168
5.2.3 Correct position/sitting height impacts resting down	169
5.2.4 Conclusion: Before playing	189
5.3 When playing	190
5.3.1 Finger should stand on the keybed	191
5.3.2 Don’t push on keys/keybed	192
5.3.3 Don’t hover when playing	194
5.3.4 Don’t relax when playing	195
5.3.5 Conclusion: When playing	210
5.4 Aiming	211
5.4.1 Aim to the point of sound	211
5.4.2 Don’t aim past point of sound	212
5.4.3 Follow through/don’t stop at the point of sound	212
5.4.4 Miscellaneous - Aiming	212
5.4.5 Conclusion: Aiming	214
5.5 Arm/Hand Support	215
5.5.1 The hand/arm should support the finger(s) when playing	216
5.5.2 The fingers should not isolate/play without support	218
5.5.3 Finger should be straight down/not tilted	220
5.5.4 Non-playing fingers should hover closely above/rest lightly on the keys	221
5.5.5 Miscellaneous – Support	235
5.5.6 Conclusion: Hand/Arm support	235
5.6 Problems Associated with “Keybedding”	237
5.6.1 Physical problems associated with “Keybedding”	238
5.6.1.1 “Keybedding” can cause tension	238
5.6.1.2 “Keybedding” can cause calluses/bleeding fingertips	239
5.6.1.3 “Keybedding” can lead to pain/injury/tendinitis	240
5.6.2 Technical Problems associated with “Keybedding”	242
5.6.2.1 “Keybedding” can cause harsh sound	242
5.6.2.2 “Keybedding” can limit playing speed	244
5.6.3 Miscellaneous - Problems associated with “Keybedding”	245
5.6.4 Conclusion: Problems associated with “Keybedding”	246
5.7 Miscellaneous - “Keybedding”	248
5.8 Conclusion: “Keybedding”	248
Conclusion	260

Appendix A: Coding frame for “Curling” analysis	264
Appendix B: Coding frame for “Keybedding” analysis	269
Appendix C: Photos of finger/hand positions related to “Curling” analysis	274
References	276

List of Tables

Table 4.1	<i>Conclusion: What is “Curling?”</i>	80
Table 4.2	<i>Conclusion: “Curling” in context</i>	98
Table 4.3	<i>Conclusion: “Curling” leads to physical/musical problems</i>	110
Table 4.4	<i>Conclusion: The “Natural curve” position</i>	124
Table 4.5	<i>Conclusion: Taubman’s proposed alternative movements to prevent “Curling”</i>	139
Table 5.1	<i>Conclusion: Piano characteristics</i>	165
Table 5.2	<i>Conclusion: Before playing</i>	189
Table 5.3	<i>List of terms used for “pushing” in different contexts</i>	193
Table 5.4	<i>Conclusion: When playing</i>	210
Table 5.5	<i>Conclusion: Hand/Arm support</i>	236
Table 5.6	<i>Conclusion: Problems associated with “Keybedding”</i>	247

List of Figures

Figure 3.1 <i>Example of a coded excerpt from the analysis on “Curling”</i>	42
Figure A1 <i>“Curling”</i>	274
Figure A2 <i>“Natural Curve”</i>	274
Figure A3 <i>“Lining up” the fingers</i>	274
Figure A4 <i>“Curling” and MCP extension</i>	274
Figure A5 <i>Extension from the “main knuckle”</i>	274
Figure A6 <i>“Curling” to play out with a longer finger</i>	274
Figure A7 <i>“Broken nail joint”</i>	275
Figure A8 <i>“Curled nail joint”</i>	275
Figure A9 <i>“Straight nail joint”</i>	275
Figure A10 <i>“Curling” with a low wrist</i>	275
Figure A11 <i>“Curled” thumb</i>	275
Figure A12 <i>Thumb in “Natural Curve”</i>	275

Chapter 1: Review of Literature

Introduction:

Over the past several decades, a growing body of research has drawn attention to the significant problem of pianists' injuries (Kok et al., 2016; Zaza, 1998), but a great deal remains unknown in the research community about the causes of these injuries (Wu, 2007; Baadjou et al., 2016). Many practitioners (Watson, 2009; Winspur & Wynn Parry, 1998) and researchers have recently begun to suggest that instrumental technique may be a significant factor in injury development. Historically, piano technique has mainly been taught on the basis of tradition, rather than scientific findings. More recently, a number of approaches to piano technique have been developed that attempt to use scientific concepts as a basis for "healthy" and "efficient" playing (Wheatley-Brown, 2011), but many of the specific recommendations given by these approaches have rarely been discussed in the scientific literature. One such approach is the Taubman Approach, which has developed a reputation for alleviating pianists' injuries and improving technical efficiency (Taubman Institute, 1986; Golandsky Institute, n.d.; Milanovic, 2012). Despite its anecdotal success, the Taubman Approach is not discussed very often in the literature related to the biomechanics of piano playing and injury prevention. The number of pianists who have claimed to be helped by this approach indicates that a deeper investigation into its premises could benefit the greater knowledge in a number of fields: piano pedagogy, biomechanics, performing arts medicine, and possibly others. The following Review of Literature will discuss previous research related to the prevalence and causes of pianist's injuries. Next, it will outline the historical development of the Taubman Approach as a tool for curing pianists' injuries. Finally, an overview of how the Taubman Approach fits into a larger historical context of different traditional schools of piano technique will be provided.

1.1 Pianists' Injuries:

In recent years, a great deal of research has been devoted to the subject of musicians' pain and injuries (Kok et al., 2016; Zaza, 1998; Baadjou et al., 2016; Wu, 2007; Silva et al., 2015). While there is evidence that these issues have existed for at least three centuries (Fry, 2000), the scientific community has only begun to investigate them in detail over the last three to four decades (Watson, 2009). Among instrumentalists, pianists are one of the most widely impacted groups (Cayea & Manchester, 1998; Ignatiadis et al., 2006). Studies have documented the experience of pain and injury among pianists of many different ages and levels. Many professionals (Kok et al., 2016; Guptill, 2011), university students (Bruno, Lorusso, and L'Abbate, 2008), teachers (Yoshimura et al., 2008), amateurs (Newmark & Lederman, 1987), and children (Gong et al., 2014) have reported pain related to piano playing. Pianists' injuries have also been reported in many different locations around the world, including parts of North America (Pak & Chesky, 2001), Europe (Shields and Dockrell, 2000), Asia (Furuya et al., 2006), Africa (Ajidahun & Phillips, 2013), and Australia (Allsop and Ackland, 2010).

1.1.1 Prevalence and Impact of Injuries: While there is a large body of evidence documenting the prevalence of pianists' injuries, the specific results of these studies can vary widely. A review of studies on pianists' injuries (Bragge, Bialocerkowski, & McMeeken, 2006) found that among 12 eligible papers, the prevalence rate ranged between 26-93%. This wide range may be partially explained by the fact that studies often differ in their definitions of performance related injury, as well as their methods of data collection and analysis (Russell, 2006). Additionally, the fact that musicians are sometimes reluctant to report problems (Fry, 2000) can make it even more difficult to understand the scope of the situation. That being said, prevalence rates among pianists are believed to be generally very high, likely similar to those of

other highly affected occupations (Russell, 2006; Bejjani, 2000). In addition to physical symptoms, playing-related injuries can have a variety of other impacts on individuals. Qualitative studies featuring interviews with injured musicians have revealed that these problems can be devastating to one's physical, emotional, occupational, and social life (Zaza, Charles, & Muszynski, 1998; Guptill, 2011). Regardless, musicians are expected to maintain a high level of performance throughout their entire lives (Watson, 2009). As a result, if they cannot find solutions to their problems, many pianists are forced to stop playing altogether (Russell, 2006).

1.1.2 Types of Injuries: Survey data indicates that pianists can experience playing-related pain in almost any area of the upper body, including the neck, back, shoulders, upper arms, forearms, hands, wrists, and fingers (Furuya et al, 2006; Bruno, Lorusso, & L'Abbate, 2008; Pak & Chesky, 2001). Many suffer from generalized pain in multiple areas, which can make treatment challenging (Wynn Parry, 2000). In addition to pain, some injuries can also result in symptoms related to a loss of tissue function, such as fatigue and decreased technical control (Fry, 2000). Diagnoses of musicians' injuries can be grouped into three general categories (in order of prevalence): musculoskeletal disorders and overuse syndromes, entrapment and peripheral neuropathies, and focal dystonias (Green, Chamagne, & Tubiana, 2000).

Musculoskeletal pain and "Overuse syndromes:" Musculoskeletal pain in musicians is often ascribed to overuse of the injured tissue. Such "overuse syndromes" are believed to occur when the "natural tolerances of the tissues...have been exceeded by use resulting in some degree of damage" (Fry, 2000). Symptoms of overuse injuries can include impaired function, as well as warmth, swelling, and pain in the affected area (Narducci, 2020). While similar overuse-related

injuries occur in other professions, they are significantly more common among pianists and other musicians compared to the general population (De Smet et al., 1998; Ignatiadis et al., 2008).

Musicians can experience musculoskeletal pain in a variety of different types of tissue, including muscles, tendons, ligaments, and joints (see Watson, 2009 and Narducci, 2020 for specific conditions). Among musicians' injuries, musculoskeletal disorders are often the most commonly documented. For example, Lederman (1994) found that of 672 injured musicians, 64% had musculoskeletal disorders. However, there is some disagreement around the biological causes of musculoskeletal disorders, and the lack of clear understanding about the physical changes that occur have led some to argue that the general symptoms attributed to "overuse syndrome" may actually encompass a number of different conditions (Watson, 2009; Winspur, 2003).

Nerve Entrapments and Peripheral Neuropathies: Upper limb nerve problems in musicians most commonly result from compression or entrapment by surrounding tissue; symptoms include pain, tingling, and possibly loss of sensation and motor control (Narducci, 2020; Watson, 2009). While neuropathies are less common among musicians than musculoskeletal problems, they are not altogether uncommon. Spinner and Amadio (2000) note that the prevalence rate of nerve compression syndromes among a number of studies on musicians ranges between 10-30%. Among these nerve syndromes they found that the most common problems were thoracic outlet, carpal tunnel (median nerve), and cubital tunnel (ulnar nerve) syndromes. Among pianists, Gohl and colleagues (2006) found that 3 of the 19 tested (16%) showed early signs of carpal tunnel syndrome.

Focal dystonia: Sometimes known as "musicians' cramp," focal dystonia is a typically painless condition in which muscles involuntarily contract, causing unusual postures and

hindering smooth movement (Hochberg & Hochberg, 2000). Focal hand dystonia is usually task specific, and therefore affects pianists' finger, hand, and arm movements at the instrument, more commonly on the dominant side (Altenmuller and Jabusch, 2010a). The onset is gradual, causing one to unintentionally play wrong notes and feel a lack of control, fluidity, and increased fatigue (Tubiana, 2000). Dystonia only occurs in about 1% of all musicians (Altenmuller and Jabusch, 2010a), but Lederman (2002) reported that out of 102 musicians with dystonia, the largest instrumental group was pianists (about 16%). Because of its detrimental effect on technique and the fact that successful treatment can be very hard to find, many cases of dystonia among professional musicians lead to career termination (Altenmuller and Jabusch, 2010a).

1.1.3 Potential Risk Factors in the Development of Injuries: The number of variables involved in the development of musicians' injuries means there is rarely a single cause and effect (Brandfonbrener, 2000; Allsop & Ackland, 2010). However, researchers have attempted to identify some contributing risk factors. Data on risk factors is typically correlational, which provides insufficient evidence for defining causal relationships (Baadjou et al., 2016). This has led to some disagreement among professionals regarding optimal prevention strategies.

1.1.4 Individual Factors: Individual factors such as gender and hand span are discussed in the literature, but the evidence related to these factors does not paint a clear picture. For example, Green, Chamagne, & Tubiana (2000) note that overuse syndromes are three times more common in women than men, while focal dystonia is more common among men. In contrast, a number of studies on pianists have found no significant differences in pain based on gender (Russell, 2006). Similarly, studies on hand span and pain have yielded conflicting results. Many have found a correlation between pain and hand span (See Boyle and Boyle, 2009 for a review), while others have found no significant relationship (Allsop and Ackland, 2010). Other individual

factors have also been identified as potential risks for incurring injury, including joint laxity, age, and antecedent trauma (see Green et al., 2000).

1.1.5 Psychological and Cultural Factors: Several psychological factors have also been identified as potentially significant for injury development. Increases in stress that typically accompany competitions, performances, and auditions can put musicians at risk (Brandfonbrener, 2000). Cultural beliefs that are common among classical musicians, like striving for perfectionism (Araujo et al., 2017) and “no pain no gain” (Bruno et al., 2005) may also increase the likelihood of injury development. That being said, there is no evidence to suggest that the injuries themselves are purely psychological in nature (Fry, 2000).

1.1.6 “Overuse” vs. “Misuse” and Injury Prevention: Given that many injuries are believed to occur as a product of “overuse” resulting from excessive repetitive motions (Fry, 2000; Sakai, 2002), it is also believed that certain practice habits can increase the potential for injury development. Some studies have found a correlation between the number of hours pianists practiced and their experience of pain (Alsopp & Ackland, 2010; Sakai, 2002). Others have found that rapidly increasing one’s amount of practice can be potentially harmful (Newmark & Lederman, 1987). Based on the premise that injuries are caused by “overuse” and excessive repetition, many researchers and clinicians advocate for prevention methods related to controlling practice behaviors. These can include limiting total practice hours, taking breaks, and gradually increasing practice length (Watson, 2009). That being said, the fact that many musicians practice for very long hours without incurring injuries (Fry, 2000) suggests that the number of hours alone may not be the most significant indicator of injury risk. In fact, Yoshimura and colleagues (2008) actually found that music teachers who practice less were more likely to experience pain. Because of these inconsistencies, some researchers have

discussed that factors related to certain methods of practice may be injurious. For example, Brandfonbrener (2000) states that playing the same musical passages repeatedly and without stopping can be problematic; however, she points out that there is no way to prescribe practice strategies from data alone.

Evidence that injuries are not solely caused by “overuse” and repetitive movement in itself has led to another perspective, which suggests that injury development may be more significantly impacted by the way pianists use their bodies at the instrument (Winspur & Wynn Parry, 1998). For example, Allsop and Ackland (2010) found a correlation between pianists’ injuries and some reported postures, including neutral wrist and elevated shoulders. In contrast to the term “overuse,” the idea that injury development has more to do with technique and ergonomics is sometimes called “misuse” (Winspur, 2003). As a result of the “misuse” model of injury development, many authors and practitioners now advocate for trying to prevent and cure playing-related problems by making changes to one’s technique (e.g. Watson, 2009; Narducci, 2020; Brown, 2000). Because correlational data is limited, some researchers have tried to use other biomechanical tools (EMG, motion tracking, etc.) to measure the impact of various ways of playing on the musculoskeletal system (e.g. Chong et al., 2015; Oikawa, 2011; see Visentin & Shan, 2011 for a review of EMG studies). In addition to empirical data, theoretical biomechanical analyses have also been used to try to determine optimal positions and movements at the piano (e.g. Wristsen, 1998; Harding et al., 1993). However, because of the limitations of this research, most technical advice from the literature consists of general recommendations of posture and alignment, rather than detailed recommendations of how to execute specific musical passages.

1.1.7 Treatment of Injuries: Once a pianist is experiencing pain or injury, it can be difficult to find help. In order to treat injuries that have already occurred, researchers and practitioners recommend a number of different possible treatments depending on the specific condition. Some treatments include total rest, physiotherapy and exercise, massage, injections, and in severe cases, surgery (Watson, 2009; Wynn Parry, 2000). However, musicians' injuries can be quite difficult to diagnose (Beijanni, 2000), and the variety of available treatments can often be overwhelming and confusing for patients (Lederman, 1994). For these reasons, finding a doctor with specialized knowledge of musician's problems is believed to be especially important (Watson, 2009). Based on the hypothesis that injuries may be caused by "misuse," a growing number of practitioners who specialize in musicians' health advocate for treating injuries by using knowledge of biomechanics (Watson, 2009; Winspur & Wynn Parry, 1998). Some practical recommendations may be given based on scientific studies on piano technique (Wristen, 1998; Watson, 2009), but a comprehensive approach to healthy piano technique is outside the scope of the current state of the literature.

1.2 Dorothy Taubman (1917-2013) and the Development of the Taubman Approach:

Dorothy Taubman was an American piano teacher from Brooklyn, New York whose career spanned from the 1940's until her death in 2013 (Milanovic, 2012; Schweitzer, 2013). During this time, she gained renown for using her approach to piano technique to cure pianists' injuries (Schweitzer, 2013; Taubman Institute, 1986). She did not originally have any affiliation with prestigious institutions or artists; however, many students from The Juilliard School began working with her in secret, which gained her a reputation as "the underground teacher" (Dyer, 1995; Taubman Institute, 1986). Taubman helped enough students to eventually earn a wider reputation as "The Pianist's Medicine Woman" (Wolff, 1986). Her abilities as a problem solver

and technical diagnostician led some to consider her a “miracle worker” and a “healer” (Beigel, 1994). Despite the somewhat mythical aura that was sometimes attached to her name, Taubman considered her approach to be “scientific” in nature, which she described as a body of knowledge that “allows for an ordered and rational means of solving technical problems” (Taubman, 1984, p. 145). She used this approach most extensively with pianists, but found that she was able to apply her principles of motion to other instruments as well (Dyer, 1995; Taubman Institute, 1986).

While she eventually gained notoriety for treating pianists’ injuries, Taubman’s inquiry into piano technique initially began in an attempt to discover the secrets of virtuosity (Milanovic, 2012). As she began teaching, she noticed that differences in ability did not seem to directly correlate with other factors like age, years of practice, or time spent doing technical exercises (Wolff, 1986; Stewart, 2011). She observed that many child prodigies could play very difficult repertoire with small hands and without the benefit of many years of muscle development, while many adults had practiced for years with little improvement (Taubman, 1984; Stewart, 2011). Upon further investigation, she did not attribute these differences solely to “talent,” but rather how individuals use their bodies at the instrument (Taubman Institute, 1995, vol. 1; Schweitzer, 2013). In order to learn more about piano technique, Taubman looked to scientific texts related to “anatomy, physics, and coordination” (Berkowitz, 1998, p. 9). Over the next five decades, she developed her own understanding of the various elements that make up what she called “coordinate motion” (Taubman Institute, 1995, vol. 1). When applying this understanding in pedagogical contexts, she found that many students’ techniques “blossomed” (Taubman Institute, 1995, vol. 1). As Taubman began teaching pianists who were suffering from pain and injury, she

found that the same principles of “coordinate motion” that allowed for technical efficiency also alleviated their physical symptoms (Wolff, 1986).

1.2.1 Taubman’s beliefs about injury - Causes, Prevention, and Treatment: Based on her private research and decades of experience working with injured players, Taubman developed certain beliefs regarding the causes, prevention, and treatment of pianists’ injuries. She disagreed with the classification of “overuse” as the main cause of musicians’ pain (Taubman, 1984). As evidence for this claim, she cited the many young children and adult amateurs she had encountered who experienced playing-related pain without many hours of practice or technically advanced repertoire (Wolff, 1986; Pratt, 1989). While she found that “accidental missteps” and bad ergonomics away from the instrument sometimes caused injuries, she concluded that most playing related symptoms were the result of what she deemed “misuse” related to “improper movement” at the instrument (Pratt, 1989; Taubman Institute, 1986; del Pico-Taylor & Tammam, 2005). As a result, she believed that the key to injury prevention was “proper technique,” which she considered to be a matter of skill and knowledge, rather than talent (Schweitzer, 2013; Taubman Institute, 1995, vol. 1). She recognized the “no pain, no gain” mantra as “false and dangerous,” (Taubman Institute, 1995, vol. 1) and she believed the pressure related to competitions was a likely contributor to the widespread problem of musicians’ injuries (Berkowitz, 1998).

Once an injury had occurred, Taubman’s experience led her to believe that the optimal method of treatment was technical retraining at the instrument, which she based on the principles of “coordinate motion” that she had uncovered through her research and decades of experience (Wolff, 1986; Milanovic, 2012). In some cases, this retraining amounted to “quick fixes” in specific technical contexts (Wolff, 1986). However, she claimed that very often, a long lasting

cure that also prevented further injury would require a full technical retraining: a comprehensive process of relearning how to move at the instrument starting from the most fundamental level (Dyer, 1995; Milanovic, 2012).

While Taubman advocated for open dialogue between music teachers and medical professionals, she disapproved of many commonly used medical interventions applied to pianists (Taubman, 1984). She claimed that many treatments, such as “therapeutic exercises” including stretching and strengthening, splinting, and surgeries were more hurtful than helpful (Taubman, 1984; Pratt, 1989; Wolff, 1986). She found that in many cases, injured pianists could find temporary relief from rest and medical interventions, only to find that their problems returned whenever they went back to playing (Pratt, 1989; Stewart, 2011). Instead of trying to treat specific symptoms of pain and fatigue as the end goal of treatment, Taubman believed that these symptoms were indications that one was engaging in harmful movements at the instrument (Taubman Institute, 1986). When retraining injured pianists, she found that “coordinate motions” at the instrument were “therapeutic” in nature; therefore, the process of learning to move “well” could serve as both re-education and treatment simultaneously (Wolff, 1986). In addition to playing-related pain, Taubman also found that her approach to retraining was successful in treating focal dystonias (Pratt, 1989).¹

1.3 Historical Overview of Piano Technique - Taubman’s Approach in Context:

Historically, piano technique has typically been taught on the basis of tradition, rather than a scientific understanding (Wristen, 1998; Taubman, 1984). Pianists who are part of distinguished “schools” of technique often take pride in their lineage (Milanovic, 2012), using a

¹ Taubman’s anecdotal success in using technical retraining to treat musician’s dystonia occurred long before similar ideas were taken up in the research literature (Milanovic, 2012). See de Lisle and colleagues, 2006 for one example of a more recent study on this subject.

pedigree of great artists as justification for the superiority of their approach over others (Visentin & Shan, 2011). When Taubman began investigating piano technique, she was looking to acquire knowledge that she believed was already widely known throughout the field (Berkowitz, 1998; Stewart, 2011). However, she found that there was actually a fundamental lack of consensus among pedagogues; many traditional approaches contradicted each other, and most had little basis in contemporary scientific knowledge (Taubman, 1984). While discovering the elements that made up her own approach, Taubman came to believe that many aspects of traditional approaches were both technically inefficient and physically harmful. Her outspoken criticism of these approaches put her at odds with many in the music community (Schneider, 1983).

Before discussing some of the basic principles that make up the Taubman Approach, a brief historical overview of certain prominent “schools” of piano technique can help contextualize Taubman’s work. First, the “finger” and “arm weight” schools will be discussed, followed by the work of two pedagogues that were significant predecessors of Taubman: Tobias Matthay and Otto Ortmann.² It is important to note that discussions of instrumental technique are often riddled with non-specific and metaphorical language, which can make it quite difficult to analyze pedagogical suggestions based on written words alone (Wheatley-Brown, 2011; Vant, 2007). Therefore, it can be hard to know when certain differences among pedagogues are based on terminology alone, or actual conflicting beliefs about technique³. However, because a great deal of pedagogical tradition is communicated verbally, choices in terminology can make a large impact on how students eventually play. Therefore, it is important to examine not only the

² For a more detailed historical overview of approaches to piano technique, see Gerig, 1974.

³ For example, Milanovic (2012) has suggested that differences of opinion between Taubman and Alan Fraser are likely due to “semantics” rather than actual disagreements on technique.

accuracy of word choice, but also how those words are applied in a particular context (pedagogical, scientific, etc.).

1.3.1 The “Finger School:” In the early days of the piano’s existence, evidence suggests that technical recommendations were mainly borrowed from that of its keyboard predecessors: the harpsichord, clavichord, and organ (Gerig, 1974; Wheatley-Brown, 2011). Possibly due to the light action and small keyboards of these early instruments, most discussion of keyboard technique from this time emphasizes the role of the fingers (Gerig, 1974; Boardman, 1955; Wheatley-Brown, 2011). Many pedagogues of this “finger school” advocated for “active” finger movements and “quiet” hands and arms (Boardman, 1955). The fingers were often taught to be actively flexed so they all form a horizontal line on the keyboard (Wheatley-Brown, 2011). An important premise of the “finger school” is that facile technique results from building the strength, flexibility, and independence of each finger so that all five fingers may be used equally (Gerig, 1974). Very often, this equality is achieved through technical exercises that consist of repeated patterns of passage work that are to be practiced daily⁴ (Wristen, 1999; Wheatley-Brown, 2011). Other exercises used by the “finger school” involve depressing all of the fingers into the keys and lifting one finger at a time as high as possible for building strength and independence (Milanovic, 2012; Taubman Institute, 1995, vol. 1). The “finger school” continued to be the dominant approach to piano technique into the middle of the 19th century (Boardman, 1955), and many of its principles and exercises have continued in popularity into the 21st century (Lin, 2002; Kong, 2001; Wristen, 1999).

1.3.2 The “Arm Weight” and “Relaxation” Schools: Contrary to the principles of the “finger school,” there have been many pedagogues who have placed less emphasis on the

⁴ For example, Czerny and Hanon wrote many well-known examples of such pattern-based exercises.

movements of individual fingers, and instead focused more on using the weight of the whole arm to depress the keys (Gerig, 1974; Boardman, 1955; Wheatley-Brown, 2011). Some believe that the increased emphasis on arm weight developed out of the physical demands of larger and heavier-action instruments starting in the mid-19th century (Boardman, 1955). That being said, there is also evidence that discussions of arm weight in keyboard technique existed at least as early as the time of Rameau and J.S. Bach (Robertson, 1991). Nineteenth century proponents of the arm weight school, such as Breithaupt, insisted upon using “relaxation” to allow gravity to assist in dropping the weight of the whole arm when playing, from the shoulder to the fingertip (Gerig, 1974). This school of thought also places great emphasis on the idea of “weight transference” when moving from finger to finger, in order to supplement the amount of force applied to each key and create evenness of tone (Robertson, 1991). Some influential “arm weight” pedagogues, such as Leschetitsky, encouraged greater wrist movement to increase the amount of “relaxation” in the playing mechanism (Boardman, 1955). As with the “finger school,” many principles of the “arm weight” school continue to be taught to the present day (Robertson, 1991).

1.3.3 Tobias Matthay (1858-1949): While he is sometimes considered to be part of the “Relaxation School” (Boardman, 1955; Wheatley-Brown, 2011), the work of English pedagogue Tobias Matthay is notable for several reasons. First, he is credited with being at the forefront of the movement beginning in the late 19th century that aimed to apply scientific ideas to piano playing (Siek, 2012). Matthay believed his pedagogy was based on the “natural laws” (Siek, 2012) related to anatomy and the physical properties of the piano mechanism (Boardman, 1955). Second, he emphasized the importance of pianistic movements that are so small as to be “invisible” (especially that of forearm rotation), which has been considered by many to be a

significant contribution to the field of piano pedagogy (Wheatley-Brown, 2011; Taubman Institute, 1995, vol. 3). At the height of his popularity, Matthay had the largest following of any artist-teacher at the time; however, criticisms of his teachings related to “relaxation” and “arm weight” caused his reputation to decline sharply in the middle of the century (Siek, 2012). While his name is barely known in most music schools today, Matthay’s writings have had an enormous impact on modern piano pedagogy (Wheatley-Brown, 2011). One can argue that many of his philosophies opened the door for future pedagogues like Taubman, who considered him to be “a genius” (Berkowitz, 1998, p. 10).

1.3.4 Otto Ortmann (1889-1979): The scientist and pedagogue Otto Ortmann became well known in the first half of the 20th century for conducting a series of scientific experiments on piano technique. In his published books, Ortmann was the first to attempt an elimination of all preconceived notions about piano playing and gather conclusions solely based on empirical observation (Gerig, 1977). His works detail aspects of anatomy, physiology, biomechanics, and piano mechanics (Wheatley-Brown, 2011). Based on his conclusions, he attacked theories of piano technique based solely on the fingers or arms, stating that both were extreme approaches focusing on only one part of the entire playing mechanism (Gerig, 1977). He also espoused an understanding of tone production purely based on the physical capabilities of the instrument, rather than more abstract and metaphorical discussions of sound that are common in the musical field (Gustafson, 2007).

Today, Ortmann’s works are controversial in the pedagogical community. Some argue that they are still extremely valuable and relevant to modern understanding of piano technique (Gustafson, 2007). However, others have argued that his work was more focused on discrediting other approaches to technique, rather than creating new understanding, and therefore it was more

damaging to the field than helpful (Siek, 2012). Ortmann's works are no less controversial in the scientific fields. The understanding of muscle function and biomechanics changed substantially in the 1950's (Anderson, 2004), several decades after Ortmann's experiments. Therefore, some of his experiments and conclusions are based on out-of-date premises. While it has been claimed that Ortmann had "enough understanding of allied sciences...to permit scientific conclusions" (Newman, as cited in Gerig, 1977), more recent publications have criticized the scientific premises behind his work, such as his incorrect use of terminology (Russell, 2006). That being said, Ortmann's books were highly influential in the several decades after their publication, and his ideas became the foundation for many later theories about piano technique and pedagogy (Gerig, 1977; Wheatley-Brown, 2011). Regardless of the "truth-value" of his conclusions, his pursuit of understanding piano playing through experimentation laid the groundwork for research that is being continued to this day (Palmer, 2006).

1.3.5 Dorothy Taubman's Approach in Context: Dorothy Taubman began teaching and investigating piano technique in the 1940's (Taubman Institute, 1986), less than two decades after the publication of Ortmann's books. Lamenting the "hearsay tradition" of piano pedagogy, she followed in the footsteps of Matthay and Ortmann by searching for a "science of technique" based on physiological principles of the hand and arm, as well as mechanical principles of the piano (Taubman, 1984). In order to better understand the body and the piano mechanism, she "spent hours in the library" reading some of the scientific literature available at that time (Berkowitz, 1998, p. 9). She frequently cited Ortmann's experiments as justification for her own pedagogical beliefs (Taubman Institute, 1995, vol. 1; Taubman, 1984), but she did not always agree with his resulting conclusions (Taubman Institute, 1986). While Taubman sometimes used

language that is consistent with modern scientific lexicon, she also sometimes used her own terminology to describe certain aspects of technique (Wheatley-Brown, 2011).

Based on her investigation and teaching experience, Taubman's approach to "coordinate technique" was built on two main principles: 1) "The finger, hand, and arm must each be asked to do only what it can do best, without stress or strain;" and 2) "The finger, hand, and arm must move together as a unit" (Wolff, 1986, p. 27). In her mind, the goal of "coordinate movement" was to use the "minimum effort for the maximum result" (Taubman Institute, 1995, vol. 1). She argued that if used properly, the body's natural physiology is capable of meeting all of the instrument's demands. Therefore, in order to acquire virtuosic technique, a pianist needs to learn how to use their body effectively to manipulate the physical mechanism of the instrument (Taubman Institute, 1986). This type of thinking, which began with Matthay, was a rather radical departure from the long tradition of pedagogical methods that advocated for building technique by using exercises to change the body's physical capabilities (Taubman Institute, 1986).

Taubman thought that exercises of repeated musical patterns were unnecessary because they involved excessive repetition outside of a practical musical context; she considered exercises for building strength, flexibility, and independence to be harmful because they encourage pianists to force their bodies to move in ways that contradict their natural physiology (Taubman Institute, 1995, vol. 1; Wolff. 1986).

In trying to understand how the fingers, hands, and arms can function as they "do best" at the piano, Taubman looked for certain concepts related to anatomy and physiology that could be applied to piano playing.⁵ These principles helped her to develop her approach based on the idea that all upper limb parts are physiologically designed to move most effectively in certain ways.

⁵ These concepts are covered in the first volume of the Taubman DVD's (Taubman Institute, 1995).

When each part moves according to its design, all parts can work as minimally as necessary to complete a musical task, which leads to a feeling of “effortlessness” that Taubman described as “physically euphoric” (Taubman, 1984, p. 152). Feelings related to “effort,” such as discomfort, fatigue, pain, etc. are thought of as symptoms indicating that one or more parts of the body is not functioning properly (Taubman Institute, 1995, vol. 1). One part is exerting too much effort, either as a result of its own “tension,” or as a compensation for another part that is too “relaxed” to do its own job (Taubman Institute, 1995, vol. 1). As a result of this belief, Taubman did not use the terms “tension” and “relaxation” in the same way they are used in scientific literature (Wheatley-Brown, 2011). For her, these terms seem to refer to opposite and extreme ends of the spectrum of muscle use. Therefore, she considered both conditions to be technically harmful (Wheatley-Brown, 2011). In the Taubman Approach, the goal of “coordinate motion” is to reach a state that Taubman described as neither “tense” nor “relaxed,” but “natural” (Berkowitz, 1998, p. 10), or “free and ready to move” (McBride Smith, 2012).

Taubman found that in order for all parts to work as minimally as possible, the finger, the hand, and the arm must “move together as a unit” (Taubman Institute, 1995, vol. 1). Implied in this principle of “unification” is an agreement with Ortmann’s belief that finger or arm-based pedagogical schools are incomplete because they focus on singling out specific parts of the whole playing mechanism (Stewart, 2011). She believed that the reason many pedagogues focused on specific body parts in isolation was that they based their technical ideology on what was most easily visible to them (Taubman Institute, 1995, vol. 1). Like Matthey and Ortmann, she believed that many of the individual elements of “coordinate motion” were either so small or combined with other motions in such a way that they could not be easily visible to the naked eye

(Taubman Institute, 1995, vol. 1).⁶ As a result, many pedagogues have focused on clearly visible finger movements and ignored smaller arm movements, which Taubman believed could lead to technical limitations and injuries (Taubman, 1984). On the other hand, she thought that focusing solely on the arm and “relaxation” often led pedagogues to neglect the finger movements necessary for playing in speed (Taubman Institute, 1995, vol. 1). Therefore, she felt that a successful technique requires using all of the parts of the playing mechanism (fingers, hands, and arms) effectively in coordination with each other in such a way that is consistent with their physiological design.

In conceiving what became the practical elements of her approach, Taubman relied on a small number of “facts and principles” about the musculoskeletal system that she felt were consistent among all individuals (Taubman Institute, 1995, vol. 1; Taubman Institute, 1986).⁷ She gathered this information as part of her independent research (Berkowitz, 1998), and used her understanding of these concepts to form a number of “basic principles” of piano playing that became the foundation of her approach (see Taubman Institute, 1995, vol. 1). These include her recommendations around aspects of proper positioning, such as sitting height, hand position, and alignment, as well as proper use of the fingers and arms. She also identified specific movements and postures as forms of “misuse” that could lead to technical inefficiency and injury (Taubman, 1984). Some examples of these “Sources of tension”⁸ include “Curling” the fingers, “Twisting”

⁶ For example, when one watches a pianist play very quickly, the fingers are the most visibly active part of the upper limb. However, Taubman believed that the arm must be moving in coordination with the fingers for the fingers to move easily, but the size of these arm movements is often so small as to be either nearly or totally undetectable to an observer (Taubman Institute, 1995, vol. 1).

⁷ These principles are described in the first of the Taubman Technique DVD’s (1995) and her presentation at the Biology of Music Making Conference (1984).

⁸ Taubman herself did not explicitly use this label to categorize all of these “harmful” movements together, but they are labeled as such by both Milanovic (2012) and Moran (2008).

the hand, positioning the wrist too high or too low, “Collapsing” finger joints, “Finger isolation,” “Stretching,” and “Keybedding” (Milanovic, 2012; Moran, 2008). She believed that avoiding these problems requires other, “coordinate” ways of playing, which allow for technical efficiency and prevent injuries from developing (Wolff, 1986; Taubman Institute, 1995, vol. 1).⁹ In the Taubman Approach, the process of identifying problematic movements and finding the correct, “coordinate” movements to replace them allows for a diagnostic, problem solving approach to passages that feel unplayable or physically uncomfortable (Durso, 2017; Topham, 2015; Milanovic, 2012).

1.3.6 Edna Golandsky and Wider Dissemination of the Taubman Approach: Edna Golandsky, who is now known as the leading exponent of the Taubman Approach (Milanovic, 2012), was in the middle of completing a master’s degree at Juilliard when she began studying secretly with Dorothy Taubman (Dyer, 1999; Taubman Institute, 1986). After achieving some success teaching Taubman’s approach, Golandsky later became Taubman’s primary associate (Taubman Institute, 1986). Golandsky and Enid Stettner helped Taubman to develop the annual two-week summer sessions called the “Taubman Institute” (Berkowitz, 1998), which began in 1977 (Dyer, 1999). At these sessions, Golandsky took over the role of delivering lectures on the approach (Taubman Institute, 1986). A set of these lectures was filmed and then released in 1995 as the first five Taubman Technique DVD’s (Taubman Institute, 1995); a second set of five DVD’s was added in 2003 (Taubman Institute, 2003). After several decades of collaboration, in which Golandsky refined and even added to aspects of the Taubman Approach, the two parted ways in 2002 due to a difference of opinions regarding the Taubman Institute (Milanovic, 2012).

⁹ Some important components of coordinate motion are Forearm rotation (discussed in DVD 2), the “Walking Hand and Arm,” (discussed in DVD 3) “In and Out” movements (discussed in DVD 4), and “Shaping” (discussed in DVD 5).

As a result, the Institute was replaced by two separate organizations: the Taubman Seminar and the Golandsky Institute (Milanovic, 2012). The latter was formed by Edna Golandsky and three of her students: John Bloomfield, Robert Durso, and Mary Moran (Golandsky Institute, n.d.). Since creating the Golandsky Institute, Edna Golandsky has also collaborated with the violinist Sophie Till to adapt the Taubman Approach to violin playing, and has also applied it to computer typing (Golandsky Institute, n.d.). The Golandsky Institute has worked to disseminate the approach to a more global audience via workshops, summer sessions, and videos, and it has developed a “Professional Training Program” that currently has 33 certified teachers located across the United States, Canada, Mexico, Europe, and Australia (Golandsky Institute, n.d.).

Outside of the Golandsky Institute, there are several other organizations dedicated to the Taubman Approach. Even since Taubman’s death in 2013 (Schweitzer, 2013), the Taubman Seminar remains active, and it is currently directed by one of her former students, Maria del Pico Taylor (Del Pico Taylor, 2004; Dorothy Taubman Seminar, 2018). Other former Taubman students, Teresa Dybvig and Sheila Page have independently created their own organizations: the *Well-Balanced Pianist* (Dybvig, 2019), and the *Keyboard Wellness Seminar* (Keyboard Wellness Seminar, 2016), respectively. Both of these organizations combine the Taubman Approach with other, more holistic approaches to musicians’ wellness. Despite the existence of these different Taubman Approach organizations, The Golandsky Institute remains the only one to have an accredited teacher training program, and so it continues to have the greatest influence on how the approach is taught in the present day (Milanovic, 2012).

1.3.7 Sources on the Taubman Approach: Taubman herself left very few written sources on the specific details of her work. She stated in interviews that she was working on a book detailing her approach (Pratt, 1989; Berkowitz, 1998). While the book was believed to be

about 80% finished around the time of Taubman's death (Milanovic, 2012), it remains unpublished at the present time. In addition to a presentation at the Biology of Music Making conference (Taubman, 1984), Taubman gave about a dozen published interviews; several others have also been given by Edna Golandsky and other former Taubman students (Milanovic, 2012). The most detailed resource on the approach from Taubman herself comes in the form of the 10 DVD set entitled *Virtuosity in a Box: The Taubman Techniques* (Taubman Institute, 1995/2003).¹⁰ In addition to the 10 DVD's, a one-hour documentary was made on Taubman's work, entitled *Choreography of the Hands: The Work of Dorothy Taubman* (Taubman Institute, 1986).¹¹

Since the creation of The Golandsky Institute, several other written sources of information have appeared on the Taubman Approach. The first is a beginner piano method book written by Golandsky Institute Board Member Mary Moran and edited by Edna Golandsky. The method book, entitled *Beginning Piano Lessons in the Taubman Approach: Basic alignment and rotation, Volume 1* (2008), provides many pictures and explanations related to the basic concepts and skills in the approach.¹² The second written source is a doctoral dissertation entitled *Learning and Teaching Healthy Piano Technique: Training as an Instructor in the Taubman Approach*, written by Golandsky Institute Associate Faculty Member Therese Milanovic (2012). In her thesis, Milanovic describes her own process of retraining in the Taubman approach with Edna Golandsky. Outside these written sources, the Golandsky Institute has produced a plethora

¹⁰ These videos consist of lectures given by Golandsky, in which she details the different aspects of the approach through verbal explanation and demonstration at the piano in a variety of musical contexts. These lectures are interspersed with comments from Taubman herself, as well as excerpts of her teaching masterclasses.

¹¹ This documentary includes interview footage with Taubman and some of her students, as well as some short masterclass excerpts, but it does not discuss many details of the approach itself.

¹² There is also a teachers' edition that provides more details for the instructor. While the subtitle, *Volume 1*, indicates that other books will follow, none have been published to date.

of video material on the approach that serve as resources on many of the details of the approach when put into practice. In addition to pedagogical sources, there are two ergonomic studies that have examined the Taubman Approach: one as it relates to piano (Pereira et al, 1997) and the other in the context of computer typing (Pereira, Tittiranonda, & Burastero, 2000). Gregory Dempster (1996) has also developed a “Typing & Mouse Manipulation Technique and Instruction Method” based on the Taubman Approach that aims to prevent injury associated with computer use.

1.3.8 Criticisms of the Taubman Approach: Despite her positive reputation among her students and supporters, Taubman was somewhat of a polarizing figure who received a great deal of criticism. Because of the almost mythical aura that surrounded her, she also developed a reputation as a “cult” leader (Schweitzer, 2013) or a “guru,” towards whom “disciples” flocked for salvation (Milanovic, 2012). Taubman and her supporters have shunned these characterizations, insisting that her success was not based on “miracles,” but rather the application of “profoundly simple principles” (Herman, 1997). Many of her detractors have found her views to be “inflexible and dogmatic,” (Schweitzer, 2012; Schweitzer, 2013), while former students have described her as being very open to new ideas (Schneider, 1998; Stewart, 2011); Taubman’s statement that she felt she was a good teacher because “I never stop being a student” (Taubman Institute, 1986) indicates that being open-minded was important to her identity as a teacher in spite of the accusations otherwise. However, she was quite outspoken in challenging the establishment in both the musical and medical fields, many of whom responded “with hostility” (Schneider, 1983). Taubman was neither a famous artist, an academic, nor a medical professional, (Milanovic, 2012) and her depiction as a “loveable-eccentric personality,” (Dyer, 1999) and a “tiny, sweet, arthritic, forgetful Brooklyn-Jewish grandmother” (Doherty,

1999) may have led to a perception that she lacked the credibility to challenge the wisdom of long-held musical traditions or highly educated medical professionals. Consequently, it seems that in her attempts to reconcile knowledge from the fields of music and science, she was often caught between them, and as a result she faced criticism from both sides.

1.3.9 Criticisms from musicians: Some major criticisms of Taubman’s work from the music field have come from those who believe there is “a different technique for every pianist,” (Topham, 2015). Taubman disagreed with this notion, as she believed that “basic principles” of physiology and motion could be applied across individual differences (Taubman Institute, 1986; Wolff, 1986). Other Taubman critics in the musical field believe that an analytical or scientific approach to piano playing destroys artistry (Stewart, 2011; Milanovic, 2012). Taubman countered these attacks by stating that “there is no separation between the technical and the musical,” (Wolff, 1986, p. 26) and that one’s “playing can only be as beautiful as the tools allow” (Taubman Institute, 1986). Some critics have attacked the sound produced by of Taubman pianists “willowy, even flaccid” (Herman, 1997); others have argued against specific aspects of the Taubman Approach, many of which contradict the premises of highly esteemed traditional approaches (Dyer, 1995). For example, many teachers support using finger exercises and strongly disagree with Taubman’s notion that they are harmful (n.a., 1986; Wilson, 1987a/b). Her ideas on forearm rotation have also been attacked by both pedagogues (e.g. Fraser, as cited in Milanovic, 2012¹³) and researchers (e.g. Wristen, 1998) as being potentially impractical or

¹³ Milanovic (2012) cites several criticisms of the Taubman Approach by both Fraser and his colleague Yankovic. Their statements were taken from online sources that have since been removed.

problematic.¹⁴ In response, Taubman and her supporters have attributed these criticisms to a lack of full understanding of the approach (Milanovic, 2012; Berkowitz, 1998).

1.3.10 Criticisms from medical professionals: In addition to musicians, the medical profession has also been “largely reluctant to embrace” Taubman’s work (Milanovic, 2012). While she stated that communication between teachers and doctors was important, Taubman’s outspoken criticism of commonly used medical interventions used to treat injured pianists (Taubman, 1984; Pratt, 1989; Wolff, 1986) likely did not help her garner support from the medical field. One early exception was the neurologist, Dr. Frank Wilson (Wolff, 1986), who was intrigued by her work and stated that “too many people appear to have been helped by her not to take her seriously” (n.a., 1986). More recently, several other medical professionals have endorsed the Taubman Approach (Golandsky Institute, n.d.), but it remains largely ignored in academic discussions related to biomechanics and injury prevention in piano playing.¹⁵

1.4 Conclusion: Taubman’s Impact on the Field

Despite the criticisms directed at her approach, Dorothy Taubman’s contributions to the field of injury-preventative technique have been “widely recognized” (Wheatley-Brown, p. 25). She seemed to believe that passing her work on to others was important (Wolff, 1986), but it appears she was also concerned about criticism and misinterpretation of her ideas (Berkowitz, 1998). These concerns, along with her belief that her work should be “scientifically proven” and “repeatable” (Beigel, 1994), often led her to be cautious in disseminating her approach, a fact

¹⁴ The well-known piano pedagogue Alan Fraser has been an outspoken critic of Taubman’s views on forearm rotation, but it has been argued that some differences between his and Taubman’s beliefs may be solely due to semantics (Milanovic, 2012). In fact, Fraser has recently stated that he has changed his opinion about Taubman’s ideas on rotation after participating in a workshop with a Taubman teacher (Fraser, 2017). That being said, rotation remains one of the most highly controversial aspects of Taubman’s work, likely due to the fact that she believed it is often an “invisible” part of pianistic movement.

¹⁵ Some exceptions are sources that briefly mention her ideas or contributions to the field, but not discuss specific aspects of her approach in detail (Greene, Champagne, & Tubiana, 2000, Chugunov, 2020).

which may explain the scarcity of sources that she left behind (Milanovic, 2012). However, the organizations that have promoted the Taubman Approach during her life and since her death in 2013 have greatly increased its popularity and acceptance throughout the music field over the last several decades (Stewart, 2011). Some of Taubman's former students currently hold positions in prestigious music schools,¹⁶ and several notable concert artists¹⁷ have publicly endorsed the Taubman Approach. The dissemination of the approach has been greatly widened by the work of the Golandsky Institute, which now has certified teachers on several different continents (Golandsky Institute, n.d.; Milanovic, 2012). Taubman's advocacy for musicians' injuries helped to bring attention to a subject that was not taken seriously in the music profession (Schneider, 1983) and largely ignored in the medical field at the time when she began her career (Watson, 2009; Fry, 2000). By the time of her death, many of her once controversial beliefs about injury prevention and treatment had entered the mainstream of thought in the research and medical communities; in contrast, others still remain contentious today.¹⁸ Taubman herself hoped that her work could have a lasting impact on the science of movement (Wolff, 1986). That being said, many of her specific ideas on instrumental playing remain to be examined in the scientific literature.

¹⁶e.g. Yehoved Kaplinsky, Chair of Piano at Juilliard, and Robert Shannon, Professor of Piano at Oberlin Conservatory (Taubman Institute, 1986).

¹⁷e.g. Leeds Competition winner Ilya Itin (Golandsky Institute, n.d.), concert artist Gabriela Montero (Herman, 1997), and Contemporary music expert Alan Feinberg (Schneider, 1983).

¹⁸ For example, it is now common to see practitioners advocate for technical retraining to correct biomechanical "misuse" (see Review of Literature above); however, many "therapeutic exercises" that Taubman criticized (Taubman, 1984) are still widely recommended (e.g. Paull & Harrison, 1999; Horvath, 2010).

Chapter 2: Research Problem

Introduction:

The Review of Literature above found that while pianists' injuries are a significant problem, there is still a great deal of disagreement among researchers and pedagogues regarding the causes and prevention of these injuries. In recent years, more emphasis has been placed on the role of technique in injury development and prevention (Watson, 2009; Winspur, 2003; Winspur & Wynn Parry, 2000). As a result, biomechanical studies have been conducted in an attempt to better understand how certain ways of playing may impact the musculoskeletal system. These studies include, but are not limited to: examinations of muscle activity (e.g. Oikawa et al., 2011), joint position (e.g. Harding et al., 1993), and dynamics of the upper limb and keyboard (e.g. Furuya & Kinoshita, 2008). One benefit of these studies is that they can measure quantitative data related to variables that are often difficult to perceive by the performer (e.g. muscle activity); however, they have a number of methodological constraints that can limit their generalizability to a wider population of pianists and musical contexts. For example, pianistic tasks are often very tightly controlled, which means they cannot accurately reflect the complexity of piano playing as it often occurs in a practical context. Furthermore, studies typically examine relatively low numbers of subjects, who may have unique physiology, movement patterns, or come from varied training backgrounds. Another issue is that these studies are often observational, and therefore do not allow researchers to study the impact of particular ways of playing over longer periods of time. Due to these methodological issues, there is still a large gap in the literature regarding specific technical advice that can be made based on scientific studies alone (Wrysten, 1998). Pedagogues, on the other hand, have the benefit of being able to work with many students to try different practical approaches and see how they impact

students over longer periods of time. However, pedagogues are not able to objectively quantify biomechanical data and control variables in the same way as scientific studies. As a result of the respective benefits and drawbacks of both the empirical and pedagogical approaches, dialogue between these two fields may be mutually beneficial. For these reasons, the need for more interdisciplinary discussion has been identified by medical professionals (Wilson, 1987b), researchers (Russell, 2006), and pedagogues (Taubman, 1984).

2.1 Previous Research on the Taubman Approach:

The anecdotal success gained by the Taubman Approach suggests it may be one example of a technical approach that could potentially help fill knowledge gaps regarding injury development and prevention. That being said, it has rarely been discussed in the scientific literature. There are only two published studies that have examined the Taubman Approach empirically. The first one, by Pereira and colleagues (1997), used Dynamic Postural Analysis to compare the wrist joint angles of Taubman teachers and students at the Taubman Institute. This study found that Taubman teachers spent less time playing at extremes of radioulnar deviation compared to students.¹⁹ The second empirical study, by Pereira and colleagues (2000), used qualitative ergonomic analysis to examine subjects who had suffered injuries related to computer use. Each participant had been retrained in computer use by using one of two different approaches, both of which were designed based on the principles of the Taubman Approach. This study found that participants with Taubman retraining in both groups typically exhibited

¹⁹ They found that Taubman students, who had varying amounts of experience with the approach “spent approximately 5 ½ times more time with wrists in extremes of radioulnar deviation than did instructors,” who had more experience with the approach. The authors point out that this study does not indicate causation, but rather suggests that the approach may assist pianists in learning to move at the instrument with less wrist deviation.

postures that may decrease their likelihood of injury.²⁰ While both of these studies were empirical, they focused on the results of training in the Taubman Approach. They did not examine its underlying theoretical framework related to the movements that may contribute to injury development.

In contrast to these two empirical studies, there are three other studies that have discussed the theoretical principles of the Taubman Approach. Milanovic (2012) documented her own process of retraining and becoming a certified Taubman teacher through the Golandsky Institute. Her thesis provides an “insider perspective” on the process of learning and pedagogy of the approach. This study details a significant amount of pedagogical information related to developing “healthy technique” as defined in the Taubman Approach. It includes a section devoted to six “sources of tension” that are considered significant potential causes of technical limitation and injury: “Curling” the fingers, “finger isolation,” “twisting” the hand, “stretching” the fingers, “Keybedding,” and playing with a “low wrist.” (see pp. 133-144). Milanovic’s discussion of Taubman’s beliefs related to injury development and prevention sometimes includes how certain scientific sources may relate to Taubman’s ideas. However, the main scope of her thesis is devoted to pedagogy and learning, and therefore does not allow for a detailed discussion of biomechanics. In addition to Milanovic’s study, Wristen (1998) discussed observations and recommendations of several historically significant pedagogues, and then proposed a new “theoretical biomechanical norm” for piano playing based on biomechanical science and observable motions captured on video. She also makes some of her own recommendations for injury prevention. While Wristen does discuss some of Taubman’s ideas in

²⁰ Results identified common features among all of these subjects, such as “standard ergonomic sitting posture,” and neutral wrist positions. Based on these conclusions, the authors state that “Taubman based movement retraining” may decrease risk factors for work-related injury.

a biomechanical context, the purpose of her thesis is to propose a new “biomechanical approach,” and so it does not include a direct analysis of the biomechanical principles underlying the Taubman Approach itself. Therefore, neither of these studies includes an in-depth biomechanical analysis of the Taubman Approach’s recommendations regarding the movements and postures that may be more likely to cause injury.

In contrast to these above-mentioned studies related to the Taubman Approach, one previous study has discussed some of Taubman’s ideas in relation to modern biomechanical understanding. In a master’s thesis, Wheatley-Brown (2011) examined the terminology used by Taubman and four other notable pedagogues to describe biomechanical concepts in piano technique. It documented how differences and inaccuracies in appropriating “scientific terminology” may contribute to confusion in the field of piano pedagogy. Wheatley-Brown examined how the five pedagogues used terminology related to the following concepts: “tension,” “relaxation,” “co-contraction,” “arm weight,” and “hand and finger shape.” She then compared their pedagogical usage of these terms to that of biomechanical science. Part of the results of this investigation indicated that some aspects of Taubman’s lexicon were either inconsistent with scientific literature, non-specific, or based on subjective feeling. In doing so, this study was a first step in incorporating some of Taubman’s ideas into scientific discussions of biomechanics and piano technique. However, while this study outlined the “systemic confusion” (p. ii) among pedagogues specifically related to language used in a pedagogical context, it did not include a deeper investigation of what that language was meant to convey within the larger context of the approaches themselves. In other words, this study found that some of the language used in the Taubman Approach is potentially problematic, but this study did not attempt to analyze the practical implications of that language and how they may or may not relate to

modern biomechanical understanding.²¹ Such an analysis would require an in-depth inquiry into the Taubman Approach that was not within the scope of Wheatley-Brown's study; therefore the biomechanical underpinning of the "sources of tension" still remains largely unexplored in the scientific literature.

Several issues may have contributed to the terminological problems in the Taubman Approach identified by Wheatley-Brown. One is the issue of the amount of time that has passed since the Taubman Approach was initially developed. Dorothy Taubman's inquiry into piano playing began in the 1940's, and the field of biomechanics has evolved substantially since that time (Anderson, 2004). While she validated many of her ideas based on Ortmann's work (Taubman, 1984; Taubman Institute, 1995, vol. 1; Milanovic, 2012), this research is now almost a century old; it is unclear if Taubman consulted more recent scientific developments that occurred during the span of her career into her approach. Given the significance of these developments, it is very possible that she used certain terminology based on sources that are no longer consistent with the current scientific literature. Furthermore, Taubman was primarily a piano teacher, rather than a scientist. She seems to have developed many of the specific aspects of her approach over several decades by examining her own technique and testing out her ideas with students (Berkowitz, 1998; Taubman Institute, 1995, vol. 1). In doing so, she would likely have spent a great deal of time trying to find language that succeeded in helping her students to move in certain ways. She would also have likely avoided language that may cause them to move in ways that she felt were problematic. Milanovic (2012) supports this idea, stating that the pedagogical language of the Taubman Approach has been specifically designed to convey the subjective, "embodied experience" of playing in a certain way (p. 257). She points out that

²¹ These implications could include the movements and postures that Taubman believed impact efficient and healthy piano technique.

metaphor is often used to convey meaning, and specific terms have been chosen to anticipate common problems. While “precise physical instructions” are also given as necessary (Milanovic, 2012, p. 258), the process through which the language of the Taubman Approach has been developed may have led teachers to prefer/avoid certain word choices for reasons that have little to do with biomechanical accuracy. Overall, the combination of time passed since Taubman’s initial investigation and the development of context-specific pedagogy may have yielded a lexicon that includes a mixture of scientific and pedagogical terms. This terminology may need to be learned initially in order to avoid confusion, especially if used in contexts where certain words may have other meanings (Milanovic, 2012) (for example, in scientific fields).

In establishing these issues of terminology in the Taubman Approach, the results Wheatley-Brown’s (2011) study exposes a potential problem for including Taubman’s ideas in scientific discussions of biomechanics and piano technique. If Taubman’s use of language is not entirely consistent with that of modern science, then her language in itself cannot be used as a clear basis upon which to engage her ideas in current scientific discussions. In attempting such a discussion based on language alone, it would be impossible to know if any differences between the two bodies of knowledge are solely due to problems with terminology, or instead due to actual substantive differences in the information that the language is being used to convey.²² Therefore, in order for Taubman’s perspective on piano technique to be accurately included in scientific discussions on piano technique, it would be necessary to analyze the language of the Taubman Approach, taking into account the various factors impacting her linguistic choices, and

²² Taubman seems to have been aware of the problem of conveying technical recommendations solely using language. She stated that while she believed Matthay’s contribution to the understanding of piano technique was substantial, she found that his ideas were not more widely accepted after his time because “many pianists and teachers who have taken the trouble to read his books...could not figure out what he meant and just how to do it” (Taubman Institute, 1995, vol. 3). Her awareness of this problem may have contributed to her hesitance to publish her ideas in written form (Beigel, 1994).

then substitute terminology that is either outdated, imprecise, or designed for a pedagogical context to be replaced with language that is consistent with equivalent modern scientific terminology. This would help to limit the potential for confusion and disagreement solely based on semantics (see Review of Literature above) and allow for a more effective transfer of knowledge between disciplines.

2.2 Research Questions:

Given the current gaps in the literature, several questions remain either totally or partially unanswered regarding the “sources of tension” identified in the Taubman Approach:

1. What are the underlying biomechanical concepts related to the “sources of tension” as identified in the Taubman Approach?
2. How can these concepts be expressed in language that is consistent with the language used in modern scientific literature?
3. What are the implications of understanding these concepts for the greater understanding and research on the biomechanics of piano technique?
4. How might the context of Taubman’s language have impacted her choices in terminology, and how does this understanding benefit transfer of knowledge between pedagogues and researchers?

2.3 Research Aims:

Given the potential benefits to both the musical and scientific communities, the aim of this study was to analyze some of the concepts in the Taubman Approach that relate to injury prevention. This analysis aimed to summarize those concepts in detail as they are presented in a number of sources on the Taubman Approach, and then to discuss their biomechanical implications using the equivalent contemporary scientific language. This study was conducted to

serve three general aims: 1) to help to bridge the gap between scientists, medical professionals, and pedagogues by summarizing and then discussing Taubman's ideas in language that is commonly used in the scientific literature; 2) to give greater clarity to concepts identified in the Taubman Approach by discussing the biomechanical issues related to those concepts in detail; 3) to help investigate how a better understanding of this approach may contribute to the greater knowledge of the biomechanics of piano technique. In addition to clarifying concepts and facilitating communication among professionals in various fields, this research also draws attention to unanswered questions about the biomechanics of piano playing. These questions can stimulate further investigation on the subject that would benefit the research, wellness, and musical communities as a whole. Calls have been made to include the Taubman Approach in more discussions related to musicians' health in the literature (Milanovic, 2012). Dorothy Taubman herself hoped that her work could "establish the foundation for the science of the movement of the fingers, hand and arm" (Wolff, 1986, p. 31). This suggests that she felt her ideas could contribute not only to scientific discussions of the piano technique, but also the larger field of biomechanics. Because of terminological differences among the fields of music and science, an analysis of the kind discussed above is necessary before her ideas can be more fully investigated.

Chapter 3: Methodology

3.1 Choice of Method:

The current study investigated the biomechanical underpinning of some of the “Sources of tension” identified in the Taubman Approach using language that is consistent with that in the scientific literature. Specifically, it focused on certain movements and postures that Taubman claimed to be potentially injurious. For the sake of clarity, these will be referred to as “Taubman concepts” for the remainder of this section. A number of Taubman concepts could have been chosen, but two were selected for the scope of this study:²³

1. **“Curling:”** described as “pulling the fingers in from the nail joint” (Milanovic, 2012, p. 546).
2. **“Keybedding:”** described as “aiming past the point of sound to press on the keybed” with “excessive force” (Milanovic, 2012, p. 204).

This study examined these Taubman concepts using qualitative content analysis (QCA). QCA is “a systematic method for searching out and describing meanings within texts of many kinds,” in which “both manifest and latent content are examined, as are meanings in context” (Drisko & Maschi, 2015, pp. 87-88). As opposed to “basic” or “quantitative” content analysis, QCA does not employ statistical methods; rather, it uses categorization to “both summarize the content found...and highlight key content” by interrogating and expanding that content (Drisko & Maschi, 2015, p. 88). While QCA is a systematic process of data analysis, it is also a flexible approach, in that it is tailored to the specific data and research questions of an individual study (Schreier, 2012). A specific methodology for QCA developed by Schreier (2012) was chosen to

²³ Brief descriptions are provided below. See Milanovic, 2012 for more detailed explanations of each concept.

carry out this analysis (see section 3.4 below for detailed description of this method). The content analysis of each Taubman concept in this study included two main parts:

1. A descriptive QCA of each Taubman concept was done first to summarize the information presented in the Taubman Approach sources. This analysis outlined both Taubman's description of the specific movement/posture, along with her justification for why it may be potentially injurious. Pianistic contexts in which that movement/posture may commonly occur were discussed where relevant, as well as her recommendations for alternative, "coordinate" ways of playing.
2. Next, a biomechanical analysis of the content from the Taubman Approach was provided in order to discuss Taubman's claims about each concept using language that is consistent with that in the contemporary scientific literature. This analysis included substituting specific terms related to anatomy and physiology, as well as clarification of any descriptions of certain postures/motions that use pedagogical or non-specific language.

3.2 Justification of Method:

While there are many other aspects of the Taubman Approach that could be investigated in a similar fashion and would likely be beneficial to the literature, the "Sources of tension" listed above were chosen because they directly relate to the issue of pianists' injuries and "misuse" (see Review of Literature). The Taubman concepts listed above do not constitute every form of "misuse" identified by the Taubman Approach. Due to the limitations of this study, these concepts were chosen because they are among the "Sources of tension" previously identified in

the literature by Milanovic (2012).²⁴ Both concepts are also listed among the “Sources of tension” in the Taubman Approach method book (Moran, 2008, pp. 17-19), and most are discussed in the first Taubman DVD (Taubman Institute, 1995, vol. 1) and her conference presentation (Taubman, 1984). Therefore, an analysis of these concepts was deemed likely to provide insight into some of the core components of the Taubman Approach and how it may contribute to larger discussions of injury prevention and piano technique.

QCA was chosen for this study because it allows for both a descriptive summarization of texts, as well as a deeper investigation into latent content (Drisko & Maschi, 2015). Because of the language issues that necessitate a biomechanical analysis of Taubman’s ideas, a basic content analysis looking to analyze her language quantitatively would be unable to provide a detailed analysis of those ideas using scientific language. QCA, on the other hand, allows researchers to describe and classify large amounts of data in a manner that is specifically related to particular research questions (Schreier, 2012). This type of analysis allowed for a clear separation of individual ideas related to each Taubman concept (“source of tension”) in a variety of contexts. The relationship between these ideas could then be investigated in order to better understand the biomechanical implications of each Taubman concept as a whole.

3.3 Sources analyzed:

This analysis was carried out using two different groups of source materials:

3.3.1 Taubman Approach Sources: Concepts were defined according to the Taubman Approach from a number of sources. Priority was given to sources from Dorothy Taubman herself:

²⁴ The other “Sources of tension” listed by Milanovic (2012) are “Finger isolation,” “Stretching,” “Twisting,” and “Low wrist.” Some of these topics are discussed in this study, but only as they relate to the two main concepts covered here.

1. *The Taubman Techniques*: 10 DVD's (Taubman Institute, 1995/2003), which consist of about 20 hours total. These DVD's include lectures by Edna Golandsky, with masterclasses and sporadic comments by Dorothy Taubman. The topics of the DVD's are as follows: 1) Introductory Principles and Concepts; 2) Forearm Rotation; 3) In and Out Arm Movements; 4) Walking Arm and Hand Movements; 5) Shaping and Octaves; 6) Grouping; 7) Leaps; 8) Interdependence of Hands; 9) Fingering; 10) Tone, Legato, and Enslavement to Notation. The first five DVD's were included in this study because they relate most directly to the topics involved.
2. Taubman's presentation at the Biology of Music Making Conference (Taubman, 1984)

Milanovic (2012) points out that the Taubman Approach has evolved to some extent in the years since the creation of the Golandsky Institute. Therefore, other materials produced by Edna Golandsky and her colleagues at the Golandsky Institute were used in order to supplement the above materials and provide greater detail for further clarification:

1. *Beginning Piano Lessons in the Taubman Approach: Basic alignment and rotation, Volume 1* (Moran, 2008): A beginner method book written by Golandsky Institute Senior Faculty Member, Mary Moran and edited by Edna Golandsky. The Teacher's Edition of this book provides many photographs and explanations for teaching the fundamental aspects of Taubman Approach. Topics include: sitting at the piano, common "Sources of tension," hand position, playing each finger, forearm rotation, and repeated notes.

2. *Learning and Teaching a Healthy Piano Technique: Training as an Instructor in the Taubman Approach* (Milanovic, 2012): a doctoral thesis, in which Milanovic describes her own process of retraining in the Taubman approach with Edna Golandsky. Milanovic frames this learning process in the context of Kolb's Experiential Learning Model and Zull's research into the biology of learning. It includes a detailed overview of the Taubman Approach that describes the basic principles, "Sources of tension," and many examples of how principles are applied to musical passages. Due to the length of this thesis, only Chapters 4 and 5 were used for this study because they relate most closely to the core aspects of the concepts being examined.

3.3.2 Scientific Sources: The following sources on anatomy, physiology, biomechanics, and musicians' health were used for general knowledge necessary for comparison with the Taubman Approach:

1. Musculoskeletal Anatomy and Physiology:
 - a. *Functional Anatomy: Musculoskeletal Anatomy, Kinesiology, and Palpation for Manual Therapists* (Cael, 2010).
2. Basic biomechanics:
 - a. *Fundamentals of Biomechanics* (Knudson, 2007)
 - b. *Applied Biomechanics: concepts and connections* (McLester & St. Pierre, 2008)
 - c. *Biomechanics of the Upper Limbs: Mechanics, Modelling and Musculoskeletal Injuries* (Freivalds, 2004)
3. Scientific sources specifically related to Musicians' Health

- a. *The Biology of Musical Performance and Performance-related Injury* (Watson, 2009)
- b. *Perspectives in Performing Arts Medicine Practice* (Lee, Morris, & Nicosia, 2020)
- c. *Medical Problems of the Instrumentalist Musician* (Tubiana & Amadio, 2000)

In addition to these sources, other scientific sources were used as necessary based on the material that needed to be analyzed. These sources included individual studies on general biomechanics, as well as those specifically related to piano playing.

3.4 QCA Methodology: A variety of QCA methodologies have been developed, each tailored to analyzing different types of material or research questions (Drisko & Maschi, 2015; Schreier, 2012). The QCA methodology chosen for this study was developed by Schreier (2012). In contrast to more fluid types of QCA, this method was chosen because it outlines a systematic sequence of steps that aims to emphasize reliability, which generally refers to the extent to which a coding frame “yields data that is free of error” (Schreier, 2012, p. 167). Because this study was descriptive in nature, reliability was thought to be a significant factor in the success of this study. Schreier outlines four main steps in the process of QCA:

1. **Data preparation:** The Taubman Approach sources were prepared for analysis. Videos were transcribed fully, and consulted later in the process in order to clarify physical demonstrations at the piano that could not be easily described in words. Then, video transcriptions were segmented into smaller units based on topics of discussion (“thematic criteria,” see Schreier, 2012, p. 134). After all sources were fully transcribed, a separate

version of each source was created to include only material deemed relevant to each concept.²⁵

- 2. Coding Frame Development:** QCA involves the development of a coding frame, which is a systematic way of categorizing material to give it clear structure based on the research questions of a particular study. In this study, categories were developed for each concept according to a systematic process (Schreier, 2012). Main categories were developed deductively, based on research questions. While the researcher's previous experience with the Taubman Approach was used generally to help guide the process of category development, sub-categories for each main category were largely developed inductively based on preliminary examination of the Taubman Approach source materials. Data-driven categories were developed using the technique of "subsumption," in which a first category was created based on an excerpt, and then following excerpts were either considered relevant to that first category, or a new category was developed (Schreier, 2012). This process was continued until all relevant data had been covered. Miscellaneous categories were added at each level (main and sub) to include material that did not fit into the established categories. Once categories were made, a coding frame was then developed, in which the name of each category was listed, followed by a description of that category, examples of what data may or may not be included, and decision rules to help determine whether or not ambiguous data belongs in that category.
- 3. Pilot Phase:** Once the preliminary coding frame was finalized, a pilot coding was done for each concept. This phase included categorizing excerpts into each code in order to test out the accuracy of the coding frame. Segmentation of the source materials into "units of

²⁵ For example, a separate version of each DVD transcript was created for the analysis on "Curling," "Keybedding," etc.

coding” (Schreier, 2012, p. 131) was done simultaneously with pilot coding. The aim of pilot coding was to increase the probability that codes accurately represented the information included in the Taubman Approach source materials, and therefore increase the reliability of the study.

- 4. Main Analysis:** After the pilot phase, coding frames were altered as necessary in an attempt to increase their reliability before final coding. Coding frames were then finalized, with no further changes made in order to increase reliability of final coding. The final coding of each category was conducted more than 10 days after the last pilot coding. An example of a coded excerpt has been provided below in Figure 3.1.

Please curl your fingers and move them up and down quickly. Now open your fingers as they fall naturally and move your fingers up and down. You will feel the difference in the freedom of motion. Now curl your fingers and move your hand up and down quickly. Again, open your fingers and move your hand up and down quickly. The difference is unmistakable.

Let me explain. In these movements we have used two different sets of muscles, long ones which extend from the tip of the fingers to the elbow and short ones from the tip of the fingers to the end of the hand. When you pull the nail joint inward, curling the fingers, the long flexor is being used. It pulls tightly under the fingers and the wrist. This creates the restriction of motion you experienced in both the finger and hand motions.

Figure 3.1. Example of a coded excerpt from the analysis on “Curling” (Taubman, 1984, p. 145-146). Colors correspond to various subcategories: yellow - “Curling” restricts hand/finger motion; green - “Natural curve” allows fingers/hand to move freely; red - “Curling” uses the long flexor muscle that pulls tightly under/over wrist/fingers; blue - fingers motions should use short flexors that don’t cross/pull tightly over the wrist; purple - “Curling” is pulling fingers in from the nail joint.

In QCA, two separate coders may analyze the material to increase the reliability of a particular study (Schreier, 2012, p. 34). However, if a second coder with sufficient knowledge of the topic of study is not available, coding can be verified by the first coder after a 10-14 day waiting period (Schreier, 2012, p. 34). In this study, a second coder with sufficient knowledge of the Taubman Approach was not available, so the primary researcher did both rounds of coding. Coefficients of agreement between the two coding sessions were calculated for each main category to assess reliability based on the following formula (Schreier, 2012, p. 170):

Percentage of agreement = (Number of units of coding on which the codes agree/Total number of units of coding) x 100

Because only one coder was used, these coefficients represent measurements of intra-coder reliability for the coding frame.²⁶ The mean coefficient of agreement for the analysis on "Curling" was found to be 94.90%. For the analysis on "Keybedding" the mean coefficient of agreement was found to be 97.81%. The mean coefficient for both analyses was 97.17%. After coding was completed, excerpts were displayed in tables to facilitate the process of summarizing each category. Each category was then summarized to describe the Taubman Approach excerpts coded within it (TA Summary). The aim of each TA Summary was to present the material related to the subject of that category, while also detailing the specific Taubman Approach sources from which that material was taken. One aspect of QCA is that it takes the context of language into account in order to better interpret its meaning (Schreier, 2012). The sources in this study cover a variety of contexts (lecture, masterclass, method book, academic writing), and so knowing the source of each excerpt was considered an essential part of analyzing the particular language used. In the TA summaries, the terminology contained in the Taubman Approach sources was used as often as possible. This was done in order to present that terminology to the reader and limit the amount of preliminary interpretation before the biomechanical analyses were conducted.

In addition to reliability, QCA is also concerned with the concept of validity, which Schreier (2012, p. 175) defines as the extent to which a coding frame "captures what it sets out to." In the current study, this relates to the extent to which each coding frame accurately

²⁶ According to Schreier (2012, pp. 172-3), coefficients of agreement should be interpreted in the context of a particular study. Inter-coder reliability is usually considered preferable to intra-coder reliability (Schreier, 2012, p. 191), so further research will be needed to more fully examine the reliability of the coding frames created by this study.

represents the corresponding Taubman concept (“Curling” or “Keybedding”). This type of validity is specifically referred to as “content validity” (Schreier, 2012, p. 189). The main researcher in this study is a pianist with several years of training in the Taubman Approach, whose experience was used to increase the validity of the QCA on the Taubman Approach sources. One way to further assess content validity is by consulting experts on the topic of study (Schreier, 2012, p. 189), For this study, a certified Taubman Approach teacher was consulted in order to help clarify certain concepts that were thought to be potentially ambiguous. This consultation occurred at various points throughout the course of the study, from the early stages of coding frame development to the process of finalizing the presentation of results (TA Summaries). This was done to help reduce potential inaccuracies in the results that may be caused by limitations and/or biases of the primary researcher.

After the TA Summaries were concluded for all categories related to a particular Taubman concept, the biomechanical analyses were conducted for those categories. These analyses were initially carried out by identifying key terms/concepts in each category that were considered essential to understanding the biomechanical underpinning of what was being described in that category. Then, the biomechanical sources relevant to those terms/concepts were investigated to identify equivalent terms/concepts in the scientific literature. Similar to the QCA, an expert in biomechanics who is also an accomplished keyboard player was consulted to discuss the relevant scientific concepts and how they may relate to the ideas contained in the TA Summaries.

3.5 Presentation of Analyses:

The more general, main categories were introduced, and then the sub-categories pertaining to that main were listed. For each sub-category, the results of the analyses were

presented in the following order: 1) TA Summary of the sub-category; 2) Biomechanical analysis of that sub-category. This presentation format was generally chosen to facilitate more direct comparison between the ideas presented in the Taubman Approach and the biomechanical analysis of those ideas. However, sometimes the ideas in more than one sub-category were related to one another in such a way that they needed to be analyzed as a group for the purpose of clarity. As a result, in some cases the TA Summaries of more than one sub-category were presented sequentially, followed by the combined biomechanical analyses of those sub-categories.²⁷ In order to differentiate the TA Summaries more clearly for the reader, they were presented with an indent. At the conclusion of each main category, a table was provided to summarize the biomechanical analysis of each subcategory. A more detailed discussion of the results from the full analysis of each Taubman concept was provided after the analysis of all the categories.

3.6 Limitation of Analyses:

Because the major aim of this study was to attempt to explain Taubman's ideas using language that is consistent with modern science, this study did not include any direct assessment of those ideas. Further research will be needed to determine whether or not the content of Taubman's ideas are consistent with modern scientific understanding. This was done both in order to confine the scope of this study solely to analyzing Taubman's language, as well as to avoid potential problems that may result when trying to define optimal criteria in piano technique.²⁸ The only exceptions to this were in cases where it was required in order to properly

²⁷ When this occurs, an introduction was provided to alert the reader to any deviation from the standard format.

²⁸ For example, it is unclear exactly what constitutes "better" technique from a scientific perspective (Kay, Turvey, & Meijer, 2003). Based on Taubman's criteria of using the "minimum effort for the maximum result," (Taubman Institute, 1995, vol. 1) this study will consider completing any particular pianistic task with minimum collective muscle contraction to be optimal.

transfer her language to scientific language. For example, if several meanings of her language were deemed plausible, then the researcher chose the option that was most consistent with modern anatomical or biomechanical understanding. This was done in order to maximize the potential benefit of knowledge transfer. An additional limitation of this study was that the biomechanical analysis of each category was done entirely qualitatively. Therefore, the ideas expressed in the Taubman Approach sources were discussed solely using verbal description, and no mathematical calculations will be included. Further research will be needed to analyze the ideas in this study using quantitative methods, which may be useful in determining the level of consistency between Taubman's ideas and current scientific understanding.

Chapter 4: “Curling”

4.1 What is “Curling?”

Introduction:

The first analysis in this study will focus on what the Taubman Approach sources call “Curling” the fingers. The first group of categories will pertain to the definition of “Curling” as it is used in the Taubman Approach sources contained in this study. These categories will include excerpts describing the physiological aspects of “Curling,” such as the joints and muscles involved. The biomechanical implications of Taubman’s use of the term “Curling” will also be discussed, including joint angles, muscle activity, and how “Curling” is said to impact the movement of various segments in the upper limb during piano playing. Finally, the term “Curling” will be discussed as it is applied to the thumb in the Taubman Approach sources. The following categories will be outlined in this section: 1) “Curling” is pulling fingers in from the nail joint; 2) Fixating causes dual muscular pulls; 3) “Curling” uses the long flexor muscle that pulls tightly under the wrist/fingers; 4) “Curling” restricts up and down hand/finger motion; 5) “Curling” prevents opening the hand; 6) Don’t “curl” the thumb.

4.1.1 "Curling" is pulling fingers in from the nail joint

TA Summary:

The term "Curling" is used differently among many different approaches to piano technique (Milanovic, 2012, p. 133). In Taubman Approach, "Curling" is defined as “pulling in” the last phalange of the fingers “from the nail joint” (Taubman, 1984, pp. 145-6; Taubman Institute, 1995, vol. 1; Moran, 2008, p. 22).

Analysis:

“**Nail joint:**” According to the anatomical literature, fingers 2-5 each have three joints (Cael, 2010, p. 130; Watson, 2009, p. 51-2):

- **Metacarpophalangeal joint (MCP):** connect the metacarpal bones in the hand to the proximal²⁹ phalanges of the fingers.
- **Proximal interphalangeal joint (PIP):** connect the proximal and middle phalanges of the fingers.
- **Distal interphalangeal joint (DIP):** connect the middle and distal³⁰ phalanges of the fingers.

Taubman uses the term “nail joint” to refer to most distal joints of fingers 2-5, which is equivalent to the “DIP joint” described in the anatomical literature.³¹

“**Pulling in:**” The DIP joints are capable of rotation in the sagittal plane (Cael, 2010, p. 4, 148):

- **DIP flexion:** When the distal phalanges move toward the palm.
- **DIP extension:** When the distal phalanges move away from the palm.

In Golandsky’s demonstration of “pulling in the nail joint,” (Taubman Institute, 1995, vol. 1) she is rotating the distal phalanges of fingers 2-5 at their DIP joints in order to move them toward the palm. Therefore, the equivalent biomechanical term for “pulling in the nail joint,” is “DIP flexion.”

²⁹ In the scientific literature, the term “proximal” means closer to the trunk (Cael, 2010).

³⁰ In the scientific literature, the term “distal” means further away from the trunk (Cael, 2010).

³¹ Ortmann (1929) also uses the term “nail joint” for the DIP joint, and so it is possible that Taubman began using it after reading his book.

Joint rotation can either be “active,” due to muscular contraction, or “passive,” due to external forces. The choice of the words “pulling in” indicates that the Taubman Approach typically uses the word "Curling" to refer to actively flexing the DIP joints out of their resting position.³² Golandsky’s statement that “any time we curl our fingers, we activate [the long flexor] muscle” (Taubman Institute, 1995, vol. 1, see category 4.2) further supports the association between the term "Curling" and active DIP flexion. It is unclear from this subcategory alone if passive flexion of DIP joints is also discouraged. The degree of DIP flexion that is considered "Curling" by the Taubman Approach will be discussed below in the discussion of the “natural curve” position (category 4.5). It is important to note that due to physiological constraints, flexing the DIP joints will also cause some flexion at the PIP joints.³³ This is not discussed in the Taubman Approach sources used in this study, possibly because "Curling" likely involves a greater increase in flexion angle at the DIP joint compared to the PIP joints. Another possible reason for discussing "Curling" solely as a DIP joint movement is that from a pedagogical point of view, "Curling" the fingers is often done to change the position of the fingertips (see below, subcategory 2.3). As a result, the pianist’s focus would likely be on DIP flexion, rather than PIP flexion when executing this movement. However, the fact that both of these joints must flex when "Curling" the fingers may be significant when considering the muscle activity involved in this movement.

³² The term “resting position” is used here to refer to the position of the finger joints when there is virtually no activity in the muscles that cross those joints. See category 4.5 below for more details on this position.

³³ This is due to the fact that the muscle that acts to flex the DIP joints (FDP), also crosses the PIP joints (Cael, 2010, p. 163). There is no opposing muscle (extensor) that crosses the PIP joints and does not also cross the DIP joints (see Cael, 2010 for descriptions of finger extensor muscles). Therefore, it is virtually impossible to flex the DIP joints without simultaneously flexing the PIP joints. The concepts related to these ideas will be discussed below in the analysis categories 4.1.3 and 4.1.4.

4.1.2 Fixating causes dual muscular pulls

TA Summary:

The Taubman Approach sources discourage “fixating,” “molding,” or “preparing” the fingers in any way before the pianist starts playing (Taubman Institute, 1995, vol. 1). Golandsky explains that doing so is problematic because “fixating is usually achieved by the use of contrary muscles, such as flexing and extending at the same time” (Taubman Institute, 1995, vol. 1). The Taubman Approach sources use the term “dual muscular pulls” when referring to activating opposing muscles at the same time (Taubman Institute, 1995, vol. 1).³⁴ Golandsky states that pianists should avoid doing so because dual muscular pulls cause tension (Taubman Institute, 1995, vol. 1). While “Curling” the fingers is not explicitly described as a form of fixation, Golandsky does discuss that pianists are often taught to mold their fingers into a curled position before playing. Therefore, it can be inferred that “molding” or “fixating” the fingers into a curled position would be one context that creates dual muscular pulls. How this relates to the specific context of “Curling” will be described in more detail below (see subcategory 4.2.1).

Analysis:

“Fixating,” “tightening,” or “preparing:” In order for a segment to maintain its position, the effect of forces acting to rotate that segment about its joint have to have a net value of zero. This brings the joint into a state called **rotational equilibrium** (McLester & St. Pierre, 2007, p. 199). In the above excerpt, Golandsky is likely using the terms “fixating” to describe placing the joint

³⁴ The excerpt that defines “dual muscular pulls” was not included in the original QCA on “Curling.” However, it was identified as relevant later on, and so it is referenced here for additional clarity in analyzing Taubman’s use of this term. Golandsky also uses the term “antagonistic pulls” to describe the same phenomenon (Taubman Institute, 1995, vol. 1).

in a state of rotational equilibrium in some way. The forces acting on a joint that can produce rotational equilibrium are not limited to those produced by muscle contractions. They can also include external forces, such as gravity. Therefore, it is possible for a joint to be in rotational equilibrium without a high degree of muscle contraction, as long as the forces acting on all sides of the joint are balanced. However, because Golandsky also uses the word “tighten” to describe the “muscular state of the fingers and hand,” she is likely referring to a state in which there is a high amount of resistance to rotation in any direction.³⁵ As a result, the fingers would only be able to move if a relatively high amount of force is applied to them. Her use of the term “preparing” indicates that she discourages “tightening” the fingers in this way before playing.

In mechanics, an object's ability to maintain a state of equilibrium when outside forces are applied is called its **stability**. A joint can be considered more stable when a relatively high force will be required to move it away from rotational equilibrium. Likewise, when a relatively small applied force can cause joint rotation, the joint can be considered less stable. If a force is applied to an object, the object may generate a force that tends to stabilize it by returning it to its equilibrium position. This force is called the object's **stiffness** (Knudson, 2007, p. 27). For example, when a spring changes length, the stiffness of that spring generates a force that tends to return the spring to its equilibrium position. If a spring generates a relatively high force that returns it to equilibrium, it is considered to have high stiffness. If a spring generates a relatively low force to return it to equilibrium, it is considered to have low stiffness. Like springs, muscles have stiffness properties, and so contracting a muscle increases the amount of force generated by

³⁵ In mechanics, the term “resistance” refers to any source of mechanical energy that acts in opposition to a force (Cael, 2010).

that muscle.³⁶ As muscles pull with more force, they increase in stiffness. The force generated by this pull can act to resist joint rotation in the opposite direction. Because joints do not have any stiffness properties of their own, the amount of stiffness across a joint is a product of the combined forces acting across that joint. The stiffness generated by muscle contractions can be used to resist forces tending to cause rotation about the joint and bring the joint back to equilibrium so that little movement occurs.

When applied to the upper limb, the concepts of stability and stiffness are interrelated. Because stiffness applies a force to return the joint to equilibrium, increasing joint stiffness will also make the joint more stable.³⁷ One interpretation of the excerpt above is that Golandsky is using the terms “fixating,” “tightening,” and “preparing” to describe using muscle contractions to create high levels of stiffness across the finger joints before one begins to play. This would also increase the stability of the joints if any force was applied that tended to cause rotation.

“Molding:” In the biomechanical sources, the joint position that requires virtually no muscular contraction is referred to as its **resting position** (Worley, 1989). “Molding” the fingers in this context likely refers to moving the finger joints into some position that is outside of their resting position, and then bringing the joints to rotational equilibrium in order to maintain that finger position. Golandsky discourages pianists from doing this to form a starting hand position before they begin playing. “Curling” the fingers to form a horizontal line as a starting position (see

³⁶ Muscle stiffness is different from spring stiffness in that the relationship between displacement and force is not linear. In typical springs, the change in the amount of force generated is constant no matter how much the spring is lengthened, whereas in muscles the change in force often increases as the muscle is lengthened (Knudson, 2007).

³⁷ As a result of this relationship, the terms “stability” and “stiffness” are often used synonymously in the medical literature. These two terms have a somewhat different meaning in mechanics, and so higher stiffness does not always mean higher stability. Because of the topic of this study, these terms will be used here with the medical definition in mind. This means that a joint that is more “stable” will move a relatively small amount of distance when a force is applied to it, compared to a joint that is less “stable.” Under this definition, an analogous statement could also be made regarding stiffness.

subcategory 2.1 below) could be an example of one such “molded” position that the Taubman Approach discourages. The muscular implications of fixating and molding the fingers will be discussed below.

“Dual Muscular Pulls” and “fixation:” According to biomechanical literature, muscles can function in several different ways when acting on a joint (McLester & St. Pierre, 2007, p. 328-9):

- **Agonists:** the muscles that move the joint in the intended direction.
- **Synergists:** the agonists that are indirectly involved and assist the agonist in producing motion in the intended direction.
- **Antagonists:** the muscles that perform joint motion opposite to that of the agonists and act to resist the intended motion.

It is very rare that only one muscle is involved in a particular task. How each muscle functions in a task depends on the specific nature of the task being performed (Vant, 2007, p. 51). A set of agonists and antagonists can be referred to as “opposing muscles” because they perform opposing actions (McLester & St. Pierre, 2007, p. 328). In the Taubman Approach excerpt above, Golandsky uses the term “contrary muscles” to refer to this same idea.³⁸ While opposing muscles are often located on opposite sides of the same joint, this is not always the case. For example, in Golandsky’s example above, the finger flexors are located on the palm side of the hand and arm, whereas the finger abductors are located in between the bones of the hand. These muscles will be discussed in greater detail below.

Golandsky states that activating opposing (contrary) muscles at the same time in order to “fixate” a joint creates “dual muscular pulls.” In the biomechanical sources, the term used to describe the contraction of opposing muscles is **co-contraction** (Andison, 2011, p. 29; Watson,

³⁸ In her example, she is referring to the finger flexor/extensor muscles.

2009, p. 90). Because opposing muscles generate force in opposite directions, the forces produced by co-contracting those muscles would tend to oppose each other. This would increase the amount of force required to cause joint rotation, and so co-contraction can be used to increase joint stability. If a force is applied to the joint when the muscles are co-contracted, the force produced by the muscles will move the joint back to its original position. As a result, co-contraction also increases joint stiffness. Co-contraction can have several practical functions, including (Andison, 2011, p. 29; Vant, 2007, pp. 51-2; Watson, 2009, p. 91):

- Increasing joint stability, both in tasks where there is joint movement and tasks where there is no joint movement
- Slowing down joint movement
- Eliminating undesired movements and maintaining posture
- Improving movement accuracy
- Helping adapt to changing environmental condition

In the context of piano playing, the external forces acting on the finger joints would be relatively low when the fingers are touching the keys before playing (starting hand position). As a result, it is possible for these joints to reach rotational equilibrium (no rotation) with a relatively small amount of muscular contraction and relatively low stiffness (see “Keybedding,” category 5.2 for more details). The only way to create a high level of stiffness across these joints in order to “fixate” or “tighten” them would be to use high levels of co-contraction. In doing so, the muscles contracting to rotate the finger joints would generate high forces pulling in opposite directions. If the forces pulling on both sides are equal (0 net force), the joint will be in rotational equilibrium, and no joint rotation will occur. However, generating high forces will cause the muscles to become stiff, and so joint stiffness will also increase. Golandsky states that “fixating”

or “tightening” the joints is usually achieved by the use of contrary muscles (co-contraction). If her definition of these terms is to increase the amount of stiffness crossing the finger joints, then the only way to achieve that would in fact be by co-contracting the muscles crossing those joints.

“Dual Muscular Pulls” and “molding:” In addition to creating joint stiffness, muscles have their own stiffness properties. This means that they have a tendency to return to their resting length when they are stretched beyond that length (Knudson, 2007, p. 51; Andison, 2011, p. 19). This is significant if the pianist first moves their fingers into a position outside of their resting position and then co-contracts the muscles crossing the finger joints in order to maintain that position (“molding”). In doing so, the muscles will not only need to generate enough force to reach rotational equilibrium, but they will also need to generate enough force to oppose their own tendency to return to resting length. An additional factor in the amount of muscle force required to maintain a “molded” position is that a muscle’s ability to produce force decreases as it gets longer or shorter than resting length. Because a muscle’s resting length typically corresponds to the resting position of the joints (see analysis of “Keybedding,” subcategory 2.3), moving the fingers to a position outside of resting position will either lengthen or shorten the muscles crossing its joints. Therefore, the amount of co-contraction needed to maintain a joint position outside of resting position will be higher than the amount needed to maintain the resting position. It is also important to note that the fingers can be “molded” into a starting position without co-contraction. However, this can only occur if the fingers are in contact with an outside surface (e.g. the keyboard) that can apply the necessary force to maintain the joint position. This idea will be discussed in further detail below in the section on “Curling” as a starting hand position (see subcategory 4.2.1).

While some degree of co-contraction is necessary for controlled movement and joint stability in piano playing (Andison, 2011; Watson, 2009), too much co-contraction can be problematic (Andison, 2011). By using co-contraction to create a high level of stiffness across the finger joints, the amount of muscle force used to keep the finger joints in rotational equilibrium will inhibit the joint movement necessary for playing. This may also potentially lead to muscle fatigue and injury, which will be discussed below (see categories 3.1 and 3.2). More details about the implications of co-contraction for joint movement during piano playing will be discussed in the next section.

4.1.3 “Curling” uses the long flexor muscle that pulls tightly under the wrist/fingers

TA Summary:

The Taubman Approach sources state that “Curling” the fingers requires the use of the “long flexor muscle;” this muscle is described as “extending from the tip of the fingers to the elbow,” and “pulling tightly under the wrist and the fingers” (Taubman, 1984, pp. 145-6; Taubman Institute, 1995, vol. 1; Milanovic, 2012, p. 133). In the BoMM conference presentation, Taubman (1984, p. 133) writes that the long flexor pulls “under” the wrist and fingers, while the other sources state that it pulls “over” the wrist (Taubman Institute, 1995, vol. 1; Taubman Institute, 1995, vol. 3; Milanovic, 2012, p. 133).

Analysis:

“Long flexor:” The anatomical literature used in this study does not use the term “long flexor” to describe a single muscle that “curls” the fingers. However, an investigation of the use of this term in the Taubman Approach sources indicates some overlap. Taubman discusses two sets of muscles that move the fingers: 1) the “long flexor muscle” (singular); and 2) the “short flexor muscles” (plural). She states that the “long flexor muscle” is located in the forearm and crosses

the wrist to move the fingers. The “short flexors” also move the fingers, but are located in the hand and do not cross the wrist (Taubman, 1984).

The biomechanical sources used in this study also identify two groups of muscles that move the fingers: 1) the “extrinsic muscles,” that originate in the forearm; and 2) the “intrinsic muscles” that originate in the hand (Freivalds, 2004, p. 167). Some scientific sources occasionally refer to the extrinsic flexors as “long flexors” (Watson, 2009, p. 77), but this is less common. The extrinsic muscles will be discussed here (see subcategory 6.2 below for discussion of intrinsic muscles):

There are two extrinsic muscles that flex fingers 2-5: The *flexor digitorum profundus* (FDP) and the *flexor digitorum superficialis* (FDS) (Watson, 2009, p. 53). Both of these muscles are located on the volar (palm) side of the forearm. A third extrinsic muscle, the *flexor pollicis longus*, acts on the thumb, and will be discussed later (see subcategory 4.1.6).

- **Flexor Digitorum Profundus (FDP):** The FDP is a deep muscle that originates on the ulna (elbow) and the interosseous membrane (Cael, 2010, p. 163; Watson, 2009, p. 53). It splits into four tendons, each of which inserts at the base of the distal phalanges (last finger bones) on the palm side of fingers 2-5 (Cael, 2010, p. 163; Watson, 2009, p. 53). The FDP is a **multiarticular muscle**, meaning that it crosses more than one joint (McLester & St. Pierre, 2007, p. 326): the wrist and all three finger joints (Watson, 2009, p. 53). When a multiarticular muscle contracts without any resistance, it produces motion at all of the joints that it crosses (McLester & St. Pierre, 2007, p. 326; Watson, 2009, p. 55). Therefore, when the FDP is activated, it has several functions. Its main function is to flex the DIP joints of fingers 2-5. However, it also assists in flexing the other joints of fingers 2-5 (PIP and MCP), as well as the wrist (Cael, 2010, p. 163; Watson, 2009, p. 53).

The FDP is the only muscle that flexes all segments of the fingers, and it is the only muscle that can flex the DIP joints (Cael, 2010, p. 163). Therefore, this muscle must be active when “Curling” the fingers during piano playing.

- **Flexor Digitorum Superficialis (FDS):** The FDS is located superficial³⁹ to the FDP (Watson, 2009, p. 53). The FDS has three heads that spread its origin across the humerus, ulna, and radius (Cael, 2010, p. 162). Like the FDP, the FDS splits into four tendons that attach on the palmar side of digits 2-5 (Watson, 2009, p. 53). However, while the FDP tendons insert near the tip of each finger, each of the FDS tendons split into two parts that attach to the middle phalanges (Watson, 2009, p. 53). These attachments occur on either side of the FDP tendon, which passes between them and attaches on the distal phalange (Freivalds, 2004, p. 168). Like the FDP, the FDS is a multiarticular muscle. It crosses the elbow, wrist, and the first two finger joints (MCP and PIP) (Cael, 2010, p. 162). As a result, its main function is to flex the PIP joints of fingers 2-5; however, it also assists in flexing the MCP joints of fingers 2-5, the wrist, and the elbow (Cael, 2010, p. 162; Watson, 2009, p. 53).

In her discussion of “Curling,” Taubman only mentions one “long flexor muscle,” whereas the biomechanical sources list two muscles in the forearm that flex fingers 2-5. The FDP is the only muscle that flexes the DIP joints, originates at the elbow, crosses over the wrist and fingers, and attaches to the fingertips. Therefore, the FDP seems to match Taubman’s anatomical and physiological description of the “long flexor” more closely than the FDS, which does not flex the DIP joints, but instead primarily flexes the PIP joints. While the Taubman Approach does not discuss PIP flexion in its description of “Curling,” PIP flexion must also occur in

³⁹ In the scientific literature, the term “superficial” means closer to the skin (Cael, 2010).

conjunction with DIP flexion due to physiological constraints (see subcategory 1.1 above).⁴⁰ If the FDP is activated alone, it will also flex the PIP joint, and there is some evidence suggesting that activity in the FDP and FDS muscles are highly coordinated during finger flexion tasks (Darling, Cole, & Miller, 1994). Therefore, it is likely that “Curling” the fingers by Taubman’s definition involves some activation of both the FDP and FDS. This coupling will have further implications for the biomechanical consequences of “Curling,” which will be discussed next.

“Pulls tightly:” The Taubman Approach sources state that the “long flexor muscle” “pulls tightly” over the wrist and fingers. Two main biomechanical factors may contribute to understanding this statement: co-contraction and muscle fibre arrangement.

Extrinsic finger muscles and co-contraction: In order to understand Taubman’s statement that the long flexor “pulls tightly,” it is important to look at the implications of contracting the extrinsic finger flexors as multiarticular muscles. As mentioned above, these muscles cross the wrist and two (for the FDS) or three (for the FDP) finger joints. If these muscles contract without any resistance, they will produce rotation at all of these joints (McLester & St. Pierre, p. 326; Watson, 2009, p. 55). In order to stop any of those joints from rotating, at least one other opposing muscle (antagonist) must contract in order to resist the force tending to cause rotation (Watson, 2009, p. 55). At the piano, if one contracts the extrinsic finger muscles by flexing the DIP and PIP joints (“Curling” the fingers), at least one opposing muscle must contract to prevent the wrist and MCP joints from flexing as well. The co-contraction necessary to flex the DIP/PIP joints, while also maintaining the position of the wrist/MCP joints will increase stiffness across all of these joints. This understanding of the impacts of “Curling” the fingers on wrist/finger

⁴⁰ This is due to the fact that the FDP crosses the DIP and PIP joints, and there is no extensor muscle that crosses the PIP, but not the DIP. As a result, when activating the FDP there is no opposing muscle that could contract to prevent the PIP from flexing as well.

stiffness can help explain Taubman's statement that the FDP (long flexor) "pulls tightly" across the wrist and fingers. Her use of the term "tight" to describe a higher level of muscle/joint stiffness due to co-contraction corresponds to Golandsky's use of this term to describe the higher level of stiffness necessary to stabilize the finger joints in a particular position (see subcategory 4.1.2). As mentioned above, increasing the flexion angle of the DIP joints will also increase that of the PIP joints. Trying to "curl" the fingers to generate relatively high stiffness may cause activation in the FDS muscles that flex the PIP joints. Therefore, doing so would increase the amount of force generated in the muscles, the amount of co-contraction, and the amount of stiffness across the joints. However, the involvement of the FDS is likely to be dependent on contextual factors, and so cannot be assumed to occur in all cases of "Curling."

"Pulling under/over:" There appears to be a discrepancy among the Taubman sources between the use of the terms "under" and "over" to describe the long flexor's pull across the wrist joint. This may be an issue of imprecise language, in which the words "over" and "under," which are typically antonyms, are actually being used to describe the same phenomenon from different points of reference. The FDP pulls "over" the wrist in the sense that it crosses over the wrist joint: it originates on one side of the joint, and it inserts on the other side of the joint. However, the FDP pulls "under the fingers and wrist" (Taubman, 1984, p. 146) in the sense that the muscle is located on the volar (palm) side of the forearm (Cael, 2010, p. 163); when the forearm is in the pronated position used for piano playing, the muscle is located between the wrist and the floor. Therefore, from the pianist's perspective, the muscle is "under" the wrist. One advantage of anatomical terminology in the scientific literature is that it describes the location of particular body parts (muscles, joints, etc.) irrespective of joint position or point of reference. In this case, an anatomical description of the FDP muscle could identify it as located on the volar side of the

forearm and crossing the wrist joint. However, this description would not cover Taubman's term "pulls tightly," which could be explained in relation to the other factors described in this section (co-contraction, force generation, stiffness, etc.).

Muscle fibre arrangement and size: Beyond the issue of co-contraction, one additional factor that may contribute to Taubman's description of the FDP ("long flexor muscle") as "pull[ing] tightly" may be the way in which its muscle fibers are arranged. There are two general classifications for muscle fiber arrangement (McLester & St. Pierre, 2007, pp. 339-341; Freivalds, 2004, p. 49, 62; Knudson, 2007, pp. 46-9): 1) **Longitudinal muscles**, in which the fibers run parallel along the longitudinal axis (length) of the muscle;⁴¹ and 2) **Pennate muscles**, in which the fibers are arranged obliquely (not parallel) along the longitudinal axis (length) of the muscle. The fiber arrangement of a muscle impacts both its contraction velocity and its ability to generate force. The longitudinal arrangement allows the muscle fibers to shorten relatively quickly. However, this high velocity of shortening makes it impossible to generate large forces (McLester & St. Pierre, 2007; pp. 322-323 Knudson, 2007, p. 79). Also, the maximum tension capability of a muscle is determined by the number of fibers in the muscle that can contract. Because longitudinal muscle fibres are longer, they take up more space, which limits the amount of total fibers that can be contained in the muscle. As a result of these factors, longitudinal muscles are more effective at rotating segments with high velocity than they are at generating high forces. In contrast, the pennate design allows more fibers to be packed into a smaller amount of space, which maximizes the force production capability of these muscles. However, this increased force capability decreases the potential velocity of the muscle contractions. Therefore, pennate muscles tend to be more effective at generating high forces than

⁴¹ These are also sometimes called "fusiform" (McLester & St. Pierre, 2007, p. 335) or "parallel" muscles (Freivalds, 2004, p. 49).

they are at rotating segments at high velocity. According to the biomechanical sources, the trade-off between force and velocity in muscles is known as the **Force-Velocity relationship** (McLester & St. Pierre, 2007, p. 322; Knudson, 2007, p. 79). As a result of this phenomenon, the arrangement of muscle fibers in a given muscle tends to relate to the typical way in which that muscle functions in the musculoskeletal system. Longitudinal muscles are often located in areas that require more range of motion and velocity, whereas pennate muscles are often located in areas that require more force (McLester & St. Pierre, 2007, p. 341).

Among pennate muscles, there are several subcategories that distinguish different muscles based on how many sets of fibers are arranged parallel to one another. The extrinsic finger muscles (including the FDS and FDP) are classified as **unipennate** muscles (Freivalds, 2004, p. 49). This means that there is only one set of fibers arranged parallel to each other, but they are arranged obliquely (not parallel) to the length of the muscle (McLester & St. Pierre, 2007, p. 338).⁴² This type of structure allows the extrinsic finger muscles to assist in generating the amount of force and stiffness across the finger/wrist joints that is necessary for gripping and grasping tasks (Long et al., 1970). In addition to fiber arrangement, the size of the extrinsic muscles contributes to their force production capability. Because these muscles are large in relation to the segments they move (finger), they are typically used to provide strength and power, rather than precision (Freivalds, 2004, p. 167; Watson, 2009, p. 53).⁴³ Both the size and fiber arrangement of the muscles involved in DIP/PIP flexion will contribute to increasing the amount of force that is created as a result of maintaining a “curled” finger position. Because these muscles are structured for greater force production, activating them to “curl” the fingers

⁴² The look of this arrangement can be compared to a bird’s feather (Freivalds, 2004, p. 49).

⁴³ For example, these muscles are able to generate enough force for tasks like rock climbing, which requires them to support almost the entirety of a person’s body weight (Koukoubis et al., 1995).

will generate more force than if they had a longitudinal design. This force will then have to be balanced by the opposing muscles to prevent the MCP/wrist joints from also flexing. As a result, muscles on both sides of the finger joints will need to generate relatively high forces to resist each other and bring the finger joints to a state of equilibrium (no rotation). This amount of co-contraction will increase the amount of stiffness across the wrist and finger joints, contributing to the feeling that Taubman describes as “tight.” The potential consequences of this “tightness” for piano playing will be discussed in the next subcategory.

4.1.4 “Curling” restricts up and down hand/finger motion

TA Summary:

The Taubman Approach states that because the long flexor pulls tightly, “Curling” the fingers “restricts” or “inhibits” the “up and down” motion of both the hand and the fingers (Taubman, 1984, p. 145-6; Taubman Institute, 1995, vol. 1; Milanovic, 2012, p. 133). In contexts where there is an audience present (Taubman, 1984, p. 145-6; Taubman Institute, 1995, vol. 1), Taubman and Golandsky encourage audience members to curl their fingers and then try to move the fingers up and down very quickly. They then ask audience members to keep their finger in the “natural curve”⁴⁴ (see category 4.5 below), and do the same thing in order to compare the difference in feeling. They claim that when “Curling” the fingers, the fingers’ motions are far more “restricted,” compared to when the fingers are in their “natural curve.” They then repeat this process and ask the audience to move the hand up and down instead of the fingers, comparing the “freedom of motion” between the curled and “natural” positions. Again, they report that the hand movements are much more “restricted” when the fingers are curled.

⁴⁴ This code was used only to refer to restriction in the “up and down” motions of the fingers/hand. “Sideways” motions of the fingers are covered below.

Analysis:

“Restriction” of hand motion: Taubman and Golandsky demonstrate that the up and down movement of the hand (flexion/extension) is “restricted” when the fingers are held in a curled position (DIP/PIP flexion). By “restricted,” they likely mean that when the DIP/PIP joints are maintaining a flexed (curled) position, the forces acting to flex/extend the wrist encounter relatively high levels of resistance. As a result, these movements require more muscle force, and so they will have a lower potential velocity and range of motion. Wrist flexion/extension is mainly achieved by two sets of muscles that attach to each side of the hand (Cael, 2010, pp. 159-61, 169-71) :

- **Wrist Flexors:** (Flexor Carpi Ulnaris, Flexor Carpi Radialis, Palmaris longus) all three wrist flexors originate at the elbow and attach to the palm side of the hand. When contracting together, they act to flex the wrist.
- **Wrist Extensors:** (Extensor Carpi Radialis Brevis, Extensor Carpi Radialis Longus, and Extensor Carpi Ulnaris): all three wrist extensors originate at the elbow and attach to the dorsal⁴⁵ side of the hand. When contracting together, they act to extend the wrist.⁴⁶

As discussed above, flexing the DIP/PIP joints (“Curling”) and maintaining that position increases wrist stiffness (subcategory 1.3). This stiffness will tend to keep the hand in its current position, and so it will resist the force of the muscles acting to flex/extend the wrist. As a result, in order to move the hand while the fingers are in the “curled” position, the wrist flexor/extensor muscles will need to generate enough force to overcome the stiffness produced by the co-

⁴⁵ In this context, the term “dorsal” is used in the scientific literature to refer to the side of the hand opposite to the palm (Edin & Abbs, 1991).

⁴⁶ These muscles can have other functions when contracting in different groupings. However, these other functions are not relevant for the analysis here.

contracting extrinsic finger muscles in order to achieve the desired amount of movement.

However, due to the force-velocity relationship (see subcategory 4.1.3), the force produced by the wrist flexors/extensors will decrease as they move with increased velocity (McLester & St. Pierre, 2007, p. 322; Knudson, 2007, p. 79). As one tries to move the hand more quickly, the muscles executing this movement will generate less force. Therefore, the likely result will be that the wrist flexor/extensor muscles will contract very frequently, but generate low forces, and so very little hand movement will occur.

In addition to decreasing the force generating capacity of the muscles moving the hand, the increased velocity will also likely increase the amount of wrist stiffness. If the fingers joints are not maintaining a flexed DIP/PIP (“curled”) position, the inertia created by the fast hand movements will tend to cause some degree of finger movement as well. In order to resist this finger motion and maintain the “curled” finger position as the hand is flexing/extending quickly, the co-contracting extrinsic finger muscles would have to generate more force/stiffness across the finger joints. Because those muscles also cross the wrist, wrist stiffness will increase as well. The muscle contractions acting to move the hand would then encounter more resistance, and the amount of force required to produce wrist flexion/extension would be further increased. As a result, the potential degree of hand movement when the fingers are “curled” would likely be very small.

“Restriction” of finger motion: In addition to restricting hand movements, Taubman and Golandsky also demonstrate that stiffening the fingers in a “curled” position (DIP/PIP flexion) also restricts the up and down movements of the fingers (flexion/extension). As with hand motion, this likely indicates that any forces applied to move the finger joints will encounter high levels of resistance. Similar to the “restriction” of hand motion, the “restriction” of finger

movement is also likely due to the co-contraction necessary to maintain the “curled” position; however, in this case the problematic co-contraction occurs across the finger joints, rather than the wrist. In the biomechanical literature, the muscles that oppose the extrinsic finger flexors are called the extrinsic finger extensors. In the first DVD (Taubman Institute, 1995, vol. 1), Golandsky discusses these muscles: “We need to know about the flexors, the muscles that move the fingers downward. And we need to know about the extensors; those are the muscles that lift our fingers. And we need to know that both of them are situated in the forearm and that they pull in opposite directions.” The biomechanical sources identify several extrinsic extensor muscles located in the forearm:

- **Extensor Digitorum (ED)**: attaches to the distal phalange of fingers 2-5. When contracted without resistance, the ED extends the DIP, PIP, MCP, wrist, and elbow joints (Cael, 2010, p. 172).
- **Extensor Indicis (EI)**: attaches to the middle phalange of the second finger. When contracted without resistance, the EI extends the MCP, PIP, and wrist joints. It also slightly supinates the forearm (Cael, 2010, p. 173).
- **Extensor Digiti Minimi (EDM)**: attaches to the middle phalange of fifth finger. When contracted without resistance, the EDM extends the MCP, PIP, wrist, and elbow joints (Cael, 2010, p. 174).

When contracting, all three of these muscles have some tendency to extend the DIP/PIP joints of fingers 2-5.⁴⁷ As a result, if the fingers are placed in a “curled” position (DIP/PIP flexion) and

⁴⁷ The intrinsic finger muscles also typically contribute to finger extension at the PIP/DIP joints (Cael, 2010, p. 179). The extensor mechanism of the fingers is quite complex, and the activity of various muscles involved in the combination of DIP/PIP flexion (“Curling”) and MCP extension described here may depend on a number of context-specific factors (e.g. position, velocity, range of motion, passive forces, etc.). A full investigation of this subject was considered outside the scope of this study. For one investigation of the muscle activity involved in MCP joint movement while maintaining IP joint position, see Darling et al., 1994.

the extensor muscles are activated without resistance, they would tend to move the DIP/PIP joints out of their “curled” position. If the pianist intends to extend the fingers from MCP joint without also extending the DIP/PIP joints, then the FDS/FDP muscles would need to continue contracting as the finger is extending from the MCP in order to maintain the flexed DIP/PIP (“curled”) position. However, the flexor muscles also cross the MCP joints, and so contracting them to maintain the curled position would also resist the forces contributing to MCP extension. This resistance would require the extensor muscles to generate more initial force to overcome that of the flexors and produce the MCP extension movement. In sum, the combination of counteracting forces produced by the flexor and extensor muscles when executing these movements will increase the amount of muscle contraction in all of the muscles necessary to produce these motions. This can help explain Taubman/Golandsky’s statements that “Curling” the fingers will “restrict” finger motion.

As with the “restriction” of hand motion described above, the increase in force needed to execute these finger movements will become more problematic as velocity increases. Due to the force-velocity relationship (see subcategory 4.1.3), the increased force generated by co-contracting the extrinsic finger flexor and extensor muscles will decrease the velocity with which they can move the fingers. Because both of these sets of muscles have a unipennate fiber arrangement (Freivalds, 2004, p. 49) (see subcategory 4.1.3), they are already somewhat less effective at generating fast movements than if they had a longitudinal design. Therefore, the velocity of the finger movements at the MCP joint will be limited if the DIP/PIP joints maintain a flexed position. Based on the combination of factors involved in attempting to move the fingers at the MCP joints quickly, while also keeping the DIP/PIP joints flexed (“curled”), doing so will result in increased co-contraction, decreased potential for velocity, and motion that is less

efficient and more jerky (McLester & St. Pierre, 2007, p. 329; Watson, 2009, p. 91). These consequences of “Curling” the fingers provide a likely explanation for the “restriction” of finger movements that Taubman and Golandsky describe.

Implications for control of muscles: An additional factor related to “Curling” and “restriction” of movement is that “Curling” the fingers may impact the pianist’s ability to control movements. This is due to the way that muscle contractions are controlled by the nervous system. The number of fibers contracted in a muscle is regulated by the motor neurons that attach to that muscle (McLester & St. Pierre, 2007, p. 318). Each neuron controls a group of muscle fibers, referred to as a **motor unit**. Activating a smaller number of motor units in a motion increases the precision capability of that motion (McLester & St. Pierre, 2007, p. 318). However, muscles that generate more force use more (and larger) motor units. Therefore, the increased force generated by “Curling” due to the variety of factors described above⁴⁸ will lead to the activation of more motor units and limit the precision of the finger movements used for key depression. McNulty (2000) found that the motor units of the extrinsic finger muscles are less sensitive in controlling the force output compared to the intrinsic muscles. Because piano playing requires a high level of muscle control for proper accuracy and timing of key depression, activating these muscles by “Curling” the fingers may lead to more force, and therefore limit one's ability to play accurately and control tone production.⁴⁹

⁴⁸ e.g. activation of extrinsic muscles, co-contraction, and high levels of wrist/finger stiffness.

⁴⁹ In addition to this issue, “Curling” may be problematic for a number of other reasons related to motor control. However, these issues are outside the context of the current study. The issue of motor units and precision was included here because it is directly related to muscle forces, and it will have implications for other issues discussed in this study.

4.1.5 “Curling” prevents opening the hand

Categories 1.5 and 1.6 discuss the relationship between “Curling” the fingers and “opening” (Taubman Institute, 1995, vol. 3) or “stretching” (Taubman Institute, 1995, vol. 1) the hand/fingers. An analysis of these categories will involve discussion of similar biomechanical concepts, and so they will be analyzed together after the summary of subcategory 1.6.

TA Summary:

The Taubman Approach sources claim that “Curling” the fingers can be problematic because it makes it very difficult to “open the hand and the fingers,” “makes playing distances a problem,” and results in a “limited hand span” (Taubman Institute, 1995, vol. 3, 5). Golandsky states that these limitations also make it hard to fit the black keys between the fingers, which is sometimes necessary when playing in the black key area (Taubman Institute, 1995, vol. 3). The excerpts in this subcategory fit into two general contexts:

- **Lining up the fingers to be the same length and playing distances:** Golandsky states that if the pianist “curls” the fingers to line them up as a starting position, it will prevent them from being able to open the hand and will make distances a problem once they start playing (Taubman Institute, 1995, vol. 3).
- **“Curling” the non playing fingers when the hand is in an open position:** Golandsky states that when playing octaves, many pianists curl the longer fingers (2-4) in order to prevent them from hitting the black keys. She says this is problematic because “Curling” the fingers limits the span of the hand (Taubman Institute, 1995, vol. 5).

4.1.6 “Curling” and Stretching together creates dual muscular pulls

TA Summary:

The Taubman Approach sources state that attempting to stretch and curl the fingers at the same time is problematic because it activates opposing muscles (Taubman Institute, 1995, vol. 1 & 4). The current analysis found three contexts where the combination of “Curling” and stretching can occur:

- **As a starting hand position:** For example, stretching to be on five white keys and then “Curling” the fingers (Taubman Institute, 1995, vol. 1).
- **When playing chords:** The hand opens to reach all of the notes and then the fingers grab to play the keys (Taubman Institute, 1995, vol. 4).
- **When playing octaves:** Golandsky states that even pianists with large hands sometimes stretch beyond the necessary distance and then have to curl the fingers to play the notes of the octave (Taubman Institute, 1995, vol. 5).
- **When playing legato distances/arpeggios:** For example, when the fingers are in a curled position and then need to reach across a distance to get to the next note (Taubman Institute, 1995, vol. 1).

In all of these examples, Taubman and Golandsky explain that the combination of “Curling” and stretching activates opposing muscles. This occurs because “Curling” is achieved by activating flexor muscles, while opening the hand/stretching is achieved by activating extensor muscles. Golandsky (Taubman Institute, 1995, vol. 1) states that the muscles that open the hand are “abductors, which are forms of extensors.” The Taubman Approach sources claim that this combination of flexion and extension is an example of “dual muscular pulls,” which causes tension (Taubman Institute, 1995, vol. 1). Golandsky

describes “Curling” and stretching the fingers before playing as a “very, very tight position.” In one masterclass, Taubman describes the look of the hand and fingers in this state as “making claws”(Taubman Institute, 1995, vol. 1).

Analysis: Because the excerpts in the above two categories are related to the same biomechanical concepts, the analysis of this section has been organized in the following way: the pedagogical terminology used by the Taubman Approach will be analyzed first to determine what may be meant by each statement. The discussion of biomechanical concepts that may explain their statements will be included after all of the statements have been analyzed. Finally, the biomechanical concepts will be discussed generally in relation to the examples given by the Taubman Approach sources of how these problems may occur in the context of piano playing.

“Open the hand/fingers:” In these excerpts, when Golandsky says “opening the hand and fingers,” she is referring to moving the fingers away from the midline of the hand, which goes through the middle of the 3rd finger. This type of movement occurs in the frontal plane (Cael, 2010, p. 4; Freivalds, 2004, p. 31). In the biomechanical sources, this type of motion is called **“finger abduction,”** which only occurs by rotating (or “spreading”) the fingers about the MCP joints (Cael, 2010, p. 148). Golandsky's statement that “Curling” makes it difficult to “open the hand” likely means that it is difficult to abduct the fingers while maintaining a flexed position at the DIP/PIP joints.

“Limited hand span:” Golandsky states that DIP/PIP flexion (“Curling”) limits one’s ability to abduct the fingers and “limits hand span,” particularly in octave playing (Taubman Institute, 1995, vol. 5). Hand span is measured as the distance from the tip of the thumb to that of the fifth finger (Sakai et al., 2006). It seems that Golandsky’s statements that “Curling” “limits hand span” or “makes it impossible to open the hand” indicate that because DIP/PIP flexion

(“Curling”) limits one's ability to abduct the fingers, it therefore decreases the maximum distance that one can create between the thumb and fifth finger.

“Stretching:” The Taubman Approach sources state that the combination of DIP/PIP flexion (“Curling”) and “stretching” is problematic. A detailed analysis of the term “stretching” in the larger context of the Taubman Approach materials is outside the scope of the current study. In the context of this analysis, the term “stretching” can generally be defined as abducting the fingers at or close to the end of their range of motion.

“Playing distances:” Golandsky also states that because DIP/PIP flexion (“Curling”) limits hand span, it “makes playing distances a problem.” This likely means that it is difficult to play legato over consecutive notes that are far apart on the keyboard.

Flexion and abduction creates “dual muscular pulls:” The Taubman Approach sources indicate that the combination of DIP/PIP flexion (“Curling”) and finger abduction (“stretching”) is problematic because “Curling” activates the flexors, while stretching activates the extensors, or the abductors, which Golandsky states are “forms of extensors” (Taubman Institute, 1995, vol. 1). A description of the flexors and extensors has been provided above (see subcategory 4.1.3), and so the abductors will be discussed here. According to the biomechanical sources, there are four main muscles/muscle groups involved in finger abduction (Cael, 2010, pp. 175, 178-9):

- **Dorsal Interosseus muscles (DI):** The DI are located on the dorsal side of the hand in between the metacarpal bones of the fingers, attaching to the proximal phalanges. These muscles abduct fingers 2, 3, and 4, but also flex the MCP joints and extend the PIP joints.
- **Abductor Digiti Minimi (ADM):** The ADM is located on the palmar side of the hand and attaches to the proximal phalange of the fifth finger. This muscle abducts only the fifth finger.

- **2 Thumb Abductors:** There are two muscles that abduct the thumb:
 - **Abductor Pollicis Longus (APL):** The APL is the larger muscle that abducts the thumb. It is located in the forearm and attaches at the base of the hand. It abducts and extends the thumb from the CMC joint. It also abducts and slightly flexes the wrist.
 - **Abductor Pollicis Brevis (APB):** The APB is located on the palmar side of the hand, and attaches to the first phalange of the thumb. It abducts and opposes the thumb from the MCP joint.

“Opening the hand” as Taubman/Golandsky describe in this subcategory requires abducting all five fingers at the same time. Therefore, this motion will activate all of the above-mentioned muscles. According to the biomechanical sources, one action of these muscles is to abduct the fingers, but almost all of them also act to extend the fingers (the APB is the only exception). This is consistent with Golandsky’s statement that the abductors are “forms of extensors.” Keeping the DIP joints in a flexed position would require contraction of the extrinsic finger flexors (FDP/FDS). The force generated by these muscles would resist that generated by the abductors that act to abduct/extend the fingers. As a result, trying to simultaneously maintain a flexed DIP/PIP joint position and abduct the fingers from the MCP joints (“opening the hand”) would require substantial co-contraction (“dual muscular pulls”). The relatively high forces generated by the opposing sets of muscles will then lead to a high level of stiffness across the finger joints. If the forces acting on both sides of the joints are equal, then the joints will be in equilibrium and will not rotate at all. If the abductors generate enough force to overcome the resistance of the flexors, then some abduction at the MCP joint will occur. However, this movement will require the abductors to generate more force than the amount that would be needed if the fingers do not

maintain a flexed position at the DIP/PIP joints (“Curling”) (McLester & St. Pierre, 2007, p. 329).

Physiological limitations of MCP joints: In addition to the muscular issues described above, another problem with combining “Curling” and “stretching” may occur due to the construction of the MCP joints. The ligaments and shape of the bones connecting at the MCP joint are such that flexing the fingers also brings the fingertips together. This type of motion is referred to in the biomechanical sources as finger **adduction**, which is the opposite of finger abduction (Cael, 2010, p. 148-9). The tendency for the fingers to adduct when they flex can be problematic for trying to “curl” and “stretch” them simultaneously. One example of this could occur if the pianist first places their DIP/PIP joints in a flexed (“curled”) position. If the pianist tries to abduct (“open”) their fingers while also trying to maintain the flexed position, they will limit the amount of abduction that they can achieve. This is because the finger bones will be constrained by the ligaments and other bones. As a result, the total range of motion for finger abduction will be smaller than if the fingers were able to fully extend. A related situation will occur in contexts in which the pianist's fingers are in an abducted (open) position. In this case, if they try to flex their fingers while trying to maintain that abducted (open) position, the ligaments and bones around the MCP joints will start to cause the fingers to adduct. Therefore, this will also decrease the amount of abduction that can be achieved. Understanding the physiological limitations of the MCP joints in this way can help explain Golandsky's statement that when pianists “curl” the “non-playing fingers” in octave playing, it “limits the span of the hand” (Taubman Institute, 1995, vol. 5).

Examples of “Curling”/Stretching in context: The examples given in these two categories can be placed into two general contexts:

- **Flexing the DIP/PIP joints (“Curling”) and then attempting to abduct the fingers (“stretching”):** One example of this context is when “Curling” the fingers as a starting hand position. In this context, Golandsky states that you “can’t open your hand.” (Taubman Institute, 1995, vol. 3) When the fingers start in a flexed (curled) position and then try to abduct (open), the force generated by the abductor/extensor muscles will have to overcome that of the flexor muscles. The high amount of co-contraction will lead to and increase in both muscle force and joint stiffness. Due to the force-velocity relationship, the increased force necessary to keep the fingers flexed while abducting will limit the pianist’s ability to move quickly. Furthermore, the physiological limitations of the MCP joints will limit the range of motion for finger abduction. These limitations will occur both when moving to depress the keys (flexion/extension), and when trying to move the finger to the next key (abduction). All of these types of motion are necessary when playing distances.
- **Abducting the fingers (stretching) and then attempting to flex the DIP/PIP joints (“Curling”):** In these excerpts, Golandsky states that “Curling” the fingers “limits the span of the hand” (Taubman Institute, 1995, vol. 5). One context this can occur is in octave playing, either by flexing both the playing fingers (1 and 5), or by flexing the non-playing fingers (e.g. finger 2). Flexing fingers 1 and 5 will tend to bring their fingertips together (adduct) due to the physiology of the MCP joints. Similarly, flexing a non-playing finger(s) in octave playing will limit that finger’s abduction capability. which will limit the potential distance that can be created between fingers 1 and 5. Both of these examples will limit the potential hand span that can be created. Furthermore, more muscle forces will be needed to execute these combinations of movement.

4.1.7 Don't "curl" the thumb

TA Summary:

In addition to advising against "Curling" fingers 2-5, the Taubman Approach also discourages "Curling" the thumb (Taubman Institute, 1995, vol. 1). This is given as a general recommendation, and also in one context, when the thumb releases a key and then moves behind the second finger. Golandsky states that sometimes pianists "curl" the thumb when bringing it closer to the second finger, which is incorrect (Taubman Institute, 1995, vol. 2).

Analysis:

"Curling" the thumb: Unlike "Curling" fingers 2-5, the term "Curling" when applied to the thumb is not explicitly defined within the Taubman materials used for this study. For fingers 2-5, "Curling" is defined as flexion at the DIP joints, which also causes flexion of the PIP joints (see subcategory 1.1). However, the thumb joints are different from those of the other fingers. The thumb can be moved from three joints (Cael, 2010, p. 130):

- **Carpometacarpal joint (CMC):** The CMC joint is located at the base of the hand and allows the thumb to touch the other finger tips (called "opposition").
- **Metacarpophalangeal joint (MCP):** the MCP joint connects the thumb to the hand.
- **Interphalangeal joint (IP):** The IP joint connects the thumb's two phalanges.

Because the thumb only has two phalanges, it does not have a DIP joint. Instead, it only has an IP joint between them. Golandsky's demonstration of "Curling" the thumb (Taubman Institute, 1995, vol. 1) indicates that in this context, "Curling" refers to flexing the thumb's IP joint. If one considers that for fingers 2-5, "Curling" refers to flexing the most distal finger joint, then flexing the IP joint of the thumb would be the equivalent motion/position for the thumb. As with

“Curling” fingers 2-5, the Taubman Approach sources do not define “Curling” the thumb as simply having any amount of flexion, but rather as actively flexing the thumb beyond that of its resting position. The muscles that may be involved in “Curling” the thumb will be discussed next.

Muscles involved in “Curling” the thumb:

There are nine muscles that act on the thumb, and so only those relevant to “Curling” the thumb will be discussed here (Cael, 2010, p. 178):

- **Flexor Pollicis Longus (FPL):** the FPL is located in the forearm and crosses the thumb’s three joints (CMC/MCP/IP), as well as the wrist. The FPL flexes all three thumb joints and assists in flexing the wrist. The FPL is the only muscle that flexes the IP joint (Cael, 2010, p. 164).
- **Extensor Pollicis Longus (EPL):** the EPL is located in the forearm and crosses the thumb’s three joints (CMC/MCP/IP), as well as the wrist. The EPL performs the opposing actions to the FPL, extending all three thumb joints and slightly abducting/extending the wrist (Cael, 2010, p. 177).
- **Extensor Pollicis Brevis (EPB):** the EPB is located in the forearm and crosses the wrist, CMC, and MCP joints of the thumb. The EPB extends the thumb at the CMC/MCP joints, and abducts the CMC/wrist joints (Cael, 2010, p. 176).

As discussed above, “Curling” finger 2-5 involves flexing two joints (DIP/PIP).

“Curling” the thumb seems to mainly involve IP joint flexion, but the amount of MCP joint flexion that is involved in “Curling” the thumb is not explicitly stated in the Taubman Approach sources used in this study. From Golandsky’s demonstration (Taubman Institute, 1995, vol. 1), it appears that most of the flexion occurs at the IP joint, with some additional flexion possibly

occurring at the MCP joint. There is no muscle that flexes only the IP joint without also crossing the MCP joint. The only muscle that can flex the IP joint, the FLP, also crosses the MCP joint. Therefore, in order to create the position that Golandsky demonstrates, the FPL must flex the IP joint, and some co-contraction will be required to prevent the MCP joint from flexing as well. This muscle would likely be the EPB, which acts to extend the thumb at the MCP joint. Once the thumb has been moved into a “curled” position, both of these muscles (FPL/EPB) would need to continue co-contracting to some degree in order keep the MCP joint in equilibrium and prevent any joint rotation. Furthermore, another extensor muscle, the EPL would likely need to contract to keep the IP joint in equilibrium as well. The activity created by all of these muscles (the FPL, EPB, and EPL) would constitute another form of “molding” as described by Golandsky, in which the fingers are brought into a state of equilibrium in a position outside of resting position (see subcategory 4.1.2 above). As such, holding the thumb in this position would be considered problematic by the Taubman Approach sources because it would require co-contraction (“dual muscular pulls”). This would increase the stiffness across the thumb joints in order to bring them to rotational equilibrium. The more the IP joint is flexed (“curled”), the more these issues would increase because the co-contracting muscles would be brought further away from their resting length (see subcategory 1.2).

In addition to the general consequences of maintaining a “curled” thumb position, additional factors may impact the thumb muscles/joints if a pianist tries to do so while using the thumb to depress a key. Once the thumb is in a flexed position (“curled”), it must abduct and/or extend in order to depress the key. If the thumb extends to depress the key, the necessary muscles (EPL/EPB) for this action would pull the thumb away from the palm of the hand. Without resistance, this would take the thumb out of the flexed (“curled”) position. Therefore, in

order to maintain the flexed position, the FPL muscle would need to remain contracted. The force produced by the FPL would resist that produced by the muscles acting to move the thumb towards the key. As described above co-contracting flexors and extensors to maintain a “curled” position when moving play the key will increase muscle tension and joint stiffness, inhibit velocity, and make movement jerky (see subcategory 4.1.4).

If the thumb abducts to play the key from a curled position, there are two muscles that could be involved:

- **The Abductor Pollicis Longus (APL):** the APL is located in the forearm and attaches to the base of the hand near the wrist. It abducts the thumb from the joint at the base of the hand, called the first carpometacarpal joint (CMC), and it slightly flexes and abducts the wrist (Cael, 2010, p. 175).
- **The Abductor Pollicis Brevis (APB):** the APB is located in the hand and attaches to the first phalange of the thumb. It abducts and opposes the thumb from the MCP joint.

Because the APL also acts to extend the thumb, activating it to play the key while maintaining a flexed (curled) IP joint will result in the same problem of co-contraction described for the thumb extensors. The APB, on the other hand, does not extend the thumb, and so it could be used to abduct the thumb into the key while maintaining a flexed position without creating this issue. However the APB is a smaller, intrinsic muscle, and so using only this muscle to abduct the thumb would limit the amount of force it could produce. Because the APB would also need to generate enough force to overcome the stiffness of the MCP joint created by the IP flexion in order to move the thumb to depress the key, this muscle would likely have to generate forces close to its maximum capability, which again, would limit speed. Despite the different muscle combinations that could be used to depress the key while maintaining a flexed (curled) IP joint,

all of them would involve an increase in stiffness and muscle force. Because maintaining a flexed (curled) IP joint does not contribute to the task of piano playing in any obvious way, this could explain why Golandsky discourages that position.⁵⁰

4.1.8 Conclusion: What is “Curling?”

The subcategories above were developed in order to help define the term “Curling” as used in the Taubman Approach sources from a biomechanical perspective. A total of 30 units of coding were used in this category. After a second coding, 29 units of coding were in agreement between the two coding sessions, making for a 96.67% agreement. The following table has been provided to display each subcategory with a brief summary of its biomechanical analysis, the sources included, and the number of units of coding contained in it:

Table 4.1 *What is “Curling?”*

Subcategory	Biomechanical Analysis	TA Sources	Units of Coding
“Curling” is pulling fingers in from nail joint	“Curling” fingers 2-5 involves actively flexing the DIP joints of the fingers. Doing so will also flex the PIP joints. It is unclear from this category alone how much flexion is considered “Curling,” as well as if passive flexion is also considered “Curling.”	Taubman, 1984; Taubman Institute, 1995, vol. 1; Moran, 2008	3
Fixating causes dual muscular pulls	“Curling” is a form of “fixation,” which involves increasing the stability of the finger joints by co-contracting muscles. This also increases the stiffness of those joints. It can also be a form of “molding,” which may refer to “fixating” in a position outside of resting position.	Taubman Institute, 1995, vol. 1	2
“Curling” uses the long flexor muscle that pulls tightly under the wrist/fingers	Actively flexing the DIP/PIP joints requires contracting the extrinsic finger muscles (FDP and FDS), which are located on the volar side of the forearm. Active DIP flexion requires contracting the FDP muscle. Because DIP flexion also causes PIP flexion, the FDS muscle may also contract. The FDP/FDS are multiarticular muscles, and so activating them for DIP/PIP flexion will also require co-contraction of finger extensor muscles to prevent the wrist/MCP joints from also flexing. These muscles have a unipennate design, and so they are typically used for generating high forces, rather than high velocity movements.	Taubman, 1984; Taubman Institute, 1995, vol. 1, 3; Milanovic, 2012	8

⁵⁰ According to the Taubman Approach, the thumb should abduct, but in conjunction with forearm rotation because the muscles that cause abduction are slow (Taubman Institute, 1995, vol. 1). Forearm rotation could assist with playing the thumb even with the IP flexed, but they also would lose some of the potential force created by intersegmental dynamics (due to inertia) because the co-contraction necessary to stabilize the IP joint would also stabilize the MCP joints. A larger discussion of this issue is outside the scope of the current study.

“Curling” restricts up and down hand/finger motion	The increased stiffness caused by the co-contraction involved in DIP/PIP flexion will generate forces that resist any attempt to flex/extend the wrist/finger joints. This will increase the muscle force necessary to produce rotation about those joints. Increasing muscle forces will also decrease the potential velocity and range of motion of these movements.	Taubman, 1984; Taubman Institute, 1995, vol. 1; Milanovic, 2012	7
“Curling” prevents opening the hand/”Curling” and Stretching together creates dual muscular pulls	The muscles that abduct the fingers also act to extend them. Therefore, trying to simultaneously flex/abduct the fingers will lead to co-contraction. Also, joint construction will cause the fingers to adduct when flexing. These factors will limit the potential hand span and increase muscle forces when playing if the pianist tries to flex/abduct the fingers at the same time. When playing, this can occur either when flexing the fingers from an abducted position, or vice-versa.	Taubman Institute, 1995, vol. 1, 3, 4, 5	“Curling” prevents opening the hand: 4 “Curling” and Stretching together creates dual muscular pulls: 4
Don’t “curl” the thumb	“Curling” the thumb can be defined as actively flexing the IP joint. This is done by contracting the FLP muscle. The FPL is a multiarticular muscle, and so IP flexion will require co-contraction of the EPB to limit movement at the MCP joint. This will increase stiffness and muscle forces needed to move the thumb when playing.	Taubman Institute, 1995, vol. 1, 2	2

4.2 “Curling” in Context

Introduction:

The Taubman Approach materials analyzed in this study identify a number of pianistic contexts in which “Curling” can occur. Because of the limited number of sources used in this study, this list cannot be considered exhaustive. However, it provides a number of examples of typical situations in which pianists are likely to “curl” their fingers for various reasons. The analysis of each subcategory will aim to summarize the relevant excerpts from the Taubman Approach sources, and then discuss those excerpts using biomechanical language. The analysis will apply the general findings related to “Curling” in the previous section to each particular pianistic context identified below. Contexts identified in the following section include: lining up the fingers as a starting position, trying to play horizontal key spots, trying to pull the finger out instead of the arm, “Curling” to prevent broken nail joints, plucking during octave playing, and

“Curling” because the wrist is too low. An additional subcategory found that “Curling” can cause fingers to feel too long, which was ultimately considered outside this scope of this study. The first two categories in this section were considered related to each other, and so they will be analyzed together after they are both summarized.

4.2.1 Don’t line up all fingers to be the same length as a starting position

TA Summary:

The Taubman Approach sources point out that one way in which “Curling” commonly occurs is when pianists line up all their fingers as a starting hand position (Taubman Institute, 1995, vol. 3; Milanovic, 2012, p. 134). Taubman identified that one important problem of piano technique is the fact that while pianists must move horizontally to play each key, the fingers are all different lengths (Taubman Institute, 1995, vol. 3). This can be particularly problematic when trying to play consecutive notes on all white keys (Taubman Institute, 1995, vol. 3; Milanovic, 2012, p. 116). One way that many pianists try to solve this problem is by lining up all of the fingers to form a straight line as a starting hand position (Taubman Institute, 1995, vol. 3; Milanovic, 2012, p. 134). This would be achieved by pulling in the long fingers (2-4) to match the length of the short fingers (1 and 5) (Taubman Institute, 1995, vol. 3). However, because this would require “Curling” fingers 2-5, the Taubman Approach strongly discourages this practice (Taubman Institute, 1995, vol. 3; Milanovic, 2012, p. 134). Because “Curling” creates many physical and technical issues, the Taubman Approach sources state that a curled starting hand position is not an effective solution to the problem of the different finger lengths (Taubman Institute, 1995, vol. 3).

4.2.2 Don't play in horizontal key spots/key spots must have and in/out relationship

TA Summary:

The Taubman Approach discourages pianists from trying to play consecutive keys on “horizontal key spots,” in which each finger plays its key at the same in and out position (Taubman Institute, 1995, vol. 3). This subcategory refers solely to the spot where each finger contacts the key, and therefore is different from lining up the fingers in a straight line to start with, which refers to the position of the fingers before one begins playing. Trying to play horizontal key spots is considered problematic when playing all white keys, as well as when playing a combination of white and black keys in the black key area (Taubman Institute, 1995, vol. 3). Golandsky points out that pianists occasionally will need to play horizontal key spots in correct playing; however, the pianist should not attempt to do this as a rule (Taubman Institute, 1995, vol. 3). In these contexts where it does occur, the pianist must do so by moving the arm in and out to allow the fingers to maintain their natural curve, rather than by “Curling” the fingers to reach the correct key spot (Taubman Institute, 1995, vol. 3).

Analysis:

“Key spot:” The Taubman Approach sources use the term “key spot” to refer to the place on the key where the finger and the key come into contact with one other. In the context of the above categories, the term “key spot” is being used to refer specifically to the position of the point of contact between the finger and the key in relation to the fallboard and the edge of the keys.

“Lining up the fingers:” The Taubman Approach sources discourage using a starting hand position in which their fingers form a straight/horizontal line. This likely means that they discourage pianists from placing their fingers on the keys in such a starting position that all five

fingers are contacting the keys at an equal distance from the edge of the key. This definition is consistent with Milanovic's (2012) criticism of approaches that encourage "lining up their fingertips on a pencil" (p. 134). Because fingers 2, 3, and 4 are typically significantly longer than fingers 1 and 5, creating such a position will require substantial flexion of these longer fingers, particularly at their PIP and DIP joints ("Curling"). That being said, the difference in finger lengths will vary to some degree based on individual differences, and so the amount of finger flexion required to "line up the fingers" will be different for each person.

Based on the analysis above, a number of problems have been identified in association with "Curling" the fingers: increased muscle tension, increased stiffness, decreased potential velocity and range of motion for finger/hand movements, etc. The majority of these issues are directly or indirectly related to co-contraction of the extrinsic finger muscles. If the pianist places their fingers "in a straight line" by active muscular contraction, then many of these issues are likely to occur. However, because the fingers are supported by the keyboard it is possible to place the fingers on the keys in a "curled" starting position without creating significant co-contraction of these muscles. The upward force created by the fingertips coming into contact with the keys, called the **contact force** (Knudson, 2007, p. 145), would allow the finger muscles to relax to some degree once they have moved the hand into that position. Doing so would prevent a high degree of stiffness caused by muscle contractions before one starts playing. Using external forces to maintain a "curled" finger position would avoid many muscular issues associated with co-contraction initially. However, these problems would still likely occur if the pianist tries to maintain this position while they are playing, which would likely lead to the issues described in the subcategory on "restriction of finger/hand movements" (4.1.4). The only way to start in a "curled" position and avoid these muscular issues when playing would be to

allow the DIP/PIP joints to extend out of the “curled” position as part of their motion to play the key(s). This would take the DIP/PIP joints out of their flexed position, but it would negate the effect of flexing them into the “horizontal line” position in the first place. Therefore, starting in this position would likely cause one of two problems: either it would 1) lead to a number of problems related to co-contraction; or it would 2) necessitate extra motion to extend the fingers before playing the key. Because adding this extra motion would not contribute in any way to completing the task of piano playing, placing the fingers in a position that requires it can be viewed as counterproductive.

In addition to the problems related to co-contraction, flexing the fingers to form a straight line will likely lead to one other issue. The longer fingers (2, 3, and 4) will have to flex to such a substantial amount to form this position that it will lead to what Golandsky describes as having the DIP joints “sticking out” (Taubman Institute, 1995, vol. 1). When the fingers are in this position, any muscle contraction to flex the fingers further will pull the fingertips towards the hand, rather than down towards the key. Therefore, the most likely way to move the fingers to depress the key from this position would be through some form of extension. This could occur either with the finger already in contact with the top of the key, or by extending the MCP to lift the fingertip off the surface of the key and then simultaneously flexing the MCP and extending the DIP/PIP joints to straighten the finger and then flexing all the finger joints to depress the key. Golandsky refers to this type of movement as “Curling and thrusting” (Taubman Institute, 1995, vol. 1), and discourages it because it would cause co-contraction (dual muscular pulls) (see category 4). These potential issues indicate that the amount of DIP/PIP flexion required to “line up” the fingers could be considered problematic in additional ways, beyond those related to general “Curling” above.

“Horizontal key spots:” In addition to discouraging flexing the fingers to place them on horizontal key spots as a starting position, the Taubman Approach sources discourage the idea of trying to depress the keys in horizontal key spots altogether, regardless of the movements used to achieve this result. It is possible to depress the keys in horizontal key spots without starting with highly flexed (“curled”) DIP/PIP joints, but doing so would require either flexing those joints when moving to depress the key or a significant amount of what Taubman called “In and Out” arm motion (see subcategory 4.6.4 below). The Taubman Approach sources describe both of these types of motion as problematic, and therefore, they discourage the idea of trying to depress the keys on horizontal key spots altogether. Instead, Taubman states that the key spots should have an “In and Out relationship” to one another (Taubman Institute, 1995, vol. 3). This seems to indicate that instead of forming a horizontal line, the arrangement of key spots are unique to each particular passage. According to the Taubman Approach sources, the key spots should be determined based on the combination of white/black keys and the length of the fingers chosen to play those keys in that sequence. While the Taubman Approach sources state that the “key spots” do not generally form a horizontal line, Golandsky states that sometimes the “key spots” do end up this way in particular passages. That being said, she implies that this should not be done intentionally as a goal in and of itself. One reason pianists may try to do this is that less force is required to depress the keys when playing closer to the edge. This issue will be discussed in further detail below (subcategory 6.4)

4.2.3 “Curling” occurs when you pull the finger out instead of the arm

TA Summary:

One explanation given by the Taubman Approach sources for why “Curling” happens when moving from note to note is that the pianist moves their finger out instead of the

arm (Taubman Institute, 1995, vol. 3). Golandsky states that the correct way to move out⁵¹ is for the entire finger, hand, and arm unit to move together (Taubman Institute, 1995, vol. 3). This movement is initiated from the forearm, but moves everything from the tip of the fingers to the shoulder (Taubman Institute, 1995, vol. 3). If one tries to move out by moving only the finger, then that finger will have to curl in order to reach the desired key spot (Taubman Institute, 1995, vol. 3). The excerpts in this subcategory indicate that one common instance in which pianists move the fingers out by themselves is to pull a longer finger (e.g. finger 3) behind a shorter finger (e.g. finger 2) (Taubman Institute, 1995, vol. 3).

Analysis:

“Pull the fingers out by themselves:” In the Taubman Approach sources, the term “out” refers to movements away from the fallboard (Taubman Institute, 1995, vol. 3; Milanovic, 2012, p. 116). “Moving out” generally seems to refer to moving the tip of the finger that is about to depress a key further away from the fallboard. This could occur either before or during the finger’s motion to depress the key. Doing so allows the point where the finger contacts the key (“key spot”) to be further away from the fallboard than it would be if the finger depressed the key in its previous position (before it moved out). Because of the number of possible movements in the upper limb, called **degrees of freedom**, there are many combinations of joint movement that could produce this result. The Taubman Approach sources advocate for using mainly arm motions to change the position of the finger in relation to the fallboard and the edge of the keys, which will be discussed in more detail below (subcategory 4.6.4). According to the Taubman Approach sources, “pulling the finger out by itself” seems to refer to changing the “key spot” in

⁵¹ In this context, “out” refers to moving away from the fallboard (Taubman Institute, 1995, vol. 3).

this way mainly by rotating the finger joints, rather than the other joints that move the hand and arm. In doing so, the position of the hand and arm are either maintained or have very minimal movement. If the pianist does not move the hand/arm, then rotation from the MCP joint alone would likely not change the key spot very much, but would instead mainly move the finger down towards the key. Therefore, the only way to change the key spot without moving the hand or arm would be to flex the DIP/PIP joints. According to the Taubman Approach sources, attempting to do so is one of the main reasons why “Curling” occurs in piano playing. Either consciously or subconsciously, the pianist aims to contact the key with the finger at a point that is further away from the fallboard than the finger’s current position. Instead of achieving this result by moving the arm and hand to translate the fingertip to the desired key spot, they rotate the finger joints (DIP/PIP). This results in “Curling” as defined by the Taubman Approach. The next subcategory will discuss a number of pianistic contexts in which “pulling the finger out by itself” can commonly occur.

4.2.4 Don’t “curl” longer fingers to play white keys/to avoid the black key area

TA Summary:

The Taubman Approach sources state that one of the main reasons why pianists curl their longer fingers when playing is to avoid the black key area (Taubman Institute, 1995, vol. 3, 5; Moran, 2008, pp. 22, 27-31, 43, 45). This can occur with the playing fingers, when the pianists curl in order to avoid playing on white keys inside of the black key area (Taubman Institute, 1995, vol. 3). It can also occur when the non-playing fingers curl to avoid touching or being close to the black keys (Taubman Institute, 1995, vol. 3, 5; Moran, 2008, pp. 22, 27-31, 43, 45). Within this subcategory, several different contexts were found in which long fingers can curl for these reasons. One example has been provided for each context:

- **As a general statement:** “Often the long fingers try to avoid the black key area by pulling into the white key area.” (Moran, 2008, p. 22)
- **When moving from a white key to play another white key with a longer finger (e.g. in a C Major scale):** “When playing all white keys, and the in and out arm movements are lacking, the long fingers, 2, 3 and 4, will be forced to curl to avoid playing in the black key area” (Taubman Institute, 1995, vol. 3).
- **When moving from a black key to play a white key with a longer finger:** “If you look at example 3, I’m really jumping a little bit ahead because I’m not showing you here an example where the thumb is on a black key, or the fifth finger on black keys, and you still have to be inside there. This is all white keys. but now this is what most people do. This is where they play the third finger [plays the third finger closer to the edge of the keys]” (Taubman Institute, 1995, vol. 3).
- **When non-playing fingers “curl” to avoid touching or being close to the black keys in single note playing:** “Let me show you what happens with my fingers, because that’s what people find, on white keys, that’s what people find to be the most difficult thing, I would say, white key scale. Let me show you what happens. If I start on the thumb, and my fingers are not doing this [flexes DIP] which is incoordinate already...” (Taubman Institute, 1995, vol. 3).
- **Also “Curling” the non-playing fingers in interval playing:** “Playing the interval of a fifth:...Be sure that the longer fingers (2, 3 and 4) do not curl.” (Moran, 2008, p. 30)

- **And octave playing:** “Another traditional way in which artists have been taught was to curl the second finger in order to tighten and keep the other fingers from hitting the keys in the way” (Taubman Institute, 1995, vol. 5).

The Taubman Approach sources state that because the 3rd finger is the longest finger, it is the finger that pianists tend to curl most often (Taubman Institute, 1995, vol. 3; Moran, 2008, p. 22).

Analysis:

“Black key area:” The Taubman Approach sources seem to use the term “black key area” to refer to the space on the keyboard between the front edge of the black keys and the fallboard.

“Non-playing fingers” “in the black key area:” This seems to indicate that the fingers that are not currently depressing the keys are extended just above the part of the keyboard that is designated as the “black key area.” In some contexts, it could also mean that those fingers are touching the keys in that part of the keyboard without depressing them. Golandsky states that the non-playing fingers should typically be “in the black key area” when playing with a shorter finger (1 or 5) on a white key.

“Playing in the black key area:” This seems to indicate that the place where the finger is contacting a white key (“key spot”) is on the part of the key that is between the edge of the black keys and the fallboard. This is very often in the space between two black keys. Golandsky indicates that “playing in the black key area” is often necessary to avoid DIP/PIP flexion (“Curling”) (see category 4.6.5 below).

“White key area:” The Taubman Approach sources use the term “white key area” to refer to the space on the keyboard between the edge of the white keys and the edge of the black keys. The

phrase “playing in the white key area” seems to indicate that when depressing a white key, the place where the finger is contacting the key (“key spot”) is in this area.

“Avoiding the black key area”/“Pulling into the white key area:” These terms seem to indicate that the DIP/PIP joints of the non-playing finger(s) are flexing (“Curling”) so that the fingertips are either touching or extended above the white keys. In this context, this is done in order to prevent them from either touching or hovering above the black keys. The Taubman Approach sources describe this phenomenon in several contexts: playing single notes, chords, and intervals/octaves. If any of the non-playing fingers are longer than the current playing finger, then doing so would require DIP/PIP flexion (“Curling”), which could be problematic for several reasons. Maintaining this flexed position with the non-playing fingers could lead to co-contraction and create stiffness across those fingers and the wrist (see subcategory 4.1.3 above). If the pianist flexes the DIP/PIP joints to avoid touching the black keys, while also trying to keep the finger from touching the keyboard by extending them above the keys (“hovering”), then extension at the MCP joint would be necessary. Doing so would further increase the amount of co-contraction because it would require increased activity of the finger extensor muscles to extend the fingers from the MCP joints. This could be even more problematic if any combination of fingers 3, 4, and/or 5 are depressing a key, because the EDC muscle extends all three of these fingers simultaneously. As a result, contracting that muscle to extend any of those fingers while one of those fingers is flexed to depress a key would further increase the amount of co-contraction required in order to keep the playing finger from also extending and releasing its key. Whether or not DIP/PIP flexion (“Curling”) is combined with MCP extension to avoid touching or extending above the black keys, that flexion would not seem to be contributing to the task of piano playing in any way. Therefore, it would create extraneous muscle contraction and stiffness

without any clear benefit. If this is done when playing intervals, chords or octaves, it would also create the additional problems related to DIP/PIP flexion and finger abduction (see categories 1.5 and 1.6 above).

“Curling” to play in the “white key area:” The Taubman Approach sources indicate that one common context in which DIP/PIP flexion (“Curling”) occurs is when moving to depress a key with a long finger (2, 3, or 4) in the white key area. The Taubman Approach sources describe two general contexts in which this occurs: 1) when depressing a black key and then moving to depress a white key with a longer finger; and 2) when depressing a white key and then moving to depress a white key with a longer finger. In both cases, the pianist is trying to contact the next key closer to the edge of the keys by flexing the DIP/PIP joints. Doing so could lead to several of the issues outlined above: increased muscle tension, stiffness, and co-contraction. In addition to these issues, trying to “curl” a finger to contact the key closer to the key edge would be problematic for a similar reason to that described in relation to the “horizontal line” starting position. Once the DIP/PIP joints are flexed to bring the fingertip just above the desired point of contact with the key (“key spot”), any more finger flexion will bring the finger closer to the palm of the hand, rather than down towards the key. Therefore, in order for the finger to move down to depress the key from this flexed position, the only muscular activity that can produce this motion would be in the finger extensors.⁵² As described above, this means that a combination of finger flexor/extensor activity will be used for key depression, increasing the amount of co-contraction, and limiting the force/velocity of the finger when depressing the key. It is possible that once the finger is in the DIP/PIP flexion (“curled”) position, its muscles could simply relax to drop the

⁵² The term “extensors” here is used generally to refer to any of the muscles that can act to cause extension at any of the finger joints. This may include the extrinsic extensors or the intrinsic muscles, which act to extend the IP joints. The movement described here will likely include a combination of these muscles, although the specific muscle activity will depend on the exact position/movement used.

finger into the key with gravity. However, in this case the DIP/PIP joints would still be in a flexed position, and so the extensor muscle would have to contract in order to balance the contact force from the key and prevent the finger from falling towards the fallboard.

4.2.5 “Curling” can cause finger(s) to feel(s) too long

TA Summary:

The Taubman Approach sources state that one consequence of “Curling” the fingers is that it can cause the fingers to feel too long. Golandsky states that this feeling is a symptom of incorrect use of the In and Out motions. This subcategory was included in the original content analysis because it seemed to be a somewhat prevalent idea related to “Curling.” However, the excerpts in this subcategory seem to relate more to issues of motor control, rather than biomechanics. Therefore, this subcategory was considered outside the scope of this study, and no analysis has been provided.

4.2.6 Don’t “curl” to prevent broken nail joints

TA Summary:

The Taubman Approach sources point out that in addition to the problem of the different finger lengths, one reason why “Curling” is often taught is to prevent the “broken” or “collapsed” nail joint. Because this problem is particularly common for children, “Curling” is often given to students as a way to “strengthen” their “weak” joint. However, Taubman disagrees with this solution. While she believes that the broken nail joint is problematic, she states that “Curling” the fingers is an extreme overcompensation that is worse than the original problem.

Analysis:

“Broken nail joint:” As described above, Taubman uses the term “nail joint” to refer to the DIP joints of fingers 2-5 (see subcategory 4.1.1). When the finger depresses a key, it generates a force downward into the key. When the finger contacts the key, it will also generate an upward force, called a contact force. Due to Newton’s third law, the contact force will be of equal magnitude and opposite direction to the downward force from the fingertip. Based on the demonstrations by Golandsky and Taubman, the Taubman Approach describes the DIP joint as “broken” when the contact force causes the DIP joint to hyperextend.⁵³ In mechanics, a relevant concept to help explain the “broken nail joint” is that of a **two-force member**, which is any object with only two forces acting on it. In order for the object to reach rotational equilibrium, the forces acting on it must be equal, opposite, and in line with each other. If the forces do not meet these requirements, the object will rotate. In the case of the “broken nail joint,” the distal phalange of the finger can be thought of as a two-force member. The two forces acting on the distal phalange are the force of the middle phalange pushing down on it and the contact force from the key pushing up on it. If these forces are equal, opposite, and in line, then the distal phalange can reach equilibrium and will not rotate. However, if they are not, the phalange will tend to rotate in one direction, causing the joint itself to translate either towards the hand (with DIP hyperextension) or towards the fallboard (with DIP flexion). In the terminology used by the Taubman Approach sources, if the joint translates toward the hand (in conjunction with DIP hyperextension), it is “broken” or “collapsed,” and if it translates toward the fallboard (in conjunction with DIP flexion) it is “curled.”

⁵³ The term “hyperextension” is used here to refer to extension of the DIP joints beyond their resting/neutral position.

“Curling” to prevent the “broken nail joint:” Because of the forces created by the weight of the arm and hand (see analysis on “Keybedding,” subcategory 2.1), and the fact that the phalange will likely not be totally perpendicular to the keyboard, the forces acting to rotate it will more likely cause it to fall toward the hand, causing hyperextension at the DIP joint (“broken nail joint”). According to the Taubman Approach sources, many teachers try to prevent the DIP joint from hyperextending by flexing it (“Curling”). If the DIP flexion is achieved by co-contracting the extrinsic finger muscles, it would increase the stiffness across the DIP joint (see above). This would stabilize the joint and prevent it from moving or rotating without a very high applied force. If the DIP flexion is achieved passively (without substantial muscle contraction) by moving the arm/hand closer to the keyboard and keeping the fingers more relaxed, it could still prevent the DIP joints from hyperextending. This is because the only way the DIP joint could hyperextend from this position is if the PIP joint gets higher (translation). However, the downward force of the finger to depress the key will not allow the PIP joint to get higher, and so the DIP joint will not be able to rotate.

In general, Taubman states that hyperextending the DIP joint is problematic.⁵⁴ While “Curling” the fingers, either with or without muscular co-contraction, will prevent this problem, Taubman discourages using the strategy because she states that doing so will create more serious problems (described throughout this analysis). Instead, she recommends placing the DIP joint in a more “straight” position, which will be discussed below (see subcategory 4.5.3 below).

4.2.7 Don’t “curl” when plucking in octave playing

TA Summary:

During octave playing, the Taubman Approach sources state that the finger, hand, and

⁵⁴ The explanation for why extending the DIP joint is problematic is outside the scope of the current study.

arm must fall freely “as a unit” when dropping into the keys (Taubman Institute, 1995, vol. 5). While this downward motion is meant to be almost entirely passive, the only active motion is a “slight plucking” motion of the fingertips, that allows for a “slight push off” from the key (Taubman Institute, 1995, vol. 5). Golandsky describes the plucking motion as a “feeling in the fingertip” which should occur in all staccato playing (Taubman Institute, 1995, vol. 5). However, she also states that it is important that this motion is felt only in the fingertip, because if the motion is done improperly it can result in "Curling" the thumb and fifth finger, which she says is “too much plucking” (Taubman Institute, 1995, vol. 5).

Analysis:

“Curling” and “Plucking:” A detailed analysis of the subject of “plucking” is considered to be outside the scope of this study. That being said, it seems to involve some type of flexion motion of fingers 1 and 5 when playing octaves. The aspect of “plucking” relevant to this study is that the fingers should not be “curled” when executing the “plucking” motion. This likely means that the pianist should not flex the DIP/PIP joints of finger 5 or the IP joint of the thumb. Doing so will likely lead to the issues related to “Curling” for the thumb and the other fingers. It would also likely lead to problems of combining finger flexion and abduction described above. One additional issue that could occur as a result of “Curling” when playing octaves is that flexing the distal joints substantially when playing each octave would cause the fingertips to get closer together. As a result, more movement would be required to extend/abduct them to the hand span necessary for playing the next octave. This would increase the amount of **work** done, which is a product of the force and the displacement. Work is expressed through the following equation: $W = FD$. When “Curling” during octave playing as described by Golandsky, muscle force would

increase due to the issues of co-contraction, stiffness, etc. associated with the combination of “flexion” and “abduction” (“stretching”) (see categories 1.5 and 1.6). Muscle displacement would increase because the fingers will need to rotate across a wider range of motion. Therefore, “Curling” the fingers when playing each octave would greatly increase the amount of work done by the pianist to complete the task.

4.2.8 “Curling” can occur because the wrist is too low

TA Summary:

The Taubman Approach sources claim that one potential cause of “Curling” the fingers is that the wrist is too low. The Taubman Approach sources advocate for a generally level wrist position (Taubman Institute, 1995, vol. 1). Therefore, the claim that a low wrist can cause “Curling” usually refers to dropping the wrist below level. However, the Taubman Approach sources suggest that when playing large chords/intervals, the wrist should be higher than level (Taubman Institute, 1995, vol. 1). In these contexts, the statement that “Curling” caused by a “low wrist” does not mean lower than level, but rather playing with the wrist lower than the “correct” position for that context. In some excerpts in this category, it is claimed that when the wrist is too low, the fingers must curl in order to prevent them from falling off the keyboard (Taubman Institute, 1995, vol. 1). The current analysis found that in this context, the words “grab” or “clench” were used as synonyms for “Curling.”

Analysis: A detailed analysis of “Curling” the fingers as a result of playing with a “low wrist” requires a discussion of wrist height, which is outside the scope of this study. Further research will be needed to examine the statements in the Taubman Approach sources related to a “low wrist” before its connection to “Curling” can be understood.

4.2.9 Conclusion: “Curling” in context

The categories above were developed in order to better understand ways that “Curling” as defined above can occur in a variety of contexts in piano playing. Categories were analyzed to determine the biomechanical implications of “Curling” in each context. A total of 66 units of coding were used in this category. After a second coding, 65 units of coding were in agreement between the two coding sessions, making for a 98.48% agreement. The following table has been provided to display each subcategory with a brief summary of its biomechanical analysis:

Table 4.2 “Curling” in context

Subcategory	Biomechanical Analysis	TA Sources	Units of Coding
Don’t line up all fingers to be the same length as a starting position	Placing the fingers on a keyboard so that all fingertips will be equidistant from the edge of the keys in relation to the fallboard. This will require substantial DIP/PIP flexion of fingers 2-5. Doing so will likely increase co-contraction, joint stiffness, and muscle forces needed for maintaining that position. That position may be achieved passively using the contact force to maintain equilibrium. However, once the fingers move to play the keys, these issues will likely occur unless the DIP/PIP joints are removed from their flexed position.	Taubman Institute, 1995, vol. 3; Milanovic, 2012	2
Don’t play in horizontal key spots/key spots must have in and out relationship	The pianist should not try to contact the keys at the same position in relation to the fallboard when playing each finger. Instead, the position of the fingertip in relation to the fallboard when it contacts the key will likely be different for each finger. The exact arrangement of fingertip positions in relation to the fallboard will be determined by the context of a musical passage.	Taubman Institute, 1995, vol. 3	6
“Curling” occurs when you pull the finger out instead of the arm	Pianists often flex the DIP/PIP joints to translate the fingertip further away from the fallboard. Instead, a combination of rotations at other joints should be used to translate the fingertips without flexing the DIP/PIP joints (see category 4.6).	Taubman Institute, 1995, vol. 3	7
Don’t “curl” longer fingers to play white keys/to avoid the black key area	Pianists often flex the DIP/PIP joints to contact a white key in the area between the edges of the white and black keys. They also often do this to prevent either touching or getting close to touching the black keys with the “non-playing fingers.”	Taubman Institute, 1995, vol. 3, 5; Moran, 2008	21
“Curling” can cause finger(s) to feel(s) too long	Considered outside the scope of this study.	Taubman Institute, 1995, vol. 3	5
Don’t “curl” to prevent broken nail joints	The contact force directed from the keyboard into the fingertip can cause the DIP joint to extend. In order to prevent this from occurring, pianists will often flex the DIP/PIP joints to increase the stiffness of the DIP joints.	Taubman Institute, 1995, vol. 1	5

	However, this will lead to other problems identified in this study. Therefore, DIP/PIP flexion is not recommended as a way to increase DIP joint stiffness.	
Don't "curl" when plucking in octave playing	A very small flexion movement is sometimes used in fingers 1 and 5 during octave playing. Detailed analysis of this type of movement is outside the scope of this study. However, substantial DIP/PIP flexion of finger 5 and IP flexion of finger 1 are discouraged because doing so will increase co-contraction, joint stiffness, limit hand span, and increase muscle forces when playing. Additionally, the amount of work done by the pianist will likely increase because both force and displacement of finger movements will likely increase.	Taubman Institute, 3 1995, vol. 5
"Curling" can occur because the wrist is too low	DIP/PIP flexion can occur if the wrist is too low. A detailed discussion of this subject requires an analysis of the concept of "Low Wrist," which is not included in this study.	Taubman Institute, 3 1995, vol. 1

4.3 "Curling" leads to physical/musical problems

Introduction:

The Taubman Approach sources state that a number of physical and technical problems can result from "Curling" the fingers when playing. The following section will summarize the main problems identified in the Taubman Approach sources, and then define those problems as discussed in relatively recent scientific literature. Then, a possible understanding of how the Taubman Approach sources connect "Curling" the fingers when playing to each particular problem will also be provided. The main problems identified in this section are pain/injury, tension/tightness, and several muscular problems: fatigue, weakness, spasm, and numbness. Focal dystonia was also identified in this section as a potential consequence of "Curling." A miscellaneous subcategory was created for other problems that the Taubman Approach sources associate with "Curling." Because the first two categories are related to similar biomechanical concepts, their analysis has been included after all three have been summarized.

4.3.1 “Curling” can lead to pain/injury

TA Summary:

Some of the Taubman Approach sources state that “Curling” can cause pain and injury.

In some contexts, these statements are made generally, without clarification as to the type of injury or the location of pain caused by “Curling” the fingers (Taubman Institute, 1995, vol. 1, 3). Excerpts from Taubman’s conference presentation suggest that the pain and injuries she associates with “Curling” are mainly muscular (1984, p. 146). In these excerpts, she states that “Curling” causes the muscles involved to have a “constant pull,” that “is exacerbated when power is needed.” She states that as a result, the muscles “can weaken and spasm,” which will cause “numbness, clenching, and pain.”

4.3.2 “Curling”/fixating creates tension/tightness

TA Summary:

The Taubman Approach states that “Curling” the fingers leads to tension and tightness.

This effect of “Curling” is described across a wide variety of contexts:

- Generally: “Curling” the fingers is described as causing “tightness” or “tension” in any context (Taubman Institute, 1995, vol. 1, 3, 5; Moran, 2008, pp. 22, 133).
- When the wrist is low and the fingers have to “grab” or “clench” to prevent falling off the keys (Taubman Institute, 1995, vol. 1).
- When fixating the fingers into a curled starting position (Taubman Institute, 1995, vol. 1).
- When “Curling” a finger to play out on a white key (Taubman Institute, 1995, vol. 3).
- When “Curling” a non-playing finger in octaves (Taubman Institute, 1995, vol. 5).

The widespread use of the terms “tension” and “tightness” to describe “Curling” in these

different contexts indicates that tension or tightness are produced when “Curling” at any time, regardless of context.

Analysis:

“Constant pull:” When the fingers are held in a curled position, the DIP/PIP joints are flexed. As discussed above, maintaining this position requires activating the FDP muscle and possibly the FDS muscle (see subcategory 4.1.3 above). In order to maintain DIP/PIP flexion while moving the fingers and hand when playing the piano, the FDP/FDS muscles will have to contract continuously, which Taubman describes as a “constant pull.” Because activating the FDP/FDS requires co-contraction of the extensor muscles to prevent movements at the wrist/MCP joints, Taubman’s statement implies that the “constant pull” will likely occur in these muscles as well. Taubman also states that the “constant pull will be exacerbated when power is needed.” This claim suggests that as the pianist tries to depress the key with more force/velocity to create louder sounds, the finger muscles will generate even more force to overcome the resistance created by the co-contracting muscles. In cases where the pianist tries to generate more force into the keys while maintaining a flexed DIP/PIP (“curled”) position, it is more likely that the FDS muscle will be activated as a synergist in order to increase force production.

“Tension”/“tightness:” The Taubman Approach sources state that “Curling” the fingers can lead to “tension” or “tightness.” Some of the consequences of “tension and “tightness” that are named in this subcategory are technical limitations: difficulty moving the fingers quickly or with control of key depression (see categories 1.3 and 1.4 above). In mechanics, the word **tension** generally describes any force that makes an object longer (e.g. a force pulling on either or both ends of a string) (Knudson, 2007, p. 69). In the biomechanical sources, the term “muscle tension” is sometimes used to describe the force generated by muscle contraction (McLester &

St. Pierre, 2007, p. 318; Knudson, 2007, p. 51; Wheatley Brown, 2011). All muscular contractions produce active tension corresponding to the amount of fibers contracting and the force generated by each individual fiber (McLester & St. Pierre, 2007, p. 318; Knudson, 2007, p. 51). However, tension can also be passive due to the force generated by muscle stiffness, which causes it to return to resting length without any muscle contraction (Knudson, 2007, p. 51).⁵⁵ The term “tension” as used in the Taubman Approach was examined in the terminology study by Wheatley-Brown (2011). This study found that the word “tension” is always used with a negative connotation, which is not consistent with the biomechanical definition. Therefore, an explanation of this term as used in the Taubman Approach is required to understand what is meant by the statements in subcategory.

Several statements by Golandsky in the first DVD (Taubman Institute, 1995, vol. 1) suggests a possible definition for the term tension:

- “[Opposing muscles] can never be used at the same time because if they are, what results are what we call ‘dual muscular pulls,’ which is another name for tension. Any time you move in a way that activates those two muscles at the same time, you’ll end up with tension.”
- “Fixating is usually achieved by the use of contrary muscles, such as flexing and extending at the same time which creates those dual muscular pulls, which cause tension...”
- “The slightest tension will limit motion... so that when we move, we never think of fixating. But we’re not relaxed either because the arm muscles are going to be working to

⁵⁵ This is also sometimes also called “elasticity” (Knudson, 2007, p. 27) or “passive tension” (Knudson, 2007, p. 51).

move us, but when we move properly and freely and there is no tension, one muscle is active and the opposing muscle has to be passive...

- “So tension can come from tension, from overusing the muscle, and it can come from tremendous relaxation, where it takes a tremendous effort to get, to move again. It takes too much effort, and it ends up as a tension.”

These statements suggest that Golandsky uses the term “tension” in two general ways: 1) to describe co-contracting muscles to increase joint stiffness; and 2) to describe contracting a muscle to a degree that is relatively high in proportion to its total capability. If the first definition is used, the Taubman Approach sources would be stating that “Curling” leads to increased joint stiffness. This is consistent with the findings in this study described above (see categories 1.3). If the second definition is used, the Taubman Approach sources would be stating that “Curling” can cause one or more muscles to contract to a relatively high degree. This is also consistent with the findings in this study suggesting that DIP/PIP flexion will lead to generally higher muscle forces for several reasons mentioned above. This understanding of the relationship between “tension” and “Curling” is also consistent with Taubman’s discussion of the “constant pull” (see above). Based on these two definitions, the use of the word “tension” among the Taubman Approach sources to describe the consequences of “Curling” the fingers seems to be internally consistent within the context of the Taubman Approach itself. However, some confusion around what is meant by “tension” is likely to occur due to the disparity between their use of the term compared to that in the biomechanical literature (see Wheatley-Brown, 2011 for more details).

In the Taubman Approach sources, the terms “tension” and “tightness” seem to be used interchangeably, often within the same statement. For example, Golandsky states that when “Curling” and “stretching” as a basic hand position, “you’re already starting with this kind of a

very, very tight position. This produces tensions even before one begins to move...” (Taubman Institute, 1995, vol. 1) She connects this experience to the co-contraction (“dual muscular pulls”) necessary to position the hand and fingers in this way (see categories 1.2 and 1.3). Based on this analysis, the subcategory on “tension” does not seem to provide any new explanation of the impacts of “Curling.” Instead, it reveals that the terms “tension” and “tightness” are possibly being used to describe both the physical effects of DIP flexion (increased force/stiffness), as well as the subjective feelings that result from it.

Fatigue: Taubman states that one potential consequence of the continuous muscle contraction that can result from “Curling” the fingers is muscle fatigue. In the biomechanical sources, muscle fatigue is defined as a decrease in the muscle’s ability to produce force, which can occur when exercising for a sustained period without rest (Cahyadi et al., 2019; Enoka & Duchateau, 2008). Muscle fatigue is thought to be caused by a number different mechanisms depending on the task being performed (Enoka & Duchateau, 2008). One possible cause is that sustained muscle contraction causes high levels of intramuscular pressure, which limits blood flow to the muscle (Freivalds, 2004, p. 205). This understanding of muscle fatigue provides an understanding of Taubman’s claim that the “constant pull” created by continuous DIP/PIP flexion when playing the piano could lead to muscle fatigue. She is likely stating that if the muscle contractions necessary to flex the DIP/PIP joints are sustained for a long enough time without rest, the muscles involved will have decreased force production capability. It is also possible that she is associating the physical, muscular consequence of “Curling” with the subjective feeling that the muscle is “tired,” which is often described colloquially as “muscle fatigue.” Taubman does not specify which muscles in particular may become fatigued as a result of “Curling.” From the above analysis on muscles involved in DIP/PIP flexion, it seems likely that she is referring to

either the extrinsic finger flexors/extensors, which co-contract to create the “curled” position and move the fingers in the sagittal plane (see subcategory 4.1.3).

Weakness/Spasm/Numbness: In addition to fatigue, Taubman also states that other potential consequences of the continuous muscle contraction that can result from “Curling” the fingers are muscle weakness, spasm, and numbness. In the biomechanical sources, these terms are defined as follows:

Weakness: Muscle weakness can be defined as a decrease in force production capability. As described above, this is synonymous with the biomechanical definition of muscle fatigue. Taubman’s use of both of these terms as separate symptoms seems to suggest that she is using the term “fatigue” in the more subjective sense of feeling tired, and the term “weakness” in the more objective sense of reduced force production capability.

Spasm: Muscle spasm can be defined as muscle contraction that is both involuntary and persistent (Mense, 2008). Like muscle fatigue, the main mechanism of muscle spasm is thought to be insufficient blood flow to the muscle⁵⁶ (Mense, 2008). Pain caused by muscle spasms can range from low to very high depending on their severity and cause.

Numbness: Numbness can be described as a loss of feeling. Numbness is sometimes accompanied by tingling sensations, and can be caused by nerve problems. However, these symptoms are also sometimes associated with muscular disorders (Freivalds, 2004, p. 205). Numbness can also be a symptom of nerve entrapments, which may occur in some cases due to sustaining abnormal joint positions when playing (Narducci, 2020). That being said, a detailed exploration of this subject is considered outside the scope of this study.

⁵⁶ This is also known as ischemia (Mense, 2008).

Pain/Injury: Taubman states that if done repetitively, “Curling” the fingers can eventually lead to muscle pain. Golandsky states more generally that “Curling” can lead to injury. The Taubman Approach sources do not clearly distinguish between the terms “pain” and “injury.” Because the physiological mechanisms of playing-related injuries are not well understood (see Review of Literature), these two concepts are often discussed in conjunction in the scientific literature, with pain as a symptom of a particular disorder. In recent years, pain is often classified into different types, depending on its underlying mechanisms and subjective presentation (Mense, 2008). Because Taubman associates “Curling” with repetitive and sustained muscle contraction, it is possible that the pain/injury associated with “Curling” in the Taubman Approach is a form of muscle pain/injury. Muscle injuries often start with acute soreness or pain due to microstrain and inflammation of the tissues brought on by repetitive and consistent use of a muscle beyond its normal function (Freivalds, 2004, p. 205; Narducci, pp. 203-4). While muscle pain often starts in the affected muscle (Freivalds, 2004, p. 205), it can also be referred to another part of the body (Mense, 2008). If the activity is stopped or continued gradually with breaks, then pain will often be resolved (Freivalds, 2004, p. 205). On the other hand, if work is continued the injury can become chronic, with such symptoms as spasm, dysfunction, and temporary disability (Freivalds, 2004, p. 205). Many of the symptoms associated with chronic muscle disorders overlap with those described by Taubman in relation to “Curling” the fingers when playing. Based on these similarities, it is possible that when the Taubman Approach sources say that “Curling” can lead to “injury,” they are referring to a chronic muscle condition that occurs from sustained and repetitive use. Such injuries can be classified as forms of “overuse injuries” that are common among musicians and are thought to sometimes result from faulty playing technique (see Review of Literature). However, because repetitive muscle use has also been linked to “overuse injuries”

in other soft tissues (e.g. tendons, muscle-tendon structures, cartilage etc.) (Narducci, 2020), another possible interpretation of the Taubman Approach’s connection between “Curling” and injury is that the repetitive and sustained use of muscles involved in DIP/PIP flexion will likely lead to an overuse injury in some other soft tissue (e.g. tendons). One possibility is that the injury will occur in the tendons that attach the extrinsic finger muscles to the bones (see analysis on “Keybedding,” subcategory 6.1.3 for more details on tendon injuries).

4.3.3 “Curling” can cause fingers to stay curled/dystonia

TA Summary:

The Taubman Approach sources state that if pianists play regularly with curled fingers, eventually the fingers can stay curled or clench to the point that the pianist will not be able to open them anymore (Taubman Institute, 1995, vol. 1, 3). Golandsky refers to this condition as dystonia (Taubman Institute, 1995, vol. 3).

Analysis:

“Stay curled”/dystonia: The Taubman Approach sources state that if a pianist “curls” their fingers often enough when playing, they will get dystonia. They describe this condition as when the fingers “stay curled” and the pianist is not able to open them. In the scientific literature, musician’s focal hand dystonia is defined as a movement disorder with symptoms of muscular incoordination or loss of voluntary motor control when playing (Altenmuller & Jabusch, 2010b). Many instrument groups are impacted, but pianists are one of the more frequently affected groups (Altenmuller & Jabusch, 2010b). Pianists with dystonia typically have symptoms in their right hand; however, the hand affected is often the dominant one (Altenmuller & Jabusch, 2010a). Symptoms of dystonia are task-specific (Altenmuller & Jabusch, 2010b), and so they tend to only occur when musicians are playing their instrument. One common symptom of

dystonia in pianists is the co-contraction of antagonist muscles, very often flexor/extensors of fingers/hand (Altenmuller & Jabusch, 2010b), which can lead to a hyperflexed or hyperextended position (Watson, 2009, p. 261). This explains Golandsky's statement that in dystonia "the fingers don't open up. They just stay curled" (Taubman Institute, 1995, vol. 3). While this condition is typically painless at onset, the resulting co-contraction may eventually lead to discomfort (Watson, 2009, p. 261). Among pianists, dystonia can disrupt one's ability to play with facility, particularly in rapid passages; if symptoms persist, the pianist may permanently lose the ability to play at a high level altogether (Watson, 2009, p. 262).

The causes of musician's dystonia are not clearly understood, but some predisposing factors have been identified. Affected musicians are more typically men, and there is thought to be a genetic component to developing dystonia (Narducci, 2020; Altenmuller & Jabusch, 2010a). Psychological traits such as perfectionism and anxiety are also commonly observed (Altenmuller & Jabusch, 2010a; Narducci, 2020). The symptoms that occur may be the result of abnormalities in various sensorimotor areas of the brain (Altenmuller & Jabusch, 2010b; Watson, 2009). These abnormalities are thought to be closely linked to sustained use of isolated body structures, particularly in the form of small and repetitive movements over long periods of time (Narducci, 2020; Altenmuller & Jabusch, 2010b). As a result, playing an instrument that requires high spatial sensorimotor precision for many hours is thought to be a triggering factor (Altenmuller & Jabusch, 2010a). The Taubman Approach sources do not provide any explanation for why repetitive DIP/PIP flexion may lead to dystonia. It seems likely that these statements are based on Taubman's professional experience working with affected pianists. One possible understanding of her connection between "Curling" and dystonia is that DIP/PIP flexion in piano playing typically requires co-contraction. They may be suggesting that if the pianist

repetitively and/or continuously co-contracts the muscles that flex the DIP/PIP joints for extended periods of time, it may lead to the brain changes associated with dystonia that eventually cause the finger muscles to co-contract every time the person plays the piano.

4.3.4 Miscellaneous - problems associated with “Curling”

TA Summary:

In addition to the issues described above, the Taubman Approach sources describe a number of other problems that result from “Curling,” including:

- **Mixed messages:** Golandsky states that trying to simultaneously “fixate and move the fingers can hinder technique because . This is a motor control issue, and so it is outside of scope of this study (Taubman Institute, 1995, vol. 1).
- **“Outside curl:”** an “outside curl” of the thumb can cause pain in the thumb and the wrist (Taubman Institute, 1995, vol. 1). This is technically not a form of “Curling” discussed in this study, and so it was not included in the other categories.
- **“Crammed feeling:”** a subjective feeling, and therefore outside the scope of this study (Taubman Institute, 1995, vol. 3).
- **“Cramping”/“Clenching:”** These terms may have some connection to dystonia (Taubman Institute, 1995, vol. 1, 3)
- **Limitation:** Milanovic states that one consequence of “Curling” is “limitation” (2012, p. 133). This likely refers to general technical limitations that would be the product of “restriction of motion,” problems with “opening the hand,” etc. that are described in this study.

- **Hindered memory:** Milanovic (2012) states that “Curling” can hinder one’s ability to memorize a piece (p. 126). Because this is a cognitive issue, it is outside the scope of this study.

Some of these potential problems are related to subjects discussed above. For example, “cramping” may be related to dystonia, and “limitation” refers to the general technical issues that have been discussed throughout this study. “Clenching” may be a synonym for “Curling.” The remaining potential issues (e.g. mixed messages, outside curl, etc.) were considered outside the scope of this study. Therefore, no analysis will be included for this category.

4.3.5 Conclusion: “Curling” leads to physical/musical problems

The categories above were developed to identify the potential physical problems that the Taubman Approach sources associate with “Curling” the fingers. Categories were analyzed to determine how the Taubman Approach sources may be drawing a connection between the biomechanical implications of “Curling” when playing and each physical problem. A total of 27 units of coding were used in this category. After a second coding, 26 units of coding were in agreement between the two coding sessions, making for a 96.30% agreement. The following table has been provided to display each subcategory with a brief summary of its biomechanical analysis:

Table 4.3 “Curling” leads to physical/musical problems

Subcategory	Biomechanical Analysis	TA sources	Units of Coding
“Curling” can lead to pain/injury	Maintaining active DIP/PIP flexion when playing the piano can lead to sustained muscle co-contraction. If continued for a long enough period of time, this may lead to muscle fatigue, spasm, numbness, and pain. If this activity is continued, a chronic muscle disorder or injury to other soft tissues (e.g. tendons) may result.	Taubman, 1984; Taubman Institute, 1995, vol. 1, 3; Moran, 2008	5
“Curling”/fixating creates tension/tightness	The sustained muscle co-contraction caused by actively flexing the DIP/PIP joints may cause the muscles	Taubman Institute, 1995, vol. 1, 3, 5;	12

	involved to become overworked. This may also increase joint stiffness and make it difficult to move when playing.	Moran, 2008; Milanovic, 2012	
“Curling” can cause fingers to stay curled/dystonia	Sustained muscle co-contraction may lead to musician’s dystonia, which is a neuromuscular condition that can cause the finger muscles to co-contract substantially every time the pianist tries to play. This may occur due to repetitively co-contracting finger muscles necessary to play with DIP/PIP flexion.	Taubman Institute, 1995, vol. 1, 3	4
Miscellaneous - problems associated with “Curling”	Several other problems were considered outside the scope of this study: “mixed messages,” pain due to an “outside curl,” “crammed feeling,” “cramping/clenching,” “Limitation,” and “hindered memory.”	Taubman Institute, 1995, vol. 1, 3; Milanovic, 2012	6

4.4 Miscellaneous - “Curling:” This miscellaneous category was created to contain excerpts regarding “Curling” that did not fit into any of the other categories in the analysis. Four units of coding were placed in this category. All four of those units of coding were in agreement between the two coding sessions, making for a 100% agreement. While some of these excerpts were discussed in relation to the categories above, the remaining categories will not be discussed in detail as part of this analysis. The excerpts contained in the “Miscellaneous- “Curling” category can be summarized as follows:

Other situations where “Curling” can occur:

- **Thrusting/straightening motion:** The “thrusting” motion often occurs in conjunction with “Curling” (Taubman Institute, 1995, vol. 1). This type of movement was discussed in the analysis of categories 2.1 and 2.2.
- **When sitting too high:** In addition to “clenching” the fingers as a result of sitting too high (see subcategory 4.2.8), they can also “clench” when sitting too low. In both cases, the Taubman Approach sources discuss that the fingers curl to prevent falling off the keyboard (Taubman Institute, 1995, vol. 1).

- **When connecting certain finger combinations:** “Curling” can be caused when playing legato from a long finger to an octave (Taubman Institute, 1995, vol. 3).⁵⁷
- **When the arm does not support the fingers:** several excerpts discuss that a lack of arm support can cause the fingers to “grab” the keys in different contexts, such as when playing octaves or chords. The subject of arm support will be discussed further in the analysis on “Keybedding” (category 5.5) (Taubman Institute, 1995, vol. 1, 2).

“Curling” related to pedagogy: A number of excerpts discuss “Curling” in a pedagogical context. These excerpts did not directly relate to the biomechanical analyses discussed in the above categories.

- “Curling” is a commonly taught hand position (Taubman Institute, 1995, vol. 1).
- People sometimes curl the fingers to prevent them from being too straight (Taubman, 1984, p. 145). Taubman suggests that doing so is an overcompensation, and that instead the fingers should be neither curled nor too straight. Her recommended hand position will be discussed below (see category 4.5).
- “Curling” and finger isolation are often recommended in finger exercises (Milanovic, 2012, p. 134).
- Terminology problem of “Curling”/“curving:” Milanovic (2012) points out that the terms “Curling” and “curving” are often used in different ways among pedagogues, which can lead to confusion (p. 133).

⁵⁷ This example was not identified explicitly as “Curling,” but Golandsky’s demonstration of the finger position used to play it in the “incorrect” way involves DIP/PIP flexion.

- “Curling” can reappear even after retraining: Milanovic (2012) states that her problem of curled fingers reappeared when relearning scales and arpeggios, and therefore needed to be replaced with new movements (p. 164).

Other:

- **Squeezing a ball is harmful as a rehabilitation exercise:** Taubman discourages medical professionals from using this treatment for musician’s injuries because it requires “Curling” the fingers, which Taubman associates with the biomechanical consequences described in the above categories (Taubman, 1984, p. 152).

Taubman’s Proposed Alternatives to “Curling”

Introduction:

The following section will discuss the finger and hand position that the Taubman Approach sources propose as an alternative to “Curling” the fingers, which Taubman called the “natural curve.” Three main categories were developed in order to define the term “natural curve” as used in the Taubman Approach: 1) “the fingers should be in the same position as when the hand is at one’s side,” 2) “the relationship of finger lengths should be maintained,” and 3) “the nail joint should be relatively straight.” These categories were developed to focus on the aspects of the “natural curve” position that are directly contrasted with “Curling” the fingers. Finally, a miscellaneous subcategory was created to include excerpts related to the natural curve that did not fit into the other three categories. Because all of the categories in this section are related to defining the “natural curve” position, the analyses of all the categories will be included after all the categories have been summarized. Excerpts from the miscellaneous subcategory will be discussed only as needed in order to help explain how the “natural curve” position is distinct

from a “curled” position. The remaining excerpts were considered outside the scope of this study.

4.5 Fingers/hand should have natural curve/position

The Taubman Approach advocates a hand position in which the fingers maintain their “natural curve.” The present analysis identified three descriptions of this “natural curve” position that differentiate it from “Curling.”

4.5.1 Natural curve position is the same as when the hand is at one’s side

TA Summary:

Milanovic (2012) points out that while many approaches to piano technique advocate for a “natural hand position,” these approaches vary in their definitions of “natural” (p. 133). In the Taubman Approach, a “natural position” is defined as keeping the fingers in their “natural curve” or “normal curve,” which is the same position as when the hand hangs at one’s side (Taubman Institute, 1995, vol. 1; Moran, 2008, p. 20). Pianists are encouraged to find this position by putting the hand at their side and then bringing the hand to the keyboard while maintaining the position of all three finger knuckles (Taubman Institute, 1995, vol. 1; Moran, 2008, p. 20). Moran (2008) states that this is to be done without tension (p. 20). Golandsky makes an explicit distinction in terminology between this type of “curving” and “Curling” the fingers by flexing the nail joint (see subcategory 4.1.1 above). Keeping the fingers in the natural curve also means that they are not stretched apart or crowded together (Moran, 2008, p. 20).

4.5.2 Fingers should stay in the same relationship to each other

TA Summary:

Once the pianist finds the correct starting position (the “natural curve”), the Taubman Approach sources indicate that they will notice that finger lengths have a certain relationship to each other (Taubman Institute, 1995, vol. 3). The thumb and fifth fingers are considered “short fingers,” while fingers 2, 3, and 4 are considered “long fingers” (Taubman Institute, 1995, vol. 3). Of the short fingers, the fifth finger is longer than the thumb. Of the three long fingers, the third finger is the longest (Taubman Institute, 1995, vol. 3). According to Milanovic (2012), one Taubman teacher refers to these relationships as the “non-variable distance of the fingers” (p. 116). This relationship of the finger lengths that occurs in the natural position should be maintained at all times (Taubman Institute, 1995, vol. 3). Doing so could potentially be problematic because of the need to move horizontally (laterally) across the keyboard while limiting one’s time spent playing in the black key area (Taubman Institute, 1995, vol. 3). However, any attempt to solve this problem by pulling the longer fingers (2, 3, or 4) toward the hand so that they are either the same length or shorter than the short fingers (1 or 5) will result in “Curling” (Taubman Institute, 1995, vol. 3). Therefore, within the Taubman Approach, a correct solution to the problem of varying finger lengths must be one that allows for moving the fingers toward and away from the fallboard without changing this relationship (Taubman Institute, 1995, vol. 3).

4.5.3 Nail joint should be relatively straight

TA Summary:

Taubman states that instead of “Curling” the fingers by pulling in the nail joint, pianists

should keep their nail joint straight, neither too far out (“curled”) or in (“collapsed”) (Taubman Institute, 1995, vol. 1). From a pedagogical point of view, she advises teachers to tell students to keep the joint “straight,” rather than telling them to curl it (Taubman Institute, 1995, vol. 1). Golandsky states that the joint should be “relatively flat” (Taubman Institute, 1995, vol. 1).

4.5.4 Miscellaneous - Natural curve position

TA Summary:

In addition to the descriptions of the correct finger position/movement described in the categories above, the current analysis identified a number of miscellaneous statements about the natural curve position/movement in the Taubman Approach sources. These statements include aspects of knuckle and finger position that give further details to the description of the “natural curve” hand position. Examples include:

- The long fingers face toward the hand and the thumb faces towards the pointer (finger 2), which allows for a slightly higher wrist/forearm (Milanovic, 2012, p. 157).
- The main knuckles should not be arched/collapsed, and should be higher than the middle knuckles. This position allows the fingers, hand, and arm to be balanced (Taubman Institute, 1995, vol. 1; Moran, 2008, pp. 23, 27, 29, 43, 51; Milanovic, 2012, p. 204).⁵⁸
- The pianist should feel that each finger knuckle is present, and not collapsed: two knuckles for the thumb, and three knuckles for fingers 2-5 (Milanovic, 2012, p. 157).
- The correct hand position is not a fixed one, but changes according to context (Milanovic, 2012, p. 109).

⁵⁸ The subject of finger/hand position and balance will be discussed in more detail in the analysis on “Keybedding” (see subcategories 5.2.1-2.3).

- There should be no feeling of tension in the hand and fingers (Moran, 2008, p. 21).
- Do not place the fingers on 5 adjacent white keys: when the hand is in its correct starting position, it typically occupies four keys or fewer, depending on hand size (Moran, 2008, p. 21; Milanovic, 2012, p. 108).

Analysis: “Natural Curve” Position

“Hanging at your side:” The Taubman Approach sources state that in the “natural curve” the position of the finger joints should be the same as when the pianist hangs their hand at the side of their body. In the biomechanical sources, this is sometimes referred to as the **resting position** (Worley, 1989; Lee & Jung, 2014).⁵⁹ Because the finger flexor muscles are stronger than the finger extensors, the resting hand position is slightly flexed at all three finger joints (Cael, 2010, p. 172; see Lee & Jung, 2014 for measured angles). However, this position is called “resting” because when the hand hangs at the side of the body, virtually no muscular contraction is required to place the joints in this position (Worley, 1989). Moran (2008) states that students “should feel no tension in their hands and fingers” while in this position (p. 20). As discussed above (see subcategory 3.2) the term “tension” is likely referring to either a relatively low amount of muscle contraction, or a relatively low joint stiffness. When the pianist places their hands on the keys in this shape, a small amount of muscular contraction will be required to maintain the position of the finger joints and counteract the normal force produced by the keys against the fingertips. However, because the finger muscles will be very close to their optimal length, and other muscles will be involved in maintaining the arm/hand position, the amount of muscle contraction necessary to do so is likely very small. Additionally, the pianist will not need to generate a high degree of stiffness across the finger joints in order to stabilize them. This is

⁵⁹ It is also sometimes referred to as the “neutral” (Lee & Jung, 2014) or “anatomical” (Cael, 2010, p. 2) position.

because the force of gravity will be pushing the fingers downward, and the keyboard will be pushing them upward. There may be some tendency for the fingers to extend due to the weight of the arm (see “Keybedding” 3.4 for more details), and so the pianist will need to generate some amount of force in the finger flexors. However, this will likely be a relatively low amount, and co-contraction/stiffness across the finger joints will be limited (if it occurs at all). This understanding of the resting hand/finger position, indicates that it can be achieved by the pianist without “tension” as defined in the Taubman Approach sources.⁶⁰

Relationship of finger lengths: The length of a human finger can be defined as the distance from the MCP joint to the fingertip.⁶¹ Each finger within a single person’s hand has a different length. In healthy hands, the third finger tends to be the longest, followed by the second and/or the fourth fingers.⁶² The 5th finger is typically shorter than the 2nd and 4th fingers, and the thumb is typically the shortest. As described above, the fingers are usually somewhat flexed in their resting position (Cael, 2010, p. 172; Lee & Jung, 2014). The relative position of the fingertips in this position typically corresponds to the relative lengths of the fingers. When the hand is placed on the keyboard in the resting position (“natural curve”), the tip of the third finger is the furthest away from the wrist.⁶³ Each of the other fingertips is placed gradually closer to the

⁶⁰ The concept of “resting on the keys” in this way is discussed in more detail in the analysis on “Keybedding” (subcategory 5.2.1).

⁶¹ Wagner (1988) studied the finger lengths of a diverse group of 238 pianists. In this study he measured total finger length as the distance between the articular space, which connects the metacarpals and proximal phalanges, and the fingertip.

⁶² Specific index (2) to ring (4) finger ratio varies among individuals (Zhang et al., 2007).

⁶³ The Taubman Approach sources do not mention the finger lengths as related to the wrist. As mentioned above, the finger lengths are defined by the distance of each fingertip to its respective MCP joint. However, because each finger has its own MCP joint, these joints can not be used as a single, consistent point of reference for all of the fingertips. Therefore, the wrist was chosen as a point of reference because it can be used to compare the position of all five fingertips.

wrist, with their relative position corresponding to their relative length. One way of explaining Golandsky's statement that “the relationship...of the fingers to each other always remain[s] the same” (Taubman Institute, 1995, vol. 3) is that the set of distances between each fingertip and the wrist should always be in the same order. In this case, the specific order will be determined by individual anthropometry, and therefore will be somewhat different for each pianist.⁶⁴ This approach to finger position is different from those that advocate “Curling” the fingers, either to make them all the same distance from the wrist (subcategory 4.2.1), or by flexing/extending any of the fingers in order to change the order (subcategory 4.2.4). Understanding the “natural curve” position in this way may help clarify Golandsky's statement that “the hand has to always remain looking this way” (Taubman Institute, 1995, vol. 3).

“Non-playing fingers” in the “black key area:” As described in subcategory 4.2.4, the Taubman Approach sources advise against flexing the DIP/PIP joints of (“Curling”) the longer non-playing fingers to avoid touching or extending above the black keys. A number of excerpts in the “Miscellaneous - Natural Curve” subcategory (5.4) indicate that in order to maintain the relationship of the fingers, the alternative proposed by the Taubman Approach is to allow the longer fingers to be “in the black key area” when playing a white key(s) with a shorter finger(s). This likely means that either the non-playing fingers are touching the black keys, or they are extended to a small degree so that they are very close to those keys (“hovering above”). Doing so would only require extension at the MCP joint(s), and would not require flexion at the DIP/PIP joints. This description would be consistent with other excerpts stating that the fingers should

⁶⁴ For example, the tip of the 3rd finger will always be the furthest away from the wrist, and the tip of the thumb will always be the closest to the wrist. The tip of the 5th finger will likely be closest after the thumb. The order of fingers 2 and 4 will depend on individual anthropometry. However, the order of distances for all five fingers will always correspond to the order of their lengths.

only be moved from the MCP joints, and that any active DIP/PIP flexion (“Curling”) should be avoided (see subcategory 4.6.1 below).

“Nail joints” should be “relatively straight:” Taubman uses the term “straight” to describe the correct position of the DIP (“nail”) joint. She uses this term to differentiate the correct position from being “curled”/“bulging” (flexed) or “broken”/“falling in” (extended). Because Golandsky describes the correct DIP joint position as “relatively flat,” rather than “straight,” it is not entirely clear exactly whether Taubman’s term “straight” is meant literally or as a relative, pedagogical term. A literal interpretation would indicate a flexion angle of 0 degrees, while a relative interpretation would likely indicate a very small amount of flexion. Because this is not clear from Taubman’s terminology alone, information provided by other categories and sources can help to clarify what is meant here. The “natural curve” position as defined by the Taubman Approach is roughly analogous to the “resting position” described in the scientific literature. Research indicates that in the resting position the DIP joint is not completely “straight,” but instead has a small flexion angle. This angle has been found to be roughly 7-10 degrees when the hand/forearm are held in the pronated (palm down) position used in piano playing (Lee & Jung, 2014). The exact angles of the DIP joints vary among the fingers and among different individuals. However, each DIP joint typically includes some degree of flexion regardless of these differences. Therefore, they would not be totally “straight”/“flat.” Further investigation of the Taubman Approach excerpts will be needed to determine how their term “natural curve” relates to this finding.

In order to get more detail about the DIP angle recommended by the Taubman Approach, other excerpts in the “Miscellaneous - Natural curve” subcategory can be examined. In one excerpt, Milanovic (2012) states that when the fingers are in the correct position “the long

fingers (2-4) [are] facing toward the hand” (p. 157) Keeping the fingers in these positions would likely require a finger position that has at least some degree of flexion at the DIP joints.

Milanovic’s (2012) comment states that achieving this position “triggered [her] triggered wrist/forearm higher...,” (p. 157) indicating that the increase in flexion angle is achieved by allowing for a slightly higher (more flexed) wrist position (see in “Keybedding,” subcategory 5.2.3 for more details). Doing so would place the fingers in a more flexed position as well, but without significantly increasing the amount of co-contraction, as would occur if the FDP/FDS muscles were used to flex the DIP/PIP joints and maintain the position of the wrist (“Curling” as described above). In another excerpt, Milanovic (2012) states that in the “natural curve,” “the thumb [is positioned] with two knuckles present, the other fingers with three” (p. 109). The term “present” here likely means that there is some degree of flexion at each joint, which would allow each joint (knuckle) to be visible.

Further clarification of the word “straight” as it applies to the term “natural curve” can be found in Golandsky’s discussion of the correct thumb position. Golandsky states that “You have to make sure that the thumb is straight. When I say straight, I mean the natural straight. I don’t mean straightening it. It shouldn’t be curled in [shows large flexion angle at IP joint], and it shouldn’t be curled out [shows extension at IP joint].” This demonstration suggests that the term “straight” is not meant to imply a total lack of flexion, but is rather being used to distinguish the correct, “natural” thumb position, from a “curled” thumb. Here, Golandsky’s term “natural straight” likely indicates that the thumb’s IP joint is in a position consistent with its resting position, whereas “curling in” or “curling out” likely refers to flexing or extending the thumb outside of the resting position, which would typically require a greater amount of muscular contraction (see subcategory 1.2). Milanovic’s (2012) statement that the thumb tip

should “face...towards the pointer” (finger 2) (p. 157) gives further evidence to this interpretation, in that she is likely stating that the IP joint should be at an angle such that if the thumb were longer, it would come in contact with the 2nd finger.

When considered in sum, the above evidence from the Taubman Approach sources indicates that the “natural curve” position does in fact include some small amount of flexion at the DIP joint. The term “straight” as used by Taubman to describe the DIP joint is more likely a pedagogical term to help students avoid flexing or extending the joint too far. In the case of flexing the DIP joint, Taubman’s pedagogical term “straight” is also likely used to prevent the student from actively flexing the joint by contracting the extrinsic finger flexors (“Curling”). Based on this understanding, Golandsky’s statement that the DIP (“nail”) joint should be “relatively flat,” which indicates a very small degree of DIP flexion, is more likely the position recommended by the Taubman Approach (“natural curve”). Golandsky’s terms “natural straight,” and “not straightening” when referring to the thumb can likely also be seen as equivalent to the word “straight” as used by Taubman regarding the correct DIP joint angle. Golandsky seems to be qualifying the term “straight” in order to prevent someone from interpreting it to mean 0 degrees of flexion. This definition is more consistent with the information provided by the other Taubman sources, as well as the scientific data on the geometry of a resting hand/finger position. Because the exact resting position for each person varies based on individual differences, the use of relative terms in a pedagogical context may allow the teachers of the Taubman Approach to recommend what they consider to be a generally “correct” position, and then work with a student to find their own personal “correct” position in the context of a lesson.

“Straight nail joint” prevents the “broken nail joint:” As mentioned above, when there is no muscle contraction across the DIP joint, the distal phalange can be thought of as a two-force member, with the force of the middle phalange pushing down on it and the contact force of the key pushing up on it. If these forces are close to equal, opposite, and in line, the distal phalange will reach equilibrium with no need for muscle contraction. The further the two forces are removed from these three conditions, the more muscle contraction/stiffness will be needed to stabilize the joint and prevent rotation from occurring. Taubman states that finding the correct joint position will stop the DIP joint from extending (“breaking”). She recommends this solution instead of substantially flexing the DIP joint (“Curling”). Physiological limitations will prevent the pianist from totally achieving all three of the above conditions while maintaining a position that is close to resting position. Therefore, they would want to find a position that is as close to achieving each condition as possible, while staying as close to resting position as possible. Taubman’s recommendation is likely intended to help the pianist find this position, which would require only a small amount of muscle contraction to keep the key down and stabilize the DIP joint. A small degree of DIP flexion (“relatively straight”) would achieve this, as it would likely require only a very small degree of activity in the finger flexors to maintain it. If so, then keeping the joint in this position will allow the pianist to use minimal muscle force to depress the key without the DIP joint flexing or extending outside of its resting position.

Additional Miscellaneous: Several other statements in the miscellaneous subcategory provide further detail regarding the placement of the finger joints in the “natural curve position.”

Golandsky states that the MCP (“main knuckle”) (see subcategory 4.6.1) should be higher than the PIP joints. This means that there will be some degree of flexion at the MCP joints, which is consistent with their typical resting hand/finger position (Lee & Jung, 2014). However, Moran

(2008, pp. 27, 29, 43, 51) says that the MCP (“main knuckle”) should not be “arched” or “collapsed.” When combined, these statements likely indicate that the MCP joints should be close to their resting position, rather than too flexed (“arched”) or extended (“collapsed”) (see “Keybedding,” subcategory 2.3 for discussion of range of motion). As mentioned above, Milanovic (2012) indicates that additional MCP flexion will be achieved in conjunction with raising the forearm and wrist (p. 157). Because the fingers are touching the keys, doing so could allow the MCP joints to have a greater flexion angle (see “Keybedding”) without more muscle contraction across those joints. Instead the higher forearm and hand position would allow the MCP joints to increase their flexion angle by relaxing the finger extensor muscles.

4.5.5 Conclusion: The “Natural curve” position

The categories above were developed to help identify the “natural curve” position as defined in the Taubman Approach from a biomechanical perspective. Categories focused on particular aspects of the “natural curve” that distinguish it from “Curling” the fingers. A total of 49 units of coding were used in this category. After a second coding, 42 units of coding were in agreement between the two coding sessions, making for a 85.71% agreement. The following table has been provided to display each subcategory with a brief summary of its biomechanical analysis:

Table 4.4 *The “Natural curve” position*

Subcategory	Biomechanical Analysis	TA sources	Units of Coding
Natural curve position is the same as when the hand is at one’s side	A resting hand/finger position is recommended because minimal muscle forces are needed to maintain this position and stabilize the joints. Muscle force will likely need to be generated mainly in the finger flexor muscles to balance out external forces from gravity and the keyboard. This will allow for little co-contraction, if any, which will lead to low joint stiffness.	Taubman Institute, 1995, vol. 1; Moran, 2008	7
Fingers should stay in the same relationship to each other	The pianist should maintain a position that is as close to resting position as possible while playing. The set of distances between each fingertip and the wrist should always	Taubman Institute, 1995, vol. 3, 5; Milanovic, 2012	13

	be in the same order. This order should correspond to the order of the finger lengths.	
Nail joint should be relatively straight	The DIP joints should have a small flexion angle that is relatively consistent with the pianist's resting position. The DIP joints should not deviate very far from this position, either by flexion or extension. This will allow forces acting on the distal phalange to be as close to parallel, in line, and opposite as possible. Therefore, the DIP joints can achieve high stability using only low muscle force/stiffness to maintain equilibrium/prevent joint rotation.	Taubman Institute, 3 1995, vol. 1
Miscellaneous - Natural curve position	Other excerpts were identified as relating to the "natural curve" position. One important detail is that the MCP joints should have some degree of flexion. However, they should remain close to their resting position, without too much deviation in either direction (flexion/extension). This will help to allow for low muscle contraction/forces while playing.	Taubman Institute, 26 1995, vol. 1, 2, 3; Moran, 2008; Milanovic, 2012

As mentioned above, the subcategories in this category were developed in order to describe ways in which the "natural curve" position is specifically differentiated from "Curling" the fingers.

The relatively high number of units of coding in the miscellaneous category suggests that there may be significant aspects of the "natural curve" position that are not described by these subcategories. This may also have contributed to the somewhat lower coefficient of agreement between the two coding sessions in this category compared to the other category in this analysis. Further research will be needed to create a coding frame that more fully describes the "natural curve" position.

4.6 Motions that prevent "Curling:"

Introduction:

The previous section discussed a number of ways in which the "natural curve" position is distinct from a "curled" position. That being said, the above analysis on "Curling" revealed that in addition to using the term "Curling" to describe the position of the finger joints, the Taubman Approach sources also use this term to describe flexing the DIP/PIP joints when moving to play the keys. In order to prevent this from occurring, Taubman proposed certain movements that she

believed could avoid “Curling” the fingers without causing other physical/technical problems. The following section will include categories that describe these movements. First, the recommended finger movements will be discussed, including Taubman’s beliefs about the physiology underlying those movements. Next, the “in and out” arm motions will be discussed, followed by the recommendation to sometimes play in the “black key area.”

4.6.1 Fingers should only move from the main knuckle

TA Summary:

According to the Taubman Approach, the fingers should only move from the “main knuckle,” which according to Milanovic (2012) is also called the “main bridge” (p. 108). Moving the finger “in one piece” from the knuckle is described as the most “coordinate way to move.” Other motions that involve moving from any of the other knuckles are considered “incoordinate.” This includes “Curling,” which involves also moving from the “nail joint” (see subcategory 4.1.1).

Analysis:

“Main knuckle:” Taubman uses the term “main knuckle” to refer to the joints where each of the fingers/thumb connects to the hand. In the anatomical literature, this joint is referred to as the Metacarpophalangeal joint (MCP) (Cael, 2010, p. 130). Milanovic (2012) confirms that these two terms are analogous (p. 108).

“One piece:” Taubman claims that the finger should move from the MCP joint “in one piece.” This likely indicates that the MCP joint should be the most proximal joint where active movement occurs. In doing so, the pianist will have the impression that all limb segments distal to that joint are actually one segment. This means that there should be no active movement at the more distal finger joints (PIP and DIP).

4.6.2 Finger motions should use short flexors that don't cross/pull tightly over the wrist

TA Summary:

The Taubman Approach sources state that in the “correct” finger motions, the fingers should only be moved from the “main knuckle” (see subcategory 4.6.1). Taubman states that the fingers are executed by using the “short flexors” muscles. Unlike the “long flexor” (see subcategory 4.1.3), the Taubman Approach sources claim that the short flexors do not “extend over the wrist.” Instead, they “move the fingers only downward,” and do not “exert any pull on the fingers or the wrist.”

Analysis:

“Move the fingers only downward:” In this context Taubman’s use of the term downward indicates moving the fingers from the MCP joint toward the keys. In the biomechanical sources, that movement is referred to as “finger flexion” (Cael, 2010, p. 148). Taubman’s statement indicates that she is describing muscles that only act to flex the fingers, and do not perform any other type of joint rotation.

“Short flexors:” The biomechanical literature used in this study does not use the term “short flexor” to describe the muscles that flex the MCP joints. As discussed above, the muscles that move the fingers and are located in the hand are known as the “intrinsic” finger muscles (Freivalds, 2004, p. 167) (see subcategory 6.1). The intrinsic finger muscles are all **uniarticular muscles**, meaning that they only cross one joint (MCP). There are two sets of intrinsic muscles that flex the fingers from the MCP joints (“main knuckles”): the lumbricals and the interosseous muscles (Cael, 2010, p. 179; Watson, 2009, p. 57).

- **Lumbricals:** The lumbricals attach to the proximal phalanges of fingers 2-5. They attach to the FDS tendon of each finger, rather than the bone. When contracted, the lumbricals flex the fingers from the MCP joints and extend the DIP/PIP joints.
- **Interosseous muscles (IO):** The IO are located in between the metacarpal bones. There are two sets of interosseous muscles:
 - **Palmar Interossei (PI):** The PI are located on the palm side of the hand. Their primary function is to adduct the fingers.
 - **Dorsal Interossei (DI):** The DI are located on the dorsal side of the hand. Their primary function is to abduct the fingers.

Both sets of interosseous muscles can also contribute to finger flexion. However, this can only occur when the fingers are straight (PIP/DIP fully extended), and the MCP has already flexed to some degree.

Taubman's description of the "short flexor" muscles indicates that they only act to flex the fingers. The interosseous muscles primarily act to adduct/abduct the fingers, and only contribute to finger flexion once the MCP has flexed to a certain degree. The Taubman Approach sources discourage the degree of MCP flexion ("arching," see subcategory 4.5.4) that would be necessary for the interosseous muscles to contribute to finger flexion. Therefore, it seems more likely that when Taubman uses the term "short flexors," she is referring to the lumbrical muscles. The lumbrical muscles are relatively small, and have relatively short tendons. This means that the force of the muscle contraction can be transferred to the bone relatively quickly (Knudson, 2007, p. 75). The combination of these factors means that the lumbricals can flex the fingers from the MCP joints with a high degree of velocity and precision. However, because of the force-velocity relationship (see subcategory 4.1.3), this means that they are less effective at

generating force, and so the extrinsic finger muscles are often used in finger tasks that require high levels of force (Freivalds, 2004, p. 167). Because the Taubman Approach sources discourage using the extrinsic finger muscles to a high degree in piano playing (see subcategory 4.1.3), she instead advocates using arm motions to assist the lumbricals in creating the fingertip force necessary for key depression (see analysis on “Keybedding,” subcategory 5.5.1).

4.6.3 Natural curve allows fingers/hand to move freely

TA Summary:

Taubman (1984) states that keeping the fingers in the natural curve position allows the fingers and hand to move freely or easily (p. 145; Taubman Institute, 1995, vol. 1). This is contrasted with the more restricted or inhibited feeling that occurs if one tries to move the hand and/or fingers while the fingers are molded into a curled position (Taubman, 1984, p. 145; Taubman Institute, 1995, vol. 1; see subcategory 4.1.4). This is demonstrated by asking audience members to compare the restricted movements of curled fingers to the free/easy movements of fingers in the natural curve (Taubman, 1984, p. 145; Taubman Institute, 1995, vol. 1).

Analysis:

Does not cross the wrist: As discussed above, Taubman states that activating the extrinsic muscles to flex the DIP/PIP joints causes these muscles to “pull tightly across the wrist” (see subcategory 1.3). The analysis of this statement found that it could be explained by the fact that activating these muscles requires co-contraction of the finger and/or wrist extensors in order to keep the wrist/MCP in their resting position. This co-contraction would increase wrist/finger stiffness, which could explain Taubman’s (1984) use of the term “tightly” (p. 146). In contrast, Taubman states that the “short flexors” do not cross the wrist, and so they would not “pull

tightly” across it. Her statement implies that the lumbricals are uniarticular muscles that only cross the MCP joints, and therefore activating them does not cause any rotation at the wrist joint. If this is true, then no co-contraction would be required across the wrist as a direct result of activating the lumbricals.⁶⁵ Therefore, activating the lumbricals to flex the fingers from the MCP will have no direct impact on wrist stiffness. That being said, it is important to note that while the lumbricals themselves only cross one joint (MCP), they originate from the tendon of the FDP muscle, rather than a bone (Cael, 2010; Watson, 2009) . This means that the effect of contracting the lumbricals will depend to some extent on the activity of the FDP muscle (Watson, 2009). If the FDP is in a constant state of activation, then the lumbricals will originate from a fixed point, and will be able to act as uniarticular muscles. However, if the FDP is not activated at all, then contracting the lumbricals may result in pulling on the FDP tendon, rather than the finger bones, and no movement will occur. Therefore, in order for the lumbricals to actively create finger movement, some activation of the FDP will likely be necessary. A full discussion of the implications of the relationship between intrinsic/extrinsic finger muscles on piano playing is outside the scope of this study. Based on Taubman’s desire to avoid activating the FDP, it seems likely that in light of the understanding of physiology provided here, her recommendation could be analyzed to mean limiting the activation of FDP to such a small degree that the amount of force it causes across the wrist joint will not require any significant level of co-contraction/stiffness (“pull tightly”).

The hand “moves freely:” Taubman states that “Curling” the fingers restricts the flexion and extension motions of the hand (see subcategory 4.1.4). As discussed above, this is likely due to the amount of co-contraction across the wrist joint that is necessary to maintain a flexed position

⁶⁵ The term “neutral position” is used here to refer to a wrist position that has 0 degrees of flexion/extension.

at the DIP/PIP joints when flexing and extending the hand (moving up and down). Because placing fingers in their resting position (“natural curve”) creates very little stiffness across the wrist, the hand will be able to flex/extend (move up/down) with far less resistance compared to if DIP/PIP joints are flexed (“curled”). Therefore, the phrase “moving freely” seems to indicate moving a joint that has low stiffness, which allows that movement to occur with minimal resistance.⁶⁶

The fingers “move freely:” Taubman also states that keeping the DIP/PIP joints in a flexed position “restricts” the flexion and extension motions of the fingers. Similar to the “restriction” of hand motions, the “restriction” of finger motions is also likely due to the amount of co-contraction necessary to maintain a flexed position at the DIP/PIP joints while playing. While the hand motions would be resisted by wrist stiffness, the finger motions would be resisted by stiffness across the finger joints. Maintaining DIP/PIP flexion while trying to flex/extend the MCP joints will result in co-contraction across all three finger joints in each finger that is moving (see subcategory 4.1.4). In contrast, placing the fingers in their resting position (“natural curve”) requires minimal finger stiffness, and so the fingers will be able to rotate about the MCP joint with little resistance. Furthermore, her statement implies that the lumbricals (“short flexors”) only cross the MCP joints, and so activating these muscles to flex the fingers from the MCP joints will not impact the motion of any other joint. As discussed above, some extrinsic muscle (FDP) contraction may be required in order for the lumbricals to actively cause finger movement (see analysis of subcategory 4.6.2). However, this amount may be so small that no significant amount of co-contraction would be required to prevent any extraneous motions. A similar

⁶⁶ This interpretation of the term “freely” is further supported by Golandsky’s statement that “when you move freely, one muscle is active and the other is passive.” This statement indicates that the term “moving freely” indicates rotating a joint with limited resistance due to co-contraction. This statement was not included in this analysis, but will be discussed in more detail in the analysis on “Keybedding” (subcategory 5.3.4).

situation will occur with the finger extensor muscles. These muscles are extrinsic, and therefore do cross the wrist (Cael, 2010). This means that some co-contraction may be necessary to keep the wrist from also extending when the finger extensor muscles are activated. However, the Taubman Approach sources recommend only a very small amount of finger extension when playing (see “Keybedding,” subcategory 5.4). Therefore, the amount of force generated across the wrist by activating the finger extensors would also probably be too small to cause any significant wrist flexion/extension, and so no significant co-contraction would be required.

4.6.4 Correct in/out movements can prevent "Curling"

TA Summary:

According to the Taubman Approach sources, one of the main reasons for "Curling" is due to the differences in finger lengths within the hand (see subcategory 4.5.2). Because the fingers cannot pull out by themselves (away from the fallboard) without "Curling" (see subcategory 2.3), the Taubman Approach sources state that it is the role of the arm to bring the finger(s) in and out as the finger is on its way down to play the key. These in and out motions, which are the subject of DVD 3, are executed by the entire playing unit from the fingertip to the shoulder (Taubman Institute, 1995, vol. 3; Milanovic, 2012, p. 116). Golandsky strongly emphasizes that these are arm motions, not finger motions, and that they are initiated from the forearm (Taubman Institute, 1995, vol. 3). The upper arm is moved passively in very small amounts so that the pianist does not get tired (Taubman Institute, 1995, vol. 3; Milanovic, 2012, p. 116). Because the in and out movements are very small, they are often thought of as minor adjustments, rather than large movements (Taubman Institute, 1995, vol. 3).

The pianist must choreograph the in and out motions on virtually every note of a passage so that they can move gradually and in as small an amount as is necessary to play a passage without any movement that is considered incoordinate (e.g. “Curling,” “twisting,” “stretching,” etc.) (Taubman Institute, 1995, vol. 3). Correct use of the in and out motions allows the fingers to stay in their natural curve position and eliminates the feeling of long/short fingers (Taubman Institute, 1995, vol. 3; Milanovic, 2012, p. 116). The subjective result when playing with the correct in and out motions is that all the fingers feel the same length (Taubman Institute, 1995, vol. 3; Milanovic, 2012, p. 116). The exact choreography of a passage depends on a variety of factors, such as the pattern of notes required, the combination of white and black keys, and the fingers used (Taubman Institute, 1995, vol. 3; Milanovic, 2012, p. 116, 133). That being said, some degree of in and out occurs in between the playing of each finger (Taubman Institute, 1995, vol. 3). One context in which in and out motions are described as particularly important are in passages that consist entirely of white keys (e.g. C Major/A Natural Minor scales/arpeggios) (Taubman Institute, 1995, vol. 3; Milanovic, 2012, p. 116, 176). While a full discussion of the In and Out motions is outside of the scope of this study, the Taubman Approach sources state that the correct use of these motions is necessary to prevent “Curling” the fingers, and therefore essential to playing without fatigue or injury (Taubman Institute, 1995, vol. 3; Milanovic, 2012, p. 116, 133).

Analysis:

A full and detailed analysis of “In and Out” arm motion is outside the scope of the current study. However some general aspects of these motions and how they impact DIP/PIP flexion (“Curling”) will be discussed below.

“In and out” arm motions: Generally, Taubman uses the term “in” to describe motion toward the fallboard, and “out” to describe motion away from the fallboard. In the Taubman Approach sources, movements “in” or “out” are conceived as a single motion in one direction or the other. Conceptualizing the “In and Out” motions in this way may be advantageous from a pedagogical perspective because it gives the pianist less to think about; they can focus on one direction that the whole arm is moving (translation), rather than the separate rotations of each joint involved. However, it is important to note that from a biomechanical perspective, moving “in” or “out” as described in the Taubman Approach seems to include rotation around both the elbow and the shoulder joints. Golandsky’s statement that both the forearm and upper arm are moving in small amounts supports this understanding. Both the forearm and the upper arm are rotated about the elbow and shoulder, respectively, in the sagittal plane. Moving closer to the fallboard (“in”) requires a combination of shoulder/elbow extension, while moving further away from the fallboard (“out”) requires a combination of shoulder/elbow flexion.⁶⁷ Golandsky also states that the “In and Out” motions are motions of the whole arm, from the shoulder to the fingertip (Taubman Institute, 1995, vol. 3). Because the hand and the fingers are connected to the forearm, they will be moved as a result of the forearm and shoulder flexion/extension. However, hand and finger rotation is not considered a part of the in and out movements.⁶⁸

“Initiated by the forearm:” Golandsky states that the “In and Out” motions are “initiated by the forearm:” “We always think of initiating from here in order to make other parts that are less

⁶⁷ The elbow angle will also be impacted by “shaping” motions, which are small up and down (flexion/extension) motions of the forearm in between the playing of each note. According to the Taubman Approach sources, the “In and Out motions” are always combined to some degree with “shaping” motions when playing, in order to make the “In and Out” motions as small as possible (Taubman Institute, 1995, vol. 5).

⁶⁸ Because “In and Out” motions are always combined with “shaping,” some wrist flexion/extension will occur with the forearm/upper arm movements. However, the Taubman Approach classifies the hand movements as part of “shaping,” rather than “In and Out.” For more details on shaping, see Taubman Institute, 1995, vol. 5 or Milanovic, 2012.

efficient move less” (Taubman Institute, 1995, vol. 3). The term “initiating” is not contained in any of the biomechanical sources used in this study. In this context, the use of this term seems to suggest that the pianist can execute these motions most efficiently by focusing their attention on moving the forearm, rather than the upper arm. According to Golandsky, doing so will make the upper arm movement as small as possible in order to translate the fingertip to the desired “key spot.” Because this is an issue of motor control, a more detailed explanation of “initiating” is outside the scope of this study. However, the biomechanical implications of too much upper arm movement will be discussed below.

Golandsky states that “If there’s too much in and out, you’ll get tired in the shoulder area” (Taubman Institute, 1995, vol. 3). This is likely due to the fact that the “in and out” motions are executed in part by rotation of the shoulder joint. In the first DVD, Golandsky states that the shoulder and upper arm are moved by “slow muscles,” and therefore the pianist should not attempt to use them when moving with high velocity or range of motion (Taubman Institute, 1995, vol. 1). The muscle fiber architecture of these muscles can offer an explanation for why this may be the case. The group of muscles that would create shoulder flexion/extension are typically **multipennate** muscles (McLester & St. Pierre, 2007; Cael, 2010). This means that their fibers are arranged obliquely (not parallel) along the longitudinal axis (length) of the muscle. Multipennate construction maximizes the force production capability of these muscles, but it also limits their ability to produce movements with high velocity and range of motion (McLester & St. Pierre, 2007; see analysis subcategory 4.1.4 above). Since some form of “in and out” motion is said to occur in between the playing of every note (Taubman Institute, 1995, vol. 3), they may need to move with relatively high velocity in certain contexts when playing. Golandsky seems to be suggesting that therefore the motions should be kept within a relatively

small range of motion. If the range of motion is made larger, then the relatively high velocity with which those motions need to occur may cause the shoulder muscles to become overworked. This may result in the feelings of fatigue (“tired”) that Golandsky describes as a result of “too much in and out” (Taubman Institute, 1995, vol. 3). Focusing on the movement of the forearm (“initiating from the forearm”) when executing the “in and out” motions may be one way to help the pianist minimize the range of motion for the shoulder movements.

“In/Out” motions and “Curling:” According to the Taubman Approach sources, one reason why pianists use DIP/PIP flexion (“Curling”) when playing is because they want to play the white keys in the area between the edge of the keyboard and the front of the black keys (“white key area”) (see category 4.2.4). Golandsky states that this is a good idea because less force is required to depress the keys when playing closer to the edge. This is due to the fact that it applies a force further away from the pivot point, or **fulcrum** of the lever that allows the key to move up and down. The distance between the fulcrum and the applied force is called the **moment arm** (McLester & St. Pierre, 2007, p. 335). The size of the moment arm is inversely proportional to the amount of force needed to create rotation. Therefore, playing the key further from the fallboard decreases the amount of force that needs to be applied to depress the key. The fingers are all different lengths, and so very often pianists will flex the DIP/PIP joints of (“curl”) their longer fingers (2, 3, and 4) in order to play in the “white key area” (see subcategory 4.2.4). The Taubman Approach sources state that flexing the fingers in this way also causes these fingers to feel as though they are too long (see subcategory 4.2.5). In order to achieve the goal of playing the key in the “white key area” the fingertip needs to be translated. The most direct way to achieve this is by causing rotation about the most distal joints (DIP/PIP) because they are closest to the fingertip. However, the Taubman Approach sources identify a number of issues related to

using DIP/PIP flexion to achieve this goal, and so they recommend using only MCP flexion to rotate the fingers (see subcategory 4.6.1). That being said, MCP rotation alone will not translate the fingertip far enough to reach the desired “key spot.” Therefore, the Taubman Approach sources recommend using the combination of elbow and shoulder extension (“out motion”) described above to translate the fingertip further away from the fallboard as it is moving down to depress the key. This is likely what Golandsky means when she states that the arm “brings the finger out,” rather than the finger “pulling out by itself,” as described in subcategory 4.2.3. The Taubman Approach sources state that the exact amount of arm motion will depend on context, and that each passage will need to be uniquely choreographed depending on a number of factors. This likely means that the pianist will have to plan out these motions in advance, allowing them to move gradually and in the smallest amount possible. While the “out” motions are more directly relevant to preventing DIP/PIP flexion (“Curling”), the “in” motions may also be necessary to prevent “Curling” when choreographing a particular passage.

4.6.5 Playing in the black key area can prevent “Curling”

TA Summary:

One context in which pianists sometimes curl their fingers is in order to play a longer finger in the white key area (see subcategory 4.2.4). While it is recommended to play in the white key area whenever possible, the Taubman Approach sources state that it is sometimes necessary to play in the black key area to avoid “Curling” in certain passages (Taubman Institute, 1995, vol. 3). The exact key spot of each finger seems to depend on several factors: the pattern/order of key required, the combination of white and black keys, and the fingers used (Taubman Institute, 1995, vol. 3). Golandsky states that the keys are heavier when playing in the black key area, and therefore doing so without

having to push with the fingers requires the involvement of the hand and forearm (Taubman Institute, 1995, vol. 3). A detailed explanation of how this occurs is outside the scope of the current study, but will be discussed briefly in the analysis on “Keybedding” (subcategory 4.5.1).

Analysis:

Playing “in the black key area” to prevent “Curling:” The excerpts in this subcategory seem to indicate that choosing not to play on “horizontal key spots” (see subcategory 4.2.2) can help avoid the problem of “Curling” in some contexts. However, doing so potentially creates another issue. Golandsky points out that one reason pianists attempt to play the white keys closer to the edge is that as the key spot becomes further away from the fallboard, less force is required to depress the key. As discussed above this is because it increases the moment arm and decreases the amount of fingertip force necessary to depress the key. If the pianist does not play with “horizontal key spots,” the implication is that some of the key spots will be closer to the fallboard and require more force to depress the key. Golandsky acknowledges this issue, and states that it can be resolved by involving the hand/arm in helping to create the fingertip force necessary for key depression. This subject will be discussed in more detail in the analysis on “Keybedding” (subcategory 5.5.1). For the purposes of this analysis, it is significant to note that the Taubman Approach sources seem to indicate that involving the hand/arm in contributing to fingertip force is essential to playing in the black key area. Because playing in the black key area is considered essential to avoiding DIP/PIP flexion (“Curling”), then hand/arm involvement can be considered essential to avoiding DIP/PIP flexion indirectly.

4.6.6 Conclusion: Taubman’s proposed alternative movements to prevent “Curling”

The categories above were developed to help identify the movements recommended by the Taubman Approach sources to be used instead of “Curling” the fingers and analyze them from a biomechanical perspective. A total of 42 units of coding were used in this category. After a second coding, 39 units of coding were in agreement between the two coding sessions, making for a 92.86% agreement. The following table has been provided to display each subcategory with a brief summary of its biomechanical analysis:

Table 4.5 *Taubman’s proposed alternative movements to prevent “Curling”*

Subcategory	Biomechanical Analysis	TA sources	Units of Coding
Fingers should only move from the main knuckle	When playing, active finger joint rotation should occur from the MCP joints, not the DIP/PIP joints. The pianist should rotate the fingers from the MCP joints as though each finger is one segment.	Taubman, 1984; Taubman Institute, 1995, vol. 1; Milanovic, 2012	6
Finger motions should use short flexors that don’t cross/pull tightly over the wrist	The intrinsic finger flexors (likely the lumbricals) should be the muscles primarily involved in finger flexion when playing. Theoretically, the lumbricals are uniarticular muscles, and so no co-contraction should be required to activate them for finger flexion. However, the lumbricals originate from the tendon of the FDP muscle. Therefore, the effect of contracting the lumbricals will depend to some extent on the activity of the FDP muscle. If the FDP is in a constant state of activation, then the lumbricals will be able to act as uniarticular muscles. Therefore, in order for the lumbricals to actively create finger flexion, some activation of the FDP will likely be necessary. The amount of FDP contraction may be so small that no significant co-contraction is required across the wrist.	Taubman, 1984; Taubman Institute, 1995, vol. 1; Milanovic, 2012	4
Natural curve allows fingers/hand to move freely	Keeping the fingers close to their resting position and using the intrinsic finger muscles requires minimal co-contraction/muscle stiffness. This allows joint rotation to occur with minimal resistance, and so lower forces will be required.	Taubman, 1984; Taubman Institute, 1995, vol. 1	10
Correct in/out movements can prevent “Curling”	The fingertip should be translated toward/away from the fallboard by rotations of the elbow/shoulder joints, rather than the finger joints. These motions should be very small because they will be executed by pennate muscles. Because of the distance between the shoulder/elbow joints and the fingertips, a relatively small amount of rotation will lead to a relatively large amount of translation. This will allow the fingertips to be translated	Taubman, 1984; Taubman Institute, 1995, vol. 3; Milanovic, 2012	14

	away from the fallboard without flexing the DIP/PIP joints.		
Playing in the black key area can prevent “Curling”	Sometimes the fingertips will need to contact the white keys in the area between the edge of the black keys and the fallboard. This will help prevent the need to flex the DIP/PIP joints. Playing in this area will decrease the moment arm of the key lever, and so more fingertip force will be required to depress the key. Therefore, the hand/forearm can be used to help generate the force for key depression in order to prevent overworking the finger muscles.	Taubman Institute, 1995, vol. 3	4

4.7 Conclusion: “Curling” the fingers

A total of six categories and 27 subcategories were created to analyze the term “Curling” as used in the Taubman Approach sources. The first main category (1.0) focused on defining the concept of “Curling” and why it is viewed as problematic. The second main category (2.0) identified contexts in which “Curling” may occur, and the third main category (3.0) identified physical problems that may result from it. The fourth and fifth main categories (4.0 and 5.0) identified Taubman’s proposed alternatives to “Curling” the fingers. Category 4 did so by describing how her recommended hand position, the “natural curve” is specifically distinct from “Curling.” Category 5 described the types of movement that Taubman proposed to allow for playing without “Curling.” A total of 216 units of coding were found in this analysis. Of those units of coding, 205 were found to be in agreement between both coding sessions, making for a coefficient of agreement of 94.90%. After the subcategories in each category were analyzed, a table was included to summarize the findings of the respective analysis of each subcategory. Therefore, only the general details of the findings in this chapter will be described here. An additional discussion of the potential implications of these findings will also be included. Next, a brief discussion of the process of analyzing the pedagogical language included in this section in a biomechanical context will be included. The discussion will conclude with the potential implications of this study for further research.

Overview of biomechanical analysis and its implications:

Generally, the Taubman Approach sources define “Curling” as flexing (“pulling in”) the DIP (“nail”) joint(s) (subcategory 1.1). The analysis above found that doing so will also likely include flexing the PIP joints (analysis of subcategory 1.1). The excerpts from the Taubman Approach sources suggest that the term “Curling” is applied to DIP/PIP flexion when it occurs either as a position or as a movement. For example, the fingers may be considered “curled” when the DIP/PIP joints are in a position that is more flexed than their resting position (e.g. “fixated/molded” in a “curled” starting position; subcategories 1.2 and 2.1); additionally, moving to play a key by flexing the DIP/PIP joints of a particular finger is also considered “Curling” (subcategories 2.3 and 2.4). In both types of situations, “Curling” is considered to be problematic. According to the Taubman Approach sources, the main source of the problems associated with “Curling” is the FDP (“long flexor”) muscle, which is involved in both executing the DIP/PIP flexion movement, as well as maintaining that position (subcategory 1.3). The analysis above found that depending on the circumstances, the FDS muscle may also be involved in “Curling” (analysis of subcategory 1.3). The FDP and FDS are both multiarticular, unipennate muscles that cross the wrist and several finger joints. Therefore, activating them when playing will likely lead to co-contraction across those joints, which may result in increased stiffness, muscle contraction, and muscle forces. In turn, this may lead to decreased velocity, range of motion, and control of both hand and finger movements (subcategories, 1.3 and 1.4). These negative impacts of “Curling” may inhibit finger movements in several different directions: flexion/extension (sagittal plane), as well as ab/adduction (frontal plane) (categories 1.4-1.6). In the Taubman Approach sources, the term “Curling” is also applied to flexing the thumb’s IP joint (subcategory 1.7). While the physiology of the thumb is somewhat different from that of the

other fingers, the term “Curling” may be applied to the thumb in this way because it describes flexing the most distal joint; IP flexion may also lead to an analogous set of negative consequences as DIP/PIP flexion of fingers 2-5 (increased stiffness, muscle forces, etc.).

The analysis of category 2 (“Curling” in context) found that the Taubman Approach sources consider the DIP/PIP flexed position/movement to be problematic in any context that it may be used. Several common contexts for “Curling” were identified. For example, many pianists place the fingers in a position with a high degree DIP/PIP flexion (“Curling”) before they start playing (subcategory 2.1); similarly, DIP/PIP flexion (“Curling”) is often used to execute the movements necessary for playing in a number of pianistic contexts (subcategories 2.2 and 2.3). “Curling” was also said to correlate with other perceived issues, such as a “low wrist” (subcategory 2.8). The analysis above found that it may be possible to avoid some of the problems associated with “Curling” the fingers if those finger(s) are in contact with the keyboard (analysis of subcategory 2.1).⁶⁹ This means that the “curled” position itself may not always be inherently problematic. However, a number of other potentially problematic issues were found likely to result in such a situation, such as increased movement necessary for playing, extraneous involvement of the finger extensors, etc. (analysis of subcategory 2.1). Therefore, the recommendation in the Taubman Approach sources to avoid DIP/PIP flexion altogether when playing may be useful, despite the fact that the specific biomechanical implications of it may vary to some degree depending on context.

In addition to the purely biomechanical issues raised in this analysis related to “Curling” the fingers, the Taubman Approach sources identify certain common beliefs about piano performance and/or pedagogy that may lead some pianists to “curl” their fingers. For example,

⁶⁹ This is not discussed in the Taubman Approach sources, but was found in the biomechanical analysis of “Curling” as a starting position (subcategory 2.1).

the pianist may attempt to contact each key at the same distance from the fallboard (“horizontal key spots;” subcategory 2.2). They may also want to generally avoid contacting the white keys in the area between the edge of the black keys and the fallboard (the “black key area;” subcategory 2.4) because more fingertip force is required for key depression (subcategory 6.5). Additionally, they may believe that extension of the DIP (“nail”) joint during key depression occurs because that joint is “weak” (subcategory 2.6). According to the Taubman Approach sources, any of these beliefs may lead the pianist to “curl” their fingers when playing, either intentionally or not. That being said, the Taubman Approach sources point out that “Curling” is often explicitly taught by many pedagogues for these reasons. In fact, “Curling” may seem to be the most intuitive solution to solve these problems and execute the task. For example, in some circumstances DIP/PIP flexion may be the most intuitive way to translate the fingertip to the desired point of contact (“key spot”). However, a central part of Taubman’s philosophy was that certain intuitions or traditional dogmas about piano playing are often wrong, and therefore need to be evaluated from a rational perspective before they are accepted (See Review of Literature). The main issues that Taubman associates with “Curling” occur due to the activation of certain muscles, and so these issues may not be obvious from the pianist’s subjective perspective. Consequently, it may seem intuitively easier to complete a pianistic task by “Curling,” without taking into account the impact of that choice on the larger context, such as technical facility over a longer series of notes, or harmful physical consequences of “Curling” the fingers repetitively over a longer period of time (see category 3). Because “Curling” may be a more intuitive choice for many pianists, avoiding it may sometimes require consciously choosing an alternative movement/position. The identification of certain contexts in which “Curling” may occur (either purposefully or not) may assist both performers and pedagogues in “diagnosing” the problem

and proposing an alternative solution. Similarly, understanding certain common beliefs in the field may help teachers to understand why students are choosing a certain motion/position, either due to implicit belief or their previous instruction.

In choosing alternatives to replace potentially harmful ways of playing, Taubman claims to use a “rational” approach, which involves choosing or avoiding particular positions/movements based on the consideration of various factors related to both human physiology and the piano mechanism (Taubman, 1984). These factors constrain the task in certain ways that will impact the effectiveness of each choice. Taubman identifies the main issue in “Curling” the fingers as the result of an apparent conflict between two main facts: 1) that the pianist must move horizontally across the keyboard to play each key with a different finger; and 2) that the pianist must play using fingers that all have different lengths (subcategory 4.2.1). Additionally, there is the fact that the necessary fingertip force for key depression increases as the fingertip is positioned closer to the fallboard. Based on these constraints, the most intuitive solution to many pianists/pedagogues may be to use DIP/PIP flexion when playing the white keys with the longer fingers (2, 3, and 4) (subcategories 2.3 and 2.4). Doing so would allow the pianist to execute the task within the constraints mentioned above. However, Taubman’s criteria for efficient technique seems to be finding the minimum muscle contraction needed in order to accomplish a desired pianistic task (“the minimum effort for the maximum result;” Taubman Institute, 1995, vol. 3). Therefore, within her framework, the biomechanics of the chosen movement/position used in a particular pianistic task must be taken into account in addition to the constraints of the task itself. In the case of “Curling,” DIP/PIP flexion can “solve” certain problems created by the task, but additional physiological constraints (such as the required use of multiarticular muscles) make it such that “Curling” the fingers may lead to additional problems.

Based on the excerpts contained in categories 1 (What is “Curling?”) and 3 (Problems associated with “Curling”), it seems clear that Taubman thought these problems were significant enough to make “Curling” the fingers a poor choice to deal with the constraints of the task. That being said, the nature of the task of piano playing is such that one can only label certain biomechanical choices as “poor” in relation to some alternative way to execute the task.

Taubman’s criteria for efficient technique suggests that a biomechanical choice may theoretically be considered “better” if it requires less muscle contraction to accomplish the task; this can be judged in relation to subjective feelings of effort (or lack thereof) experienced by the pianist (Taubman Institute, 1995, vol. 1). In the case of “Curling” Taubman proposes that the pianist keep their finger joints as close to their resting position as possible when playing (category 5), while using mainly rotation about the MCP joints to move the fingers (subcategory 6.1). According to the analysis above, this combination will likely reduce the muscle contraction used when playing and prevent the need for significant co-contraction of multiarticular muscles that are typically used in DIP/PIP flexion (“Curling”) (analyses of category 5, and subcategories 6.1 and 6.2). That being said, the constraints of the task will often cause the pianist to want to translate their fingertip(s) away from the fallboard, which cannot be achieved solely by MCP flexion. Therefore, the Taubman Approach sources suggest combining MCP rotation with that of more proximal joints: the elbow and the shoulder (“in and out motions,” subcategory 6.4). These joints move relatively large segments, and so only a small amount of shoulder/elbow flexion/extension will be required in relation to their total range of motion in order to translate the fingertip the necessary distance. It is important to note that the Taubman Approach sources state that finding the right type of movement is not the only part of the solution, and that these movements must be done in certain ways to avoid other potential problems from occurring. For

example, the amount of shoulder/elbow flexion/extension needed will vary depending on the context; however, the motions should generally be kept quite small. Too much motion may be effortful, and therefore it will not be suitable as an alternative to the “problem” of “Curling” the fingers (subcategory 6.4). Generally, it seems that Taubman attempts to base her recommendations on aspects of physiology that are relatively consistent among individuals. However, these recommendations may not be an intuitive choice for every individual pianist. This means that they may need to be learned consciously, but Taubman seems to be suggesting that doing so is more beneficial in the long run.

Analysis of Language:

Analyzing the pedagogical language in the Taubman Approach sources was sometimes a fairly straightforward process; however, certain challenges were encountered along the way. The most straightforward part of the analysis was related to certain anatomical terms which seem to have relatively unambiguous meaning. In these instances, all that was required was a direct substitution of the appropriate scientific term. For example, terms used by the Taubman Approach sources to signify particular joints (e.g. “nail joints” or “main knuckles”) could be easily replaced (DIP and MCP joints, respectively). However, the analysis of other anatomical terms required certain considerations to be taken into account before the appropriate scientific term could be identified. For example, the specific muscles that Taubman labelled as the “long flexor” and “short flexors” needed to be identified among more than one possible choice. The most likely choice was made mainly by examining Taubman’s description of the muscles’ location and function, as well as by looking at how those muscles may or may not be involved in the context of piano playing. For instance, the IO muscles were excluded as a choice for “short flexors” because their flexion activity does not apply to the finger joint positions that Taubman

recommends. Throughout the analyses, descriptions were added as necessary for anatomical parts that are not specifically mentioned in the Taubman Approach sources (e.g. some of the muscles that move the thumb). This was done only in places where it was deemed necessary for understanding the underlying biomechanics of a particular concept.

While scientific language could be directly substituted for much of Taubman's anatomical terminology, biomechanical descriptions were generally more challenging to analyze. Several factors were involved in complicating this process. One significant challenge occurred due to the fact that biomechanical terms were more likely to be mixed with subjective pedagogical language, which is often designed to evoke an "embodied experience" for the pianist (Milanovic, 2012, p. 257). For example, "Curling" is defined as "pulling in" the fingers from the DIP ("nail") joints, which describes what the pianist would experience when moving/positioning the fingers in this way. However, the meaning of the term "in" can vary based on the point of reference, and so its meaning may change based on context. In the case of "Curling," "pulling in" seems to suggest moving the fingertips closer to the hand (flexion). That being said, Milanovic (2012) points out that the term "in" as used in this context may be confused with the "in" movements meant to describe translating the fingertip(s) towards the fallboard (subcategory 4.6.4). In order to limit similar translation problems in this study, context was taken into account as much as possible. This included the use of visual images and demonstrations. Additionally, the impact of subtle differences between subjective terms on their resulting biomechanics was not always clearly demarcated. For example, terms like "fixating" and "molding" the fingers are used to describe the experience created by the combination of certain hand/finger positions and muscular states (see subcategory 1.2). While both of these experiences are described in the Taubman Approach sources as occurring due to co-contraction ("dual muscular pulls"), subtle

differences in word choice between the two terms may imply slight differences that are not explicitly delineated in the Taubman Approach sources (see analysis of subcategory 1.2). In these situations, differences in word choices were considered to be deliberate, and so certain nuanced differences were discussed as if they had varying biomechanical implications.⁷⁰

Another complicating factor was found in some circumstances where biomechanical rationales are given to explain why a particular subjective experience is or is not recommended. In some situations, this only required a simple substitution of the current scientific term. For example, when a certain manner of playing is discouraged because it causes “dual muscular pulls,” the term “co-contraction” could be easily substituted. However, in other situations more analysis was required to determine what exactly was meant by certain biomechanical terminology used in the Taubman Approach sources. For example, the Taubman Approach sources state that the experience of “restricted” movements caused by “Curling” the fingers (subcategory 1.4) occurs due to fact that the “long flexor” muscle “pulls tightly” across the wrist and fingers (subcategory 1.3). The latter statement seems to be intended as an objective explanation of muscle activity. However, the phrase “pulls tightly” does not directly correlate to language used in the scientific literature. Instead, it seems to have subjective connotations related to the experience caused by the muscle activity. As a result, it was necessary to analyze both the terms “long flexor” and “pulls tightly” in order to better understand the proposed biomechanical explanation for “restricted” movements. This meant that several layers of analysis were required before a coherent biomechanical explanation of all of these terms could be found. Therefore, one potential limitation of this study is that the analysis of certain pedagogical terms was dependent

⁷⁰A similar situation occurred regarding different terms used in the Taubman Approach sources to describe the implications of combining DIP/PIP flexion and MCP abduction; see subcategories 1.5 and 1.6

on an accurate understanding of other pedagogical terms. If one term was either not fully understood or misunderstood, it could impact the accuracy of the analysis for other related terms.

A third challenge in analyzing Taubman's biomechanical language in this section came about because a single subjective experience may actually be caused by the interaction of many distinct, but interrelated biomechanical factors. This issue was also relevant to the analysis of the term "restricted." The experience encompassed by this one term may be the result of a number of factors: increased stiffness, increased muscle force required for movement, decreased velocity and range of motion, among others (see analysis of subcategory 1.4). The analysis of this term was further complicated by the fact that many of these factors interact with one another in order to create the resulting experience. In order to take multiple potentially significant factors into account, certain biomechanical concepts were discussed in this study that were not explicitly mentioned in the Taubman Approach sources, but were likely to cause the resulting experience that they describe. In the case of "restricted" movements, concepts such as stiffness, muscle fiber architecture, and the force-velocity relationship were all discussed because they may collectively lead to the subjective result described in the Taubman Approach sources. In some cases, the analysis provided may seem to have stretched the boundaries of the stated limitations of this study because it went beyond a direct analysis of the manifest content in Taubman Approach sources themselves. However, one of the main aims of this study was to try to extrapolate knowledge about the biomechanics of piano playing (latent content) from her experiences and ideas (see Research Problem and Methodology); therefore, whether or not Taubman was aware of certain particular biomechanical concepts that may explain her ideas in more detail was considered to be irrelevant. That being said, priority was given to explanations that seemed to relate to her descriptions in the most direct way. Further research will be required to investigate

whether or not the concepts applied accurately reflect the biomechanics of “Curling” the fingers as implied in the Taubman Approach sources.

A final challenge encountered was that it was not always evident whether certain pedagogical terms were meant to be taken as literal or relative descriptions. Milanovic (2012) points out that language in the Taubman Approach has been constructed to anticipate certain common problems. This suggests that Taubman’s choices in language may have been influenced by pedagogical factors that cause her to avoid using the most precise scientific terminology. The most significant example of this in the analysis on “Curling” was Taubman’s recommendation that the DIP (“nail”) joint should be “straight.” It was unclear if this term was meant to be taken literally (0 degrees of flexion/extension), or as a relative term that is between two extremes (too much flexion or extension). In situations where the language alone may have been meant literally or figuratively, a combination of other sources were used to attempt to find the most accurate meaning possible. These included pictures, videos, and relevant verbal excerpts from other sources. For example, the fact that Taubman’s use of the term “straight” was likely not meant to be taken literally is reflected in the language used in other relevant sources (see analysis of category 5).

Despite some of the challenges involved in analyzing the Taubman Approach language from a biomechanical perspective, the pedagogical language used to describe the concepts related to “Curling” seems to have a high level of internal consistency among the sources (see the tables provided at the conclusion of each category). For example, the distinction between “Curling” and “curving” the fingers, which is explicitly delineated at the beginning of the first DVD (Taubman Institute, 1995, vol. 1) is maintained throughout all of the sources used in this study. Many other terms that seem to have unique meanings within the Taubman Approach (“in

and out” movements, “freedom” vs. “restriction” of movements, etc.) are similarly used in a standardized fashion throughout the sources. Even a term such as “tension” which is not used in a way that is consistent with their use in the scientific literature (Wheatley-Brown, 2011), does seem to have a consistent meaning (or set of meanings) within the context of the Taubman Approach. This gives evidence to Milanovic’s (2012) claim that the pedagogical language of the Taubman Approach has been deliberately crafted as its own lexicon, and therefore must initially be learned in context in order for its unique meaning within the approach to be understood. Another finding from this analysis is that there are a number of terms used by the Taubman Approach sources related to piano playing that do not appear to have any concise equivalent in the modern scientific literature (e.g. “key spot” “black key area,” etc.). In order to attempt to explain the relevant concepts without using these terms, the writer often had to resort to description, which may actually increase the potential difficulty for the reader. In these situations, it was found that invented terminology can be quite useful in describing ideas concisely, as long as a clear definition for those terms can be ascertained.

While consistency of terminology among the Taubman Approach sources was generally high, there were some exceptions. The DVD’s were found to include a number concepts/ideas that did not appear in the other sources. This may be explained by the fact that the DVD’s are the most comprehensive source used in this study, both in terms of length and diversity of context (both lecture and masterclass). Additionally, there are also some instances in which unique pedagogical/metaphorical language is used in the thesis by Milanovic (2012), but is not found in the other sources. For example, she cites the term “non-variable distance” as used to describe the fact that the finger lengths should always have the “same relationship” (see subcategory 4.5.2). The most likely reason for the appearance of such terms in her thesis, but not other sources is

that she acknowledges some terms were given to her in lessons by particular Taubman teachers. This reflects the idea that language in the Taubman Approach continues to be used practically; while the main core lexicon has been established and standardized, teachers may have their own idiosyncratic methods of instructing students on certain concepts. Therefore, some level of increased terminological variety is inevitable as the approach becomes increasingly widespread.

Recommendations for further research:

As stated in Chapter 2 section, the main aim of this study was to explain Taubman's ideas using language that is consistent with modern science. It did not seek to make a full evaluation of the claims laid out in the Taubman Approach related to the subject of "Curling." Therefore, further research is needed to do so. At the time of publication, no studies have been performed to the researcher's knowledge on the subject of DIP/PIP flexion and movement at the piano. Several studies have examined finger joint position and muscle use when depressing the key (e.g. Harding et al., 1993; Wolf et al., 1993). Therefore, quantitative examination of the biomechanical premises discussed in categories 1, 5, and 6 would be a beneficial contribution to the literature. The analyses provided in this study may be used as a basis to operationalize pedagogical terminology so that such studies can be done. Additionally, some of the contexts of "Curling" identified in category 2 could be used to examine those biomechanical premises as they relate to specific pianistic situations. Alternative movements described in category 5 can be tested to examine how they compare with "Curling" in terms of the factors described by the Taubman Approach sources. While methodological constraints make it challenging to directly identify biomechanical causes for certain injuries (see Review of Literature), the findings of category 3 may be useful to pianists and teachers who are attempting to alleviate problems that may be related to "Curling" the fingers.

Chapter 5: “Keybedding”

Introduction:

The second analysis in this study will focus on what the Taubman Approach sources call “Keybedding.” Milanovic (2012) describes the term “Keybedding” as “aiming past the point of sound to press on the keybed” with “excessive force” (p. 204). Among the Taubman Approach sources used in this study, Milanovic’s thesis is the only one that explicitly uses this term, which she attributes to Matthey (p. 141). However, the general set of ideas that may relate to the term “Keybedding” are present throughout all of the Taubman Approach sources used in this study, in which they are identified as a potential cause of physical and technical problems. Therefore, the categories in this analysis were developed in order to organize the issues and problems associated with “Keybedding” in such a way that their biomechanical implications could be described in more detail. Four groups of categories were created in order to organize the material. First the characteristics of the piano that are relevant to “Keybedding” will be discussed. Next the codes related to “resting down” on the keys and how that can be done correctly/incorrectly will be discussed. Next, the terminology related to the recommended and discouraged ways to depress the key. The concept of hand and arm support will then be discussed as it is related to keeping the key depressed. Finally, the fourth group of categories will outline physical and musical problems that are associated with “Keybedding” in the Taubman Approach sources.

5.1 Characteristics of the piano:

Introduction:

The first group of categories will pertain to the characteristics of the piano mechanism that are discussed in the Taubman Approach sources contained in this study. These categories

will pertain only to the aspects of piano mechanics that may relate to the subject of “Keybedding.” The following categories will be discussed in this section: 1) The piano is a speed tool; 2) The point of sound is where the hammer hits the string; 3) There is no sound on the bottom of the key; 4) The keys hit back with equal force; 5) The keys are weighted. Finally, a miscellaneous subcategory will be discussed.

5.1.1 The piano is a speed tool

TA Summary:

Golandsky states that the piano “is a speed tool that requires perfect timing and aiming, much the same as a tennis racket or golf club” (Taubman Institute, 1995, vol. 1). She says that when playing the piano, there are two speeds and two directions (Taubman Institute, 1995, vol. 2), which Taubman called horizontal speed and vertical speed (1984, p. 147). Horizontal speed is the speed of movement from key to key; it determines the tempo of the music. Vertical speed is the speed of the key as it goes down; it determines the volume of the sound produced by the hammer hitting the string. A faster vertical speed creates a louder sound, while a slower key speed creates a softer sound (Taubman, 1984, p. 148; Taubman Institute, 1995, vol. 1). That being said, if the pianist tries to play with too much vertical speed, the resulting sound will be harsh (Taubman Institute, 1995, vol. 1, 4; Milanovic, 2012, p. 141). Therefore, they claim there must be another way to create loud sounds without moving the fingers very fast (Taubman Institute, 1995, vol. 1). On the other hand, as the pianist depresses the key progressively slower and slower, eventually no sound will be produced (Taubman Institute, 1995, vol. 1). Taubman (1984) states that pianists often confuse horizontal and vertical speed, and therefore try to play at a faster tempo by moving their fingers very fast into the keys (p. 147). However, she cites

the fact that pianists can play softly at a fast tempo as evidence that these two speeds are distinct from one another:

“Horizontal motion is produced by arm movements carrying the fingers across the keyboard. This the arm can do easily at great speeds. The distance the finger must move to depress a key is so small that when it moves somewhat slower it does not interfere at all with the horizontal speed. Remember that pianists can play fast and softly at the same time, and must depress the key slower for soft playing” (p. 148).

Analysis:

“**The piano is a speed tool:**” Taubman divides speed at the piano in two different categories: “horizontal speed” and “vertical speed.” She states that “horizontal speed” determines tempo, and “vertical speed” determines dynamics. Because this analysis focuses on key depression, only “vertical speed” will be discussed here.

“**Vertical speed:**” According to Taubman “vertical speed” is defined as the “speed into the key.” This likely refers to the velocity of the finger (finger velocity) as it depresses the key, which then impacts how quickly the key is depressed (key velocity). Due to the high number of independent movements of the upper limb, called **degrees of freedom**, there are an extremely high number of movement combinations that can be used to depress a key. Because there are more muscles than there are degrees of freedom, called **muscular redundancy**, there are also a high number of muscle combinations that can be contracted to create those different movements (Kutch & Valero-Cuevas, 2012). The movements/muscles chosen will impact the amount of key velocity (“vertical speed”), as well as muscle force(s) required to create it. Regardless of the motions used, Taubman states that fingertip/key velocity (“vertical speed”) determines the volume of the sound produced.

“Vertical speed” and dynamics: In order to understand the impact of key speed on the sound produced, it is important to discuss how piano sound is produced. As noted by Golandsky, a single piano sound is created by a hammer hitting a string (Taubman Institute, 1995, vol. 1). When the hammer hits the string, the string begins to vibrate and produce sound waves. The volume of the sound is determined by the amplitude of those sound waves, which is directly proportional to the amount of energy in the vibrating string. In mechanics, **energy** is an object’s capacity for doing work (Knudson, 2007, p. 151).⁷¹ The energy in the string will be generated by the energy of the hammer coming into contact with it. Because the hammer is moving, it will have **kinetic energy**. Kinetic energy is determined by the mass and velocity of the moving object and is expressed through the equation $E=1/2mv^2$. Therefore, the square of velocity of the hammer when it contacts the string will be directly proportional to the volume of the sound that is produced. As the hammer velocity increases, the volume of the sound produced by the hammer hitting the string will also increase. Likewise, as the hammer velocity decreases, the volume produced will also decrease. This understanding of piano sound is consistent with Golandsky’s statement that in order to get a softer sound, the pianist must “[slow] down...the speed with which the hammer strikes the string” (Taubman Institute, 1995, vol. 5). A number of statements in the Taubman Approach sources indicate that the key velocity directly determines the velocity of the hammer when it strikes the string. For example, Golandsky states that “if you put the key down very slowly there is no sound. And if you put it down a little bit faster there is sound, and as you go faster and faster there’s more and more sound” (Taubman Institute, 1995, vol. 1). This relationship of key and hammer velocity is consistent with the sources on piano

⁷¹ Mechanical work done by an object is a product of the force and displacement of that object in a particular direction (Knudson, 2007, p. 155). This concept will be discussed in more detail below (see analysis of subcategory 5.3.4)

mechanics used in this study (Reblitz, 2019). A piano key is a type of lever mechanism. The hammer is connected to the key through a series of interconnected mechanisms, called the **piano action**. When the key starts moving downward, the series of levers begin to move the hammer towards the string. When the key is depressed to a certain point, it triggers the **escapement**, a mechanism which releases the hammer before it hits the string. When the hammer is released, its inertia causes it to continue moving and hit the string (Reblitz, 2019). After hitting the string, the hammer rebounds off it and then returns to its original position so the key can be played again (Reblitz, 2019). The speed that the hammer moves is directly proportional to key velocity (“vertical speed”). Faster key velocity will generate a louder sound. Slower key velocity will get a softer sound. If key velocity is too low, the hammer will not have enough inertia to reach the string, and so it will fall down without any sound being produced. Key velocity is controlled by the pianist’s fingertip(s). Therefore, energy is transferred from the fingertip to string through a series of interconnected systems: the fingertip moves the key, which moves the hammer, which then hits the string. This understanding relationship between finger velocity and dynamics is consistent with a number of statements in the Taubman Approach sources (see TA Summary above). This is also likely what Golandsky means by describing the piano as “a speed tool” (Taubman Institute, 1995, vol. 1) and stating that “the finger controls the hammer.”⁷²

“Distance to the keybed:” Taubman Approach sources state that “from the surface of the key to the keybed is a distance of about $\frac{3}{8}$ inch” (Taubman Institute, 1995, vol. 1). In the piano mechanics sources, the amount that the key moves down from its resting position to its fully

⁷² It is important to note that the Taubman Approach sources discuss that excessive finger velocity is problematic for a number of technical and musical reasons. On the musical side, they state that too much “vertical speed” (finger velocity) causes a harsh sound, and therefore loud sounds should be produced in a way that does not involve “fast fingers.” This will be discussed in further detail below (subcategory 5.3.2). The technical problems associated with high finger velocity will be discussed as well (subcategory 5.6.2).

depressed position is called the **key dip**, which is typically about $\frac{3}{8}$ in. (Reblitz, 2019, p. 135). This is consistent with the amount of distance “from the surface of the key to the keybed” described in the Taubman Approach sources (Taubman Institute, 1995, vol. 1). This can help explain Taubman’s statement that “the distance the finger must move to depress a key is...small.” Because the Taubman Approach sources advocate keeping the fingers either close to the keys or on them (see below, subcategory 5.5.4), the finger will only need to move approximately $\frac{3}{8}$ inch (perhaps slightly more) to depress the key. According to Taubman, this means that the differences in key velocity (“vertical speed”) needed to produce various sounds will have virtually no impact on the time interval between the depression of each key (horizontal speed, which determines tempo).

5.1.2 The point of sound is where the hammer hits the string

TA Summary:

According to Golandsky, “if you put the key down very slowly, you’ll feel a little bit of a bump. And it’s at that point of the bump that the hammer hits the string and falls back” (Taubman Institute, 1995, vol. 1). In the Taubman Approach, the place where the bump is located is called the “point of sound” (Taubman Institute, 1995, vol. 1). The Taubman Approach sources state that the distance from the surface of the key to the keybed is about $\frac{3}{8}$ inch, and that the point of sound is about $\frac{1}{8}$ inch below the surface (Taubman Institute, 1995, vol. 1). In order to play softly, Golandsky states that the pianist must “slow the point of sound,” which “can slow the action of the hammers’ escapement to the string” (Taubman Institute, 1995, vol. 1).

Analysis:

“Point of sound:” Golandsky describes the term “point of sound” as “the bump” at which point “the hammer hits the string and falls back.” She says that this is typically $\frac{1}{8}$ in. below the surface of the key. The term “point of sound” does not appear in the sources on piano mechanics used in this study. Based on Golandsky’s statements, the term “point of sound” seems to refer to what the sources on piano mechanics call the **letoff**. The letoff is the point in the key dip where the escapement releases the hammer toward the string (Reblitz, 2019). When the key reaches the point in the key dip where the letoff occurs, the pianist will feel the “bump” described by Golandsky. According to the piano mechanics sources used in this study, the letoff is typically located approximately $\frac{1}{8}$ in. from the surface of the key (Reblitz, 2019). This is consistent with the description of the “point of sound” in the Taubman Approach sources. From a mechanical perspective, the letoff is not the exact spot where the hammer hits the string, but rather when the hammer is released and continues moving towards the string. Because the interval between the time the hammer is released and when it hits the string is small, it will feel virtually instantaneous to the pianist. The key velocity as it passes the letoff will determine the velocity of the hammer, and therefore the volume of the sound. This explains why the Taubman Approach sources call it the “point of sound.” From a pedagogical point of view, this term may be useful because the pianist will learn to associate their movement at the letoff with the sound being produced. The subject of “point of sound” will be discussed further in the section on “aiming” (subcategories 6.4.1-4).

“Slow the point of sound:” Golandsky’s statement that the pianist should “slow the point of sound” suggests that in order to play more softly, the pianist should focus on the velocity of the key specifically as it passes the letoff (“point of sound”). Because the key velocity at this point

will determine that of the hammer when it strikes the string, trying to depress the key more slowly as it passes that point will help them produce a softer sound (Reblitz, 2019).

5.1.3 There is no sound on the bottom of the key

TA Summary:

According to the Taubman Approach sources, because the point of sound is where the hammer hits the string, the finger can only impact the sound produced by a key as it approaches the point of sound (Taubman Institute, 1995, vol. 2). Any activity that occurs beyond the point of sound will have no impact on the resulting tone (Taubman Institute, 1995, vol. 1, 2; Milanovic, 2012, p. 141). This includes movement when the finger is on the keybed. Golandsky states that “by the time we get to the bottom of the key, the hammer has already hit the string and fallen back” (Taubman Institute, 1995, vol. 1), and so there is “no sound at the bottom of the key,” (Taubman Institute, 1995, vol. 2, 4). That means that any extra movement on the keybed will have no impact on sound (Taubman Institute, 1995, vol. 1).

Analysis:

“No sound on the bottom of the key:” Golandsky states that “there is no sound on the bottom of the key” (Taubman Institute, 1995, vol. 1). Once the hammer is released by the escapement mechanism, its velocity when moving towards the string cannot be changed by the pianist. Therefore, the pianist cannot impact the sound once the key is depressed beyond the letoff. Any change in key velocity in the space between the letoff and the keybed will not have any impact on the sound produced. Once the hammer hits the string, all the pianist can do is release the key. Doing so will cause the dampers to stop the string from vibrating and stop the sound. Additionally, when the key is fully depressed, any further downward movement or force applied

to the key will not impact the sound in any way. This understanding of the piano mechanism can help explain Golandsky's statement above.

5.1.4 The keys are weighted

TA Summary:

Golandsky states that “the keys are weighted,” and that “the keys are heaviest at the surface” (Taubman Institute, 1995, vol. 1, 4). She says that in order to depress a key, the pianist must provide enough weight to “overcome surface resistance” (Taubman Institute, 1995, vol. 1, 2, 4). When discussing chord playing, she states that “if you put a pencil over several keys, you will note that more weight is required to put down several keys, compared to just one” (Taubman Institute, 1995, vol. 4). According to Golandsky, this fact is important in chord playing because the pianist will need to provide enough weight to depress all of the keys, which is more than the amount needed to play just one key (Taubman Institute, 1995, vol. 4).

Analysis:

“Weighted” keys/“Surface resistance:” Golandsky states that “the keys are weighted,” and so the pianist must “overcome surface resistance” to put the keys down (Taubman Institute, 1995, vol. 1, 4). As discussed above, the piano action is a type of lever mechanism. The key is one half of the lever, and the other half is located behind the fallboard. Between them there is a pivot point, called the **balance rail** (Reblitz, 2019). The keys have lead weights inside them on both sides of the balance rail. The purpose of these weights is to balance the amount of weight on each side and keep the key in its resting position (not depressed). The amount of weight added also determines how much weight is needed to depress the key, called the **downweight**. The

downweight for a typical piano is approximately 50-55g⁷³ (Reblitz, 2019). This is likely what Golandsky means by the term “surface resistance,” which needs to be “overcome” to depress the key (Taubman Institute, 1995, vol. 1, 2, & 4). As discussed above, key velocity is proportional to the volume of the resulting sound. Because the downweight represents the minimum force needed to depress the key, applying that amount of force will create a very soft sound, if any. In order to produce very loud sound, the pianist will likely need to apply force with a much larger magnitude (Palmieri, 2003).⁷⁴ Another aspect of the keys being “weighted” is that there is a force that brings the keys back to their resting position once they are released, called the **upweight**. The upweight for a typical piano is approximately 20-22g (Reblitz, 2019). This means that after the pianist has depressed the key, they must continue applying at least that much force to prevent it from coming up. If the key comes up far enough, the dampers will stop the sound. If it comes up a smaller amount, the sound will continue ringing. However, the Taubman Approach sources state that allowing the key to come up a small amount can cause technical problems, which will be discussed in further detail below (subcategory 5.3.3). Golandsky’s statement that “The key is heaviest at the surface” is likely a reference to the fact that the downweight is larger than the upweight. Therefore, the pianist needs to apply more force to depress the key than they do to keep it depressed. The difference between the force applied to depress the key and the upweight will increase as the volume of the desired sound increases.⁷⁵

⁷³ Generally, grams are used as a measurement of mass, rather than weight (force). However, in the context of piano regulation, forces on the keys are typically measured using grams.

⁷⁴ For example, Kinoshita and colleagues (2007) used a force transducer to measure fingertip force in piano keystrokes at various dynamic levels. The loudest sounds measured in this study were produced by forces near 60N, which is above 6000g.

⁷⁵ While the minimum amount of weight needed to depress the key (downweight) is consistent, the pianist will need to apply more force to get a louder sound. For this reason, the difference between the force applied to depress the key and the upweight (always 20-22g) will increase when the pianist wants a louder sound.

Several notes are “much heavier than playing one note:” Golandsky’s claim that several notes are “much heavier than one note” (Taubman Institute, 1995, vol. 4) refers to the fact that in order to depress more than one key, the pianist will have to supply enough force to overcome the downweight of each of those keys. The downweight of each key will likely be fairly consistent, and so the fingertip force at each individual key will only need to be 50-55g. However, the amount of total force that the pianist needs to apply in order to put down all the keys of a particular chord will be at least the combined downweight of all of the keys being played.⁷⁶ This also applies to keeping the keys depressed, in which case the pianist will need to apply more force than the combined upweight of all the keys.⁷⁷ According to the Taubman Approach sources, these facts will have implications for chord playing, which will be discussed below (subcategory 5.5.1).

5.1.5 The keys hit back with equal force

TA Summary:

Golandsky states that “when we hit the key very, very fast, the key hits us back with equal force. Every action has a reaction equal and opposite to itself.” (Taubman Institute, 1995, vol. 1) As a result, she states that playing with very fast fingers or excessive force can lead to a number of physical and technical problems.⁷⁸

Analysis:

“Hits back with equal force:” When Golandsky states that “every action has a reaction equal and opposite to itself,” she is referring to **Newton’s third law**, which states that when one object

⁷⁶ For example, playing a three note chord would require a minimum of 150-165g.

⁷⁷ In the case of a three note chord, that would be at least 60-66g.

⁷⁸ The Taubman Approach sources also state that the keys can “rebound” the pianist “in a good way” (Taubman Institute, 1995, vol. 5). However, this was considered to be outside the scope of this study.

exerts a force on another object, the second object also exerts a force on the first object that is both equal in magnitude and opposite in direction. In piano playing, this means that the force generated by the finger hitting the key will simultaneously generate an equal force from the key back into the finger. Because this force is generated by two objects coming into contact with one another, it is called the **contact force**.

“Fast fingers” and contact force: Golandsky states that moving the finger into the key with high velocity/force will generate a high force back into the finger. However, it is important to note that it only takes about 50g to move the key, and so the key will move out of the way before a very high force can be applied. As a result, the force from contacting the key itself (“hitting”) will not be high. In contrast, the keybed is a hard surface that will not move out of the way due to the force applied by a finger. If finger velocity is high when the key hits the keybed, the contact force from the keybed will stop the finger from moving. In order for this to occur, the finger will have to decelerate from its current velocity (relatively high) to 0 velocity in a very small amount of time. Therefore, the change in velocity, or acceleration will be high. Because, force is equal to the product of mass and acceleration ($F=ma$), then the contact force produced by the finger hitting the keybed at a high velocity will be relatively high.

5.1.6 Miscellaneous - Piano characteristics

TA Summary:

The miscellaneous subcategory indicates a few other excerpts related to the characteristics of the piano. None of these excerpts were considered relevant to the subject of “Keybedding,” and so they will not be discussed here.

5.1.7 Conclusion: Piano characteristics

The categories above were developed in order to describe the aspects of the piano mechanism identified in the Taubman Approach sources that may be necessary to better understand the concept of “Keybedding.” A total of 55 units of coding were used in this category. After a second coding, 52 units of coding were in agreement between the two coding sessions, making for a 94.54% agreement. The following table has been provided to display each subcategory with a brief summary of its biomechanical analysis:

Table 5.1 *Piano characteristics*

Subcategory	Biomechanical	Taubman Sources	Units of coding
The piano is a speed tool	Piano sound is produced by a hammer hitting a string. The hammer is attached to the key and is released towards the string due to the escapement mechanism. The volume of the sound produced is determined by the energy in the string, which is produced by the velocity of the hammer. Hammer velocity is determined by key velocity. Therefore, the key velocity determines the volume of the resulting sound. Due to the number of degrees of freedom and muscular redundancy in the upper limb, there are many combinations of joint movements/muscle contractions that can be used to produce a particular key velocity. The key dip on a piano is typically about $\frac{3}{8}$ inch from the top of the key when it is not depressed.	Taubman 1984; Taubman Institute, 1995, vols. 1, 2, 4, & 5; Milanovic, 2012	27
The point of sound is where the hammer hits the string	The point in the key dip in which the hammer is released towards the string is called the letoff, which is about $\frac{1}{8}$ inch from the top of the key. Controlling the key velocity as it passes this point will allow the pianist to control the volume of the resulting sound.	Taubman Institute, 1995, vols. 1 & 4	7
There is no sound on the bottom of the key	The letoff occurs before the key is fully depressed. Therefore, once the key is fully depressed, the volume of the resulting sound cannot be changed.	Taubman Institute, 1995, vols. 1, 2, & 4; Milanovic, 2012	4
The keys are weighted	A piano key is a lever mechanism, in which lead weights are placed on either side of the balance rail to balance the amount of weight on each side. The downweight required to depress a key is typically 50-55g. The upweight required to keep the key fully depressed is typically about 20-22g. Therefore more force is required to depress the key than to keep it depressed. The total amount of force required to play several keys is equal to the combined downweight of those keys. The total amount of force required to keep several keys depressed is equal to the combined upweight of those keys.	Taubman Institute, 1995, vols. 1 & 4	10

The keys hit back with equal force	When one object exerts a force on another object, the second object also exerts a force on the first object that is both equal in magnitude and opposite in direction. Therefore, the force applied to a key by a finger will create a contact force from the key back into the finger. Because the downweight of one key is only 50g, the pianist cannot apply a high degree of force to the key without it moving. However, the keybed is a hard surface and so applying a high fingertip force to the key may result in a high contact force when the key is fully depressed.	Taubman, 1984; Taubman Institute, 1995, vols. 1 & 5	5
Miscellaneous - piano characteristics	Considered irrelevant for this analysis.		2

5.2 Before playing:

Introduction:

The next group of categories will discuss the position and muscular state of the upper limb when the pianist places their fingers on the keys before playing. These categories were included in the analysis on “Keybedding” because the Taubman Approach sources use similar language to describe both the feelings associated with placing the fingers on the keys before playing and those associated with playing.⁷⁹ Three categories were developed to describe the excerpts related to placing the fingers on the keys before playing: 1) The fingers should rest down on the keys before playing; 2) Don’t hover/relax before playing; 3) The correct position/sitting height impacts resting down. A miscellaneous subcategory was created for this category, but no excerpts were coded. Because these categories are all biomechanically interrelated, they have been analyzed collectively after the summaries of all three categories.

⁷⁹ This applies to a number of terms/phrases used to describe both the recommended way of playing and ways of playing that are discouraged.

5.2.1 The fingers should rest down on the keys before playing

TA Summary:

The Taubman Approach sources state that before the pianist begins playing, the fingers should be resting down on the keys to create the correct balance at the keyboard (Taubman Institute, 1995, vol. 1; also see Moran, 2008, pp. 7-15). When resting down, the weight of the fingers, hand, and arm will be equally distributed among these parts (Taubman Institute, 1995, vol. 1), and the forearms will be directed toward the piano (Moran, 2008, p. 15). While the fingers will feel rested down, they will do so lightly, without causing any of the keys to go down (Taubman Institute, 1995, vol. 1). Because the keys are weighted, giving the fingers the correct amount of weight will allow the keys to hold up the fingers, while also giving them the sensation that they are resting down (Taubman Institute, 1995, vol. 1). Golandsky states that “there has to be a sense of contact between the fingertip and the key, holding lightly” (Taubman Institute, 1995, vol. 1). Because the fingertips are the only points of contact between the pianist and the keyboard, the fingers have to hold enough to prevent them from falling, but not so much that the keys start to go down (Taubman Institute, 1995, vol. 1). The correct hand position, in which the main knuckles are above the middle knuckles allows the fingers to feel balanced and rest down properly (Taubman Institute, 1995, vol. 1). Besides the correct sitting height, resting down properly allows the fingers, hand, and arm to feel unified at the keyboard (Taubman Institute, 1995, vol. 1), which means that the fingers can get the support of the hand and the arm when playing (see subcategory 5.5.1).

5.2.2 Don't hover/relax before playing

TA Summary:

The Taubman Approach sources identify two general types of problems that may interfere with the correct resting down on the keys before playing, and therefore hinder the motions necessary to play: holding up and relaxing down (Taubman Institute, 1995, vol. 1, 4; Moran, 2008, p. 13). Holding up, or hovering is described as problematic for a few reasons. Milanovic (2012) suggests that when hovering, the finger is not connected to the key (p. 105). Also, Golandsky states that “because everything is up,” the hand and arm will not be able to support the fingers when playing (Taubman Institute, 1995, vol. 4). Holding up can occur in a number of different parts of the upper limb. Holding or grabbing onto the keys with the fingers is discouraged because there will be too much weight and the keys will go down (Taubman Institute, 1995, vol. 4). The excerpts in this subcategory also discourage holding up in the shoulders and upper arm, because this can inhibit arm movement or cause either fatigue or pain (Taubman Institute, 1995, vol. 1, 4; Moran). According to Golandsky, holding up is not always visible, and can still occur when the pianist looks as though they are resting on the keys (Taubman Institute, 1995, vol. 1).

Relaxation before playing is considered problematic. Like hovering, relaxation is discouraged in the shoulders and upper arm because it can cause all the weight to fall on the fingers (Taubman Institute, 1995, vol. 1, 4). This will cause the keys to go down and make it difficult to move the fingers (Taubman Institute, 1995, vol. 1). Relaxing the fingers is also discouraged because it can cause the knuckles to collapse (Milanovic, 2012, p. 166). In addition to the problems caused by either holding up or relaxing, the

excerpts in this subcategory indicate that there is often a relationship between these two types of problems. For example, if the arm is too relaxed, then the fingers will have to hold onto the keys in order to prevent falling off the keyboard (Taubman Institute, 1995, vol. 1). In contrast, if the fingers don't hold enough, then the arm will have to hold up in order to prevent falling off (Taubman Institute, 1995, vol. 1, 4). Golandsky describes this type of compensation as “the whole story of technique, that when a right part doesn't work, the wrong part will come in, and that part was not meant to do the job, and usually it ends up as sensations of fatigue and pain” (Taubman Institute, 1995, vol. 1). Either holding/relaxing can also occur in the wrist.

5.2.3 Correct position/sitting height impacts resting down

TA Summary:

The Taubman Approach sources suggest that the position/height of the body at the instrument impacts the pianist's ability to rest down and balance on the keys properly (Taubman Institute, 1995, vol. 1). A full examination of position/sitting height as discussed in the Taubman Approach is outside the scope of this study. However, a general discussion will be included to give a brief overview of how sitting height impacts resting down and key depression in the context of this analysis.

Correct position/sitting height: According to the Taubman Approach sources, the correct sitting height is one in which the forearm and elbow are on a straight plane with the keyboard when the keys are not depressed (Taubman Institute, 1995, vol. 1; Moran, 2008, p. 8; Milanovic, 2012, p. 102). This height depends on “the ratio of the upper arm to the torso” (Milanovic, 2012; also see Taubman Institute, 1995, vol. 1), and can be found by “extending a book from the top surface of the white keys to the back of the

forearm” (Moran, 2008, p. 8). That being said, the exact height that is most comfortable will vary to some extent among individuals (Milanovic, 2012, p. 103). According to the Taubman Approach sources, the correct sitting height allows for the fingers, hand, and arm to be unified, without having to relax or hold up any part of the upper limb (Taubman Institute, 1995, vol. 1). One aspect of this is the correct starting hand position is one in which the main knuckles are slightly above the middle knuckles (Taubman Institute, 1995, vol. 1). This hand position allows the fingers, hand, and arm to feel balanced and rest down properly on the keys (Taubman Institute, 1995, vol. 1). In contrast to the correct sitting height, the Taubman Approach sources state that sitting too high or too low can be problematic because it may change the position of the upper limb and lead to relaxation and/or hovering (Taubman Institute, 1995, vol. 1, 4).

Sitting too high: When the pianist sits too high, the elbow is significantly higher than the keyboard (Taubman Institute, 1995, vol. 1). This can cause the pianist to feel like they are hovering above the keys (Taubman Institute, 1995, vol. 1, 4; Milanovic, 2012, p. 105). As a result, one or more limb parts (shoulder, upper arm, forearm, etc.) may relax down in order to compensate (Taubman Institute, 1995, vol. 1, 4; Milanovic, 2012, p. 105).

Sitting too low: When the pianist sits too low, the elbow is lower than the keyboard. This may cause the weight to fall in the improper place (Taubman Institute, 1995, vol. 1; Milanovic, 2012, p. 104). As a result, one or more limb parts may hold up/hover in order to compensate.

As discussed in the previous subcategory, the interaction between hovering/relaxation can be complex. The same is true for sitting height, and so the analysis of this

subcategory will focus on the general impact that sitting height may have on resting down, based on the examples in these excerpts.⁸⁰

Analysis: Before playing

“The keyboard holds you up:” Golandsky describes “resting down” in the following way:

“When we rest down, and the weight is equally distributed between the fingers, hand, and forearm, and the keys are weighted, they have weights, the combination of the resting and keys holding us so-called ‘up’ will give us the perfect sensation of resting down without falling” (Taubman Institute, 1995, vol. 1). In mechanics, the term **weight** refers to the force of gravity acting on an object to accelerate it toward the ground. Any force that acts to resist the force of gravity on that object and bring it to a state of equilibrium is called a **supportive force**. In order to do so, the combined supportive forces acting on an object must be of equal magnitude and opposite direction to the force of gravity, which will be the case when an object is in a state of constant velocity. In the case of the upper limb, its weight tends to pull it towards the ground. If that weight is unsupported by anything other than the passive tissues in the body (ligaments, cartilage, etc.), the limb will hang in its resting position at the pianist’s side. If the upper limb is not in contact with any surface outside the body, then the only supportive force(s) that can be applied to it will have to come from muscle contractions and through other connective tissue around the joints. For example, if the pianist holds their upper limb in front of them in any static position, the muscles crossing each joint will have to contract to generate the forces necessary to resist the force of gravity acting on each segment. If these muscle forces generate enough net force to balance the force of gravity, the joints will be in equilibrium, and no movement will

⁸⁰ In addition to sitting height, other factors such as distance, torso position, sitting on the front edge of the bench, and placement of the feet are discussed as important aspects of proper sitting at the piano. While all of these elements are necessary to create the proper balance and alignment at the keyboard (Moran, 2008, p. 15; Milanovic, 2012, p. 103), they will not be discussed here in order to limit the scope of this study.

occur. In this case, the muscle forces across each joint can be considered supportive forces. If the upper limb is in contact with an outside surface, then external forces can be acting as supportive forces as well. For example, if the pianist places their fingertips on the piano, a contact force from the keyboard will be directed upward into the fingers, and an equal/opposite force will be directed from the fingertips downward into the keyboard. The downward force is sometimes called the “fingertip force” (e.g. Harding et al. 1993). The upward contact force can be used to help support the upper limb weight to some extent. This can explain what Golandsky means by the “keys holding us so-called ‘up.’” In this context, her choice of words indicates she wants to avoid using the term “holding up” in a pedagogical context, which may lead the pianist to do something that she considers to be problematic (see “holding up” below). Because the contact force from the keyboard into the fingertip contributes to supporting some of the upper limb weight, it can allow the pianist to reduce the amount of weight that is being supported by forces generated from muscle contractions. If the pianist does so, less effort will be required to maintain the position of the upper limb. The pianist will likely feel more of the effect of the downward force of gravity, which Golandsky describes as a feeling of “resting” on the keyboard. The result will be that the upper limb is supported by a combination of the contact force from the keyboard and the collective forces of muscle contractions across the upper limb joints. The combination of these forces pushing up and the force of gravity pulling down on the upper limb gives the pianist a feeling that they are “resting down” on the keys. Golandsky states that when “resting down,” the keys should not go down, and the pianist should not feel as though they are “falling.” Finding the proper state of “resting down” helps the pianist find the proper “balance” at the keyboard, which will be discussed below.

“Resting down” without the keys going down: As described above, when “resting down,” the weight of the upper limb will be supported by a combination of the contact force from the keyboard and the muscle forces across the joints. Golandsky states that if done properly, this should occur “without the keys going down.” She states that the keys may go down if “there is too much weight” (Taubman Institute, 1995, vol. 1). As a result, she claims that the correct amount of weight supported by the keys is “very little” (Taubman Institute, 1995, vol. 1). The average weight of an adult upper limb can be thought of as somewhere close to 3750g.⁸¹ This amount of weight is much heavier than the typical downweight of 50-55g required to depress one piano key (Reblitz, 2019). If one finger is touching the keyboard and the muscles in the upper limb are not generating any force, then the key will be supporting a very large proportion of the entire weight of the upper limb. Therefore, the fingertip force will be much larger than 50-55g, and the key will go down (Reblitz, 2019). If the pianist is touching several keys, the upper limb weight will be supported by all of those keys.⁸² The amount of weight that is supported by each individual key will likely vary. However, if any key is supporting more than 50-55g, that key will go down. Because the upper limb will be heavier than the combined downweight of the keys being touched, at least one of the fingertip forces will still likely be large enough to cause the key(s) to go down if no other supportive forces are applied.⁸³ This can explain Golandsky’s

⁸¹ Measurements of upper limb mass suggest that it is on average approximately 5% of total body mass (Winter, 1979, as cited in Ethier & Simmons, 2007). This will vary to some extent depending on the individual. The upper limb weight given here was based on a person whose total weight is approximately 75kg (about 165 lbs.), which may be considered close to average. In this particular example, it would take 75 keys to hold up the entire weight of the upper limb.

⁸² Again, in this situation there are no muscle forces helping to support the upper limb. A small degree of upper limb weight will still be supported by passive tissues, and so the amount of weight supported by the keyboard will be slightly less than its entire weight.

⁸³ For example, the pianist can touch a maximum of five keys, which have a combined weight of approximately 250-275g. This amount is still much smaller than that of the average upper limb.

statement that “too much weight” from the upper limb can cause the keys to go down before the pianist starts playing (Taubman Institute, 1995, vol. 1). The Taubman Approach sources advocate for a starting hand position that typically covers no more than four keys (Milanovic, 2012, p. 108).⁸⁴ Because each key has a downweight of 50-55g (Reblitz, 2019), that means that the total upper limb weight that can be supported by those keys is about 200-220g.⁸⁵ This is only a relatively small fraction of the total upper limb weight (3750g on average), which explains Golandsky’s statement that the correct amount of weight supported by the keyboard is “very little” (Taubman Institute, 1995, vol. 1). Similarly, this may explain Moran’s (2008) description of this activity as “resting lightly” on the keys (p. 15). The remaining upper limb weight that is not supported by the keyboard (approximately 3475-3500g if touching four keys) will instead have to be supported by a combination of muscle contractions across one or more joints in the upper limb.⁸⁶

One significant issue is that the upper limb is a group of linked, rigid bodies subject to force application, called a **kinetic chain** (McLester & St. Pierre, 2007, p. 45). Because all of the segments in a particular chain are linked together by joints, then the position and forces applied to each segment in the chain can affect that of the others (McLester & St. Pierre, 2007, p. 45). When the fingertips are on the keyboard, the fingertips would be supported (“held up”) by the keys. However, the force of gravity would generally tend to cause all of the other segments to fall towards the ground if no other supportive forces are applied. If the entire limb was all one segment, the keyboard could support the entire weight of that segment because there would be no

⁸⁴ This will vary slightly among individuals according to hand size.

⁸⁵ It will be 150-165g if the fingers are touching only 3 keys.

⁸⁶ As noted above, passive tissues will also contribute to supporting the upper limb.

points for joint rotation to occur (fulcrums) other than the shoulder. However, the upper limb is made up of several segments connected by joints, and so muscle forces must be applied across those joints to generate enough force to bring it to equilibrium. If insufficient force is applied across any one joint, there will be a non-zero net force on that joint tending to pull the adjacent segments downward. In order to maintain the position of the entire upper limb, muscles crossing the other joints will have to compensate by generating increased forces.

“Balance” and “Resting down without falling:” Golandsky states that “resting down” helps create the “correct balance at the keyboard.” She also states that resting down should occur “without falling.” Two mechanical concepts may be relevant here. The first concept is that of balance, which is the degree of control a person has over their body in relation to a base of support (Knudson, 2007, p. 184). In piano playing, the term balance as used here likely refers to the balance of the fingers on the keyboard. The second concept is that of a kinetic chain, which has been described above. Because the upper limb is a kinetic chain, the “balance” of the fingers on the keyboard is determined in some part by the position and forces acting on all of the joints of the upper limb. In order to be considered balanced, the pianist would need to be able to maintain the joint position of the fingers using minimal muscle contraction across all joints. If the fingers are not balanced, then they will have a tendency to slide in one direction or another.⁸⁷ This is most likely to occur in one of two directions: towards the fallboard, or away from the fallboard and off the keys. Due to the force of friction, the fingers may tilt, rather than slide. In either case, this may give the pianist the feeling that they are “falling” in one direction, as described by Golandsky (Taubman Institute, 1995, vol. 1). The direction that the fingers tend to slide or tilt will depend on the specific position of the joints and the combination of forces acting

⁸⁷ The joints may also tend to collapse, which will be discussed below (see analysis of subcategory 3.4).

on each segment (gravity, muscle contractions, passive tissues, etc.). Because of the number of possible combinations of joint positions and forces involved, this can occur in many different ways. Golandsky's statements related to "resting down" suggest that two general factors are important to finding the "correct balance at the keyboard" as defined by the Taubman Approach: joint position and distribution of muscle forces.

"Balance" and joint position: One way in which the fingers may be balanced is if they are placed in such a position that little or no muscle contraction is required to maintain the position.

Without any muscle contraction, the forces acting on the upper limb occur in two general directions when the hand is on the piano: 1) the forces directed downward due to gravity (weight); and 2) the forces directed from the keyboard into the fingertips (contact forces).

Because the upper limb bones are attached at the joints that connect them, any force applied to one bone will cause it to push on the adjacent bone (and vice-versa due to Newton's third law).

In order to achieve a finger position that requires no muscle contraction to maintain, the forces acting on each finger bone will need to be parallel, opposite, and in-line. This would allow the joints to be stabilized⁸⁸ simply by the forces of the bones pushing on each other in both directions. In this way, the bones could be described as "supporting" one another. If the forces acting on the joints do not meet these three conditions, then the bones will not fully support one another. The forces acting on each bone will tend to cause joint rotation, and muscle forces will need to be added as necessary in order to stabilize each joint and bring it to rotational equilibrium. Hypothetically, the only way to make the finger bones truly "balanced" in piano

⁸⁸ As discussed in the analysis of "Curling," subcategory 4.1.3, the term "stability" is used differently in the medical and engineering fields. This study uses the term "stability" to refer to a joint that has enough stiffness to maintain equilibrium position when a small force is applied to it. This is consistent with the definition used in the medical field.

playing would be to position them straight over the keys, forming a 90 degree flexion angle at the wrist and angles of 0 degrees at the finger joints.⁸⁹ However, doing so would be impractical for a number of reasons, and likely impossible to play. The opposite extreme would be if the hand and fingers are totally “flat,” forming angles of 0 degrees at the finger joints and the wrist. In this position, the forces acting on the fingers/hand in both directions would tend to extend them with very little support from the adjacent bones. Therefore, a high degree of co-contraction across the fingers/wrist would be required to support the upper limb weight and stabilize the joints against the contact force. As the segments are positioned in a way that moves further away from the hypothetical “balanced position” and closer to the “flat” position, it is likely that gradually more muscle contraction will be required. Placing the fingers in a position in which the forces tend to cause a greater degree of finger/wrist extension will also likely increase the feeling of “falling off” the keyboard. Because it is not practical to play with a finger position that is entirely balanced, the Taubman Approach sources seem to recommend a position that is close to balanced, while still minimizing the amount of muscle contraction needed across all of the joints in order to maintain that position. Because these factors are somewhat in conflict with one another, they will need to be managed in a way that is some form a compromise.⁹⁰ This understanding of an upper limb position that can minimize muscle forces necessary for playing gives one possible explanation of what the Taubman Approach sources are describing when they use the term “balanced.” If the muscle forces across each joint are small enough, they will be

⁸⁹ This assumes that there is no friction between the fingers and the keys. When friction is taken into account, the fingers may also be balanced at an angle outside of 90 degrees.

⁹⁰ For example, having 0 degrees of flexion at the DIP joint will bring it to the end of its range of motion. Finding a position that compromises them all will minimize the amount of muscle forces necessary to maintain that position.

subjectively negligible, and the pianist will feel as though they are “balanced” in a way that requires very little physical effort.

Joint position and the “mid-range of motion:” In order to minimize the amount of muscle contraction necessary across all of the joints, the Taubman Approach sources recommend that the shoulder and wrist are close to their resting position (Taubman Institute, 1995, vol. 1; Moran, 2008, p. 13; Milanovic, 2012, p. 103). The elbow will be in the middle part of its range of motion, so that the forearm and hand are close to level with the tops of the keys. They also recommend that the fingers are kept close to their resting position (see analysis on “Curling,” category 4.5). One reason why this position is recommended relates to Golandsky’s statement (citing Ortmann) that “the physiologically best movement is one permitting motion in the midrange of motion. It is easiest and smoothest near the middle range, increasing in difficulty as it approaches either extreme of the range” (Taubman Institute, 1995, vol. 1).⁹¹ According to the biomechanical sources, the total extent of possible movement for a single joint is called its **range of motion** (Cael, 2010, p. 68).⁹² The range of motion for a particular joint is limited by a number of factors, including the shape of the bones that form the joint, the surrounding ligaments, the length and ability of tissues crossing that joint to stretch (e.g. muscles, nerves, tendons), etc. (Cael, 2010, p. 68). These factors will impact range of motion differently for each joint and each individual (Grimston, Nigg, & Hanley, 1993). That being said, one significant factor related to Golandsky’s statement may be related to muscle length. The relevant biomechanical principle

⁹¹ The excerpt that discusses “range of motion” was not included in the original QCA on “Keybedding.” However, it was identified as relevant later on, and so it is referenced here for additional clarity in analyzing Taubman’s use of this term. Golandsky also uses the term “antagonistic pulls” to describe the same phenomenon (Taubman Institute, 1995, vol. 1).

⁹² Range of motion can also be called “joint excursion” (McLester & St. Pierre, 2007, p. 341).

here is called the **Length-Tension relationship** (McLester & St. Pierre, 2007, p. 320).⁹³ This principle states that there is a relationship between the length of a given muscle and the amount of force that muscle can produce when contracting (contractile force). Muscle contraction occurs due to the binding of two proteins, called actin and myosin. When these proteins bind, they cause the muscle fiber to contract, which shortens the muscle and generates a force. In order for binding to occur, the filaments containing actin and myosin need to be in a position in which they overlap. Because the force generated by a contracting muscle is directly related to the number of binding filaments, a muscle can produce its maximum contractile force when it is at a length that allows for as many filaments to overlap as possible. Within the human body, this optimal length typically corresponds to a muscle's resting length (McLester & St. Pierre, 2007, p. 344).

As the muscle lengthens or shortens, each muscle fiber decreases in its ability to generate force (McLester & St. Pierre, 2007, p. 371). When a muscle is made longer or shorter than its optimal length, fewer filaments are able to bind to one another, and so less force is produced by contracting a single fiber (McLester & St. Pierre, 2007, p. 371). In the body, a muscle is usually closest to its optimal length when the joints that it crosses are at or near the middle of their range of motion (McLester & St. Pierre, 2007, p. 371; Knudson, 2007, p. 84),⁹⁴ which is sometimes called the **neutral zone** (Fagarasanu, Kumar, & Narayan, 2004). As the joints move out of the neutral zone and towards the extreme ends of their range of motion, the muscles surrounding those joints will either be lengthened or shortened. Therefore, the muscles will become less

⁹³ It is also referred to as the "Force-Length relationship" (Knudson, 2007, p. 84)

⁹⁴ Maximum force production capability for a single muscle actually occurs when that muscle is slightly longer than its resting length. This occurs because of the passive tension generated when a muscle is lengthened (McLester & St. Pierre, 2007, p. 322).

effective in generating contractile force, and more muscle fibers will need to contract in order to generate the force needed to execute the task. This can only be achieved by activating more motor units, which also makes it more difficult to control movement (see analysis on “Curling,” subcategory 4.1.4). The increased muscle contraction and decreased ability to control muscles that are outside of their length can explain Golandsky’s statements that movement “increases in difficulty” as joints approach “the extreme range of motion.”⁹⁵

Finger position and “balance:” Besides the issue of range of motion, Golandsky points out another aspect of the recommended finger position that specifically relates to the “correct balance:” “the main knuckle is a little bit higher than the middle knuckle...that’s where it allows again the fingers, hand, and arm to feel balanced, resting down this way” (Taubman Institute, 1995, vol. 1). As discussed in the analysis on “Curling,” (subcategory 4.6.1), the Taubman Approach sources used the term “main knuckle” to refer to the MCP joints of the fingers (Milanovic, 2012, p. 204). The term “middle knuckle” used here seems to refer to the PIP joints.⁹⁶ If the pianist wants to keep their wrist and finger joints close to their resting/neutral position (as advocated by the Taubman Approach), then in order to find a “balanced” position they will want the hand to be positioned in such a way that it pushes downward on the proximal phalanx of each finger. This means that the hand and the MCP joints would need to be above the proximal phalanx and the PIP joints, as Golandsky describes. Because this position is not perfectly balanced, the contact force from keys will still tend to cause the fingers/hand to extend

⁹⁵ Taubman cites Ortmann as her source on the subject of range of motion (Taubman Institute, 1995, vol. 1). Ortmann’s book was published in 1929, when the sliding filament theory had yet to be established (in the 1950’s). However, it seems that the subjective evidence of leaving the neutral zone (“increasing in difficulty”) would have led both Ortmann and Taubman to the practical conclusion that doing so was problematic, even if the underlying muscle mechanics were not well understood at the time. The explanation provided above represents the current understanding of why this subjective experience occurs.

⁹⁶ See the analysis on “Curling,” subcategory 1.1 for a more detailed description of finger joints.

to some degree. Therefore, some activity will be needed in the finger/wrist flexors to stabilize those joints. That being said, because each muscle crossing the finger joints has a different force production capability, the exact position that will require minimal muscle contraction to maintain will vary slightly among individuals. In general, the position will be one in which the fingers are curved, with some degree of flexion at each finger joint (Harding et al., 1993).⁹⁷ Because this is close to the resting/neutral position, this position can be achieved with minimal muscle contraction away from the piano. Once the fingers are touching the keys, the only muscle force necessary to maintain this position will be a small amount to stabilize the joints against the contact force. The contact force will push upward on the distal phalanx, which will then push up on each of the finger bones. The proximal phalanx would then push up on the hand. In opposition to these forces, the arm and hand will push down on the finger bones, which then push on the keyboard. The finger position could hypothetically be made closer to fully balanced with more MCP flexion. However, because of the physiology of the hand, increasing the MCP flexion angle too far beyond the resting/neutral position would require activating flexor muscles and also cause the hand to extend (Watson, 2009), which is also considered problematic. Therefore, the Taubman Approach sources discourage too much MCP flexion, which they refer to as “arching the hand” (Taubman Institute, 1995, vol. 1; also Milanovic, 2012, p. 109; Also mentioned in the analysis on “Curling,” subcategory 4.5.4).

“Balance” of the forearms “directed towards the piano:” One way in which the Taubman Approach sources may be trying to achieve a slightly higher MCP flexion angle (more “balanced”) is by “direct[ing] the balance” of the forearms “forward” (Moran, 2008, p. 24). This term likely indicates that the elbows are brought slightly closer to the keyboard via a small

⁹⁷ Because this hand/finger position takes the form of a curve, it is sometimes referred to as the “arch” of the hand (Tubiana & Chamagne, 2005).

degree of shoulder flexion, without changing the position where the fingers contact the keys.⁹⁸ Because the upper limb is a kinetic chain, doing so can make all of the parts between the elbow and the MCP joints get higher: the forearm, wrist, hand, and MCP joints.⁹⁹ The finger bones will also be moved to a position that is slightly closer to being perpendicular to the keys, meaning that the contact force will get closer to being parallel to the bones. As a result, less muscle contraction can be used across the finger joints, which will help the pianist to feel more “balanced” at the keyboard. Because the arm is so long compared to the fingers, the change in angle will be relatively small at the shoulder compared to its total range of motion, whereas the change in angle at the finger joints will be relatively larger. As a result, doing so will avoid the need to achieve a more advantageous MCP joint angle solely by activating the finger flexor muscles. Because the wrist and hand get higher, it will also negate the possibility of wrist extension that can occur in conjunction with activating the MCP flexors. In sum, combination of hand position and forearms directed “forward” will help the pianist to feel “balanced” at the keyboard because they will reduce the amount of muscle contraction necessary to stabilize the finger joints against both the contact force directed upward and the weight of the hand/arm directed downward. Feeling “balanced” in this way will also remove any feelings of “falling off the keys” which are associated with increased muscle forces to stabilize the joints.¹⁰⁰ One additional factor is related to the **center of gravity**, which is the point at which the force of

⁹⁸ The Taubman Approach sources call this position a “key spot” (Taubman Institute, 1995, vol. 3; also see analysis on “Curling,” subcategory 4.2.2)

⁹⁹ This will only occur if the point of contact between the fingertip and the keys is not permitted to change.

¹⁰⁰ Both Moran (2008, p. 7) and Milanovic (2012, p. 103) indicate that the position and balance of the torso and feet have an impact on the proper “balance at the keyboard.” However, these factors will not be discussed here in order to limit the scope of this study. Generally, moving the torso forward by slightly rotating the hip joints will also bring the elbows closer to the keyboard. This means that less shoulder flexion will be needed to achieve the “forward” position. Other factors may be involved here that are outside the scope of this investigation.

gravity seems to be concentrated or considered to act (Knudson, 2007, p. 180; McLester & St. Pierre, 2007, p. 99). When the fingertips are touching the keys, the center of gravity is likely somewhere in the forearm, closer to the elbow than the wrist. Moving the elbow closer to the keyboard (“forward”) may bring the center of gravity slightly closer to the fingertips. This could potentially help reduce the feeling of “falling off” the keys. However, this would be a small shift, and so it will likely not make a large difference.

Sense of key contact and “holding lightly:” Golandsky states that when resting down properly, “there has to be a sense of contact between the fingertip and the key, holding lightly.” This “sense of contact” is likely produced by the pianist’s perception of the contact force against the fingertip. This can be described as “holding lightly” because the amount of force will be relatively low (less than 50g per finger), and that force will be generated mainly by the finger flexors. One potential benefit of this is that the pianist will get to experience the feeling of low fingertip force, which Golandsky states is equivalent to the recommended amount of force when the key is fully depressed (Taubman Institute, 1995, vol. 4). Feeling this amount of force before playing can give the pianist an experiential basis which can then be transferred to playing (Moran, 2008, p. 14).¹⁰¹

“Balance” and distribution of forces: As discussed above, the force of gravity acting on the upper limb would cause it to hang at the pianist’s side if no supportive forces are applied (outside of passive tissues). The keyboard can be used to support some of the upper limb weight, but this amount must be relatively small if the pianist does not want the keys to go down. Therefore, a combination of muscle contractions must be used across the upper limb joints in order to maintain its position. Because the upper limb is a kinetic chain, the forces applied by muscle

¹⁰¹ Golandsky states that the feeling of resting down is analogous to the feeling of “resting on the key bottom,” (see subcategory 5.3.1 below).

contractions across one joint may impact those needed across the other joints to support the entire upper limb. In order to apply muscle contractions in a way that is “balanced” and avoids either the problem of keys going down or the feeling of “falling off,” Golandsky states that the “[support for the upper limb] weight is equally distributed between the fingers, hand, and forearm” (Taubman Institute, 1995, vol. 1). If taken literally, this statement seems to suggest that the muscles crossing the elbow, wrist, and finger joints all contract equally to share the burden of supporting the upper limb weight that is not supported by the keyboard. However, the segments all have different weights, and so this statement likely does not indicate that there should be an equal magnitude of force generated across each joint. Instead, it could mean that the task of supporting the upper limb weight is distributed across all of the joints in such a way that allows for all muscles involved to contract only to a small degree. In this case, each joint would have a relatively low degree of muscle force across it, but still enough to resist the force of gravity tending to pull the upper limb towards the floor. This could help the pianist feel balanced by maintaining the position of the joints using a generally low amount of muscle contraction.

Hovering/Relaxation: Golandsky states two general ways that the distribution of forces could be problematic, which will disrupt the “correct balance at the keyboard” and potentially cause a feeling of “falling off:” hovering and relaxation.

Hovering: Golandsky states that “resting down” should occur “in the proper amount so there is no feeling of hovering,” “which takes very little [weight].” As mentioned above, the amount of upper limb weight that can be supported by the keyboard is relatively small. The small amount of resulting contact force between the fingertip and the keyboard will also require a small amount of muscle force across the finger joints to stabilize them, which Golandsky described as “holding lightly.” However, she states that “when the fingers don’t hold on, there is no sense of contact

with the key,...the upper arm will take over and hold us on the keyboard so we don't fall off." If the pianist decreases the amount of upper limb weight that is supported by the keys, it will decrease the contact force at the fingertips. The muscle contraction across the fingers will also likely decrease, and the fingers will no longer feel as though they are "holding on" to the keys to a small extent. If no other muscle forces are applied across the other upper limb joints, the force gravity would tend to pull the upper limb towards the ground. Because the upper limb is a kinetic chain, this would tend to pull the fingers off the keyboard. In order to prevent this from occurring, the pianist will need to compensate for the decrease in contact force with muscle forces to support the remaining upper limb weight and maintain the position of all of the joints. The compensating muscle forces can be achieved in two general ways: 1) by activating muscles that oppose gravity, (e.g. the elbow flexors); or 2) by co-contracting muscles across one or more joints to increase stiffness and prevent any significant movement from occurring. In either case, the results of "hovering" by reducing the amount of upper limb weight supported by the keyboard will lead to increased muscle contraction in the upper limb. The increased muscle contraction needed to maintain the position of one or more joints in this way will likely result in the feeling of "holding up" that Golandsky describes. She also states that "The holding up is not always something that is visible." This likely means that the increased muscle contraction across one or more joints will not necessarily result in a change in joint geometry. Therefore, the pianist may feel that they are using more effort due to increased muscle contraction. However, an observer would not necessarily notice any visible difference in muscle forces if the joints do not change position. Because the additional muscle contraction caused by "holding up"/"hovering" will not contribute to the task of playing in any beneficial way, the Taubman Approach sources consider it to be problematic. Golandsky identifies that one common area for "holding up" is the

shoulder/upper arm. However, the many degrees of freedom and muscular redundancy in the upper limb make it so that “holding up” as a result of “hovering” can occur in a variety of joint/muscle combinations.

Relaxation: In addition to hovering, Golandsky states that “relaxation” can be problematic when “resting down:” “When I’m resting down like this you don’t see a relaxation. I’m not talking about relaxation. I’m only talking [about] the proper resting in the proper amount so there is no feeling of hovering.” As described above, “hovering” or “holding up” can result when there is increased muscle contraction across one or more joints. The term “relaxation” seems to refer to the opposite condition, in which there is too little contraction across any joint.¹⁰² In this case, there will be less support for the upper limb weight coming from muscle forces. In order to prevent the keys from going down or a change in joint position, the pianist will need to compensate for the decrease in force across one joint by increasing the force across another joint. This will disrupt the distribution of muscle contraction across each of the joints described above as necessary to finding the “correct balance” (see above). Furthermore, it may lead to a feeling of “falling” in one direction or the other, depending on the specific combination of joint positions and muscle forces. The interaction between muscle contraction across the various upper limb joints can explain the relationship between “relaxation” and “hovering” that was found in the analysis of subcategory 5.2.2 (above). The specific examples provided by the Taubman

¹⁰² The use of the term “relaxation” as used in the Taubman Approach and the scientific literature was studied by Wheatley-Brown (2012). She states that in the biomechanical sources, the term “relaxation” can be used in a few different ways. It can sometimes be used to indicate reducing the neural input to a muscle, which reduces the degree of contraction and force output. The term can also be used to indicate a lack of muscle forces occurring across a joint. This will also result in a lack of stiffness across that joint. The Taubman Approach sources seem to use the term “relaxation” in reference to either a joint (e.g. the shoulder, wrist, etc.) or a segment (e.g. the upper arm). This indicates that they are using the term “relaxation” in the latter definition, in which the person reduces the amount of muscle forces/stiffness across a joint. As noted by Wheatley-Brown, the term “relaxation” is exclusively used in the Taubman Approach sources as a pejorative term, only when indicating such a low degree of muscle force/stiffness across a joint that it is considered problematic.

Approach sources likely represent some common ways in which this can occur. However, the many degrees of freedom and muscular redundancy in the upper limb make it so that this relationship can occur in a variety of joint/muscle combinations.¹⁰³

Impact of sitting height on resting down: Because the upper limb is a kinetic chain, its joint angles are interdependent. However, the specific structural design of a particular kinetic chain can affect exactly how the joints relate to one another. The human arm is called a **Serial** or **Simple kinetic chain** because each segment has no more than two linkages (McLester & St. Pierre, 2007, p. 45). This is significant because it impacts the total degrees of freedom of the chain. If each segment only has two linkages, then changing the position or angle of one segment will impact that of the adjacent segments (McLester & St. Pierre, 2007, p. 45). In the arm, the position/angle of each joint depends on that of the adjacent proximal joint (Tubiana & Chamagne, 2005). For example, the position/angle of the fingers is dependent on that of the wrist, which is dependent on that of the elbow, which is dependent on that of the shoulder. Golandsky states that sitting height is determined by the “length of the upper arm,” and Milanovic (2012) adds that it is the “ratio of the upper arm to the torso” (p. 104). Another way of describing this is that the height of the bench will determine the amount of height difference between the pianist’s shoulder and the keyboard. Because the position/angle of the shoulder impacts that of the other joints in some way, then changing the sitting height will change the joint geometry of most or all of the upper limb. This is significant because changing the joint geometry will also impact how the force of gravity affects each segment, which will therefore impact the amount of muscle contraction/force necessary to support the weight of the arm,

¹⁰³ If two joints in the upper limb have too little muscle contraction across them (“relaxation”), this will cause a change in joint geometry, which will be discussed below (see analysis of subcategory 5.3.4).

stabilize the joints, and eventually to move and depress the keys when playing. Because the upper limb has many degrees of freedom, there are many possible combinations of joint angles when the hands are on the keyboard. The Taubman Approach sources used in this study describe a number of likely possibilities that may correlate with certain changes in sitting height. That being said, a full analysis of this subject and its significance is outside the scope of this study.

The Taubman Approach sources recommend a sitting height that allows for the recommended joint positions described above (neutral shoulder, wrist, fingers; elbow in middle range). Golandsky states that this position would also “give the fingers the support of the hand and the forearm.” This subject will be discussed below (subcategory 5.5.1). The statements in the Taubman Approach source seem to suggest that the recommended joint position, proper “balance,” joint position, and distribution of muscle forces, would combine to allow for minimal muscle contraction across all of the joints when “resting down” on the keyboard before playing. In contrast, adjusting the sitting height higher or lower than the recommended position may impact these factors in different ways. Golandsky points out a number of choices that individual pianists may make in order to perform the task of playing at a particular sitting height. A detailed investigation of each of these potential choices is outside the scope of this study. However, the general claim of the Taubman Approach sources is that all of these choices would be problematic for a variety of reasons, depending on context. Overall, the Taubman Approach sources seem to be suggesting that the recommended sitting height will minimize the amount of muscle contractions/forces needed across each joint that create the “correct balance at the keyboard” described in this analysis. On the other hand, deviating from that height will change those muscle contractions/forces in a way that will result in some combination of “hovering” and/or “relaxation” as described above.

5.2.4 Conclusion: Before playing

The subcategories above were created in order to identify the important concepts in the Taubman Approach sources related to the position and muscular state of the upper limb before playing. A total of 78 units of coding were used in this category. After a second coding, 74 units of coding were in agreement between the two coding sessions, making for a 94.87% agreement. The following table has been provided to display each subcategory with a brief summary of its biomechanical analysis:

Table 5.2 *Before playing*

Subcategories	Biomechanical analysis	TA sources	Units of coding
The fingers should rest down on the keys before playing	When placing the fingers on the keys before playing, the upper limb is supported by a combination of muscle forces, passive tissues, and the contact force from the keyboard. The amount of weight that is supported by the keys must be less than 50g per key in order to prevent the keys from going down. As a result, only a small fraction of the total upper limb weight can be supported by the keyboard. Because the upper limb is a kinetic chain, the distribution of muscle forces across the upper limb joints should allow the fingers to feel balanced on the keyboard. This also allows for the upper limb to be supported by a minimal amount of muscle contraction across all of the joints. The sensation of the fingertips on the keys will give the pianist the experience of low fingertip force that can be transferred to playing.	Taubman Institute, 1995, vol. 1; Moran, 2008; Milanovic, 2012	12
Don't hover/relax before playing	If fingertip force is too low, then less upper limb weight can be supported by the keyboard. As a result, more muscle contraction will be required to compensate. This can occur by activating muscles that oppose gravity or increasing stiffness across one or more joints. Similarly, having too little muscle contraction across the joints can lead to compensation across one or more other joints. It also may cause the fingers to tend to slide/tilt on the keys in one direction and make them feel less balanced.	Taubman Institute, 1995, vols. 1 & 4; Moran, 2008; Milanovic, 2012	18
The correct position/sitting height impacts resting down	The position of the joints can also impact the feeling that the fingers are balanced on the keyboard. A finger position in which the fingers are closer to parallel, opposite, and in-line will be closer to balanced, and therefore will hypothetically require less muscle contraction to maintain. However this is not totally possible because of physiological limitations. Therefore, the recommended position is one in which the shoulders, wrist, and fingers are close to neutral. The hand and elbow are close to parallel to the top of the keys, and the hand/MCP joints are above the	Taubman Institute, 1995, vols. 1 & 4; Moran, 2008; Milanovic, 2012	45

PIP joints. In this position, the contact force will tend to extend the fingers/hand to some extent, and so a small degree of finger flexion will be required to stabilize the joints. Changing the sitting height will change the position of the joints; however, there are many possible ways this can occur.

Miscellaneous - before playing

Considered irrelevant for this analysis

3

5.3 When playing:

Introduction:

The categories in this section include statements related to the feelings/movements relevant to depressing the keys and keeping them depressed. That being said, the movements to depress the keys are very complicated. Therefore, they will be included in the TA summaries, but the biomechanical analysis of these categories will mainly focus on keeping the key down. Both of these conditions (depressing the key and keeping it depressed) were included in the summaries because it was not clear in some of the excerpts whether the terms applied to one situation or the other. Furthermore, based on the preliminary examination of the Taubman Approach sources, it seemed likely that connections are made between how the pianist approaches depressing the keys and the resulting force, muscle contraction, etc. when the key is finally depressed. Categories in this section were developed to organize terms related to feelings of playing in the recommended way, as well as ways that are considered problematic for a variety of reasons. The following categories were developed related to depressing the keys: 1) Finger should stand on the keybed; 2) Don't push on keys/keybed; 3) Don't hover when playing; 4) Don't relax when playing. Finally, a miscellaneous subcategory was included to contain terms not included in the other categories. The terms related to the recommended way of playing were included in the first subcategory, while the terms related to problematic ways of playing were included in the latter three categories. Each of the categories describing different problems was created to include a

constellation of terms that seem to be related to a similar type of issue. For example, the excerpts in the subcategory on “pushing” all include terms related to feelings of excess effort in the fingers or fingertip force (e.g. “pressing,” “grabbing,” etc.). The categories related to “hovering” and “relaxation” were created to include terms relevant to generally having too much or too little muscle contraction, respectively. This was based on the way the terms “hovering” and “relaxation” were used in reference to the conditions before playing (see subcategory 4.2.2 above).

5.3.1 Finger should stand on the keybed

TA Summary:

The Taubman Approach sources state that the finger should stand or balance on the keybed when it depresses a key (Taubman Institute, 1995, vol. 1; Moran, 2008, p. 32; Milanovic, 2012, p. 141). Golandsky states that this is equivalent to the feeling of resting down on the keys before playing (Taubman Institute, 1995, vol. 4). Various words are used throughout the Taubman Approach sources to describe this feeling: “standing,” “rested,” “easy resting,” “doing nothing,” “centered,” “strong,” “solid,” “balanced,” “lightly balanced,” “settled,” “finished,” “easy,” “down,” “on the bottom,” and “earthbound” (Taubman Institute, 1995, vol. 1, 2, 3, 4, 5; Milanovic, 2012; Moran, 2008). Golandsky compares the correct feeling of the finger on the keybed to standing on the ground (Taubman Institute, 1995, vol. 1). When moving from one key to the next, she says that most of the arm weight remains resting down to support the playing finger (Taubman Institute, 1995, vol. 4). When putting the key down, Milanovic (2012) states that the pianist should have a sense of key contact, which makes playing feels controlled (p. 157). A sense of going down with the keys while playing can also help create a

feeling of precision (Milanovic, 2012, p. 172). Golandsky states that the overriding feeling should be one of “walking on the bottom of the key,” and that playing should feel solid even when playing softly (Taubman Institute, 1995, vol. 1, 4). According to Milanovic (2012), Taubman described the feeling of the fingers on the keyboard as “like butter” (p. 111). When the finger is balanced on the keyboard, it can feel like an “anti-climax” if one is used to pushing (Milanovic, 2012, p. 141). Golandsky also states that the fingertips are the main point of contact with the key (Taubman Institute, 1995, vol. 1), but Golandsky points out that the pianist sometimes will need to play more on the pad of the finger when playing black keys in order to avoid falling off (Taubman Institute, 1995, vol. 2).

5.3.2 Don’t push on keys/keyboard

TA Summary:

In contrast to the correct feeling of standing on the keyboard, the Taubman Approach sources state that the pianist should not push on the keys or the keyboard (Taubman Institute, 1995, vol. 1, 2, 4, 5; Moran, 2008, p. 30). According to Milanovic (2012), pressing on the keyboard is defined as “Keybedding” (p. 141).¹⁰⁴ The excerpts in this subcategory identify a number of terms that are used to describe pushing when playing, both in the context of moving down to play the key, as well as when the finger is on the keyboard. The table below outlines the terms used in each context, as well as the terms used in both contexts.

¹⁰⁴ Milanovic (2012) states that the term “Keybedding” was first used by Matthay (p. 141). This term is not actually used by Taubman or Golandsky in any of the sources used in this study. Milanovic may have adopted it in order to have a concise term for using excessive force on the keyboard. It has been used in this study for the same reason.

Table 5.3 *List of terms used for “pushing” in different contexts*

Putting key down	Keeping key down	Both
fast into key	press	force/excessive force
struck forcefully	grip	push
snapping thumb	activity	squeeze
	effort	grab
	push-off	hitting hard
		work/work hard

Note. This table outlines a number of terms used in the Taubman Approach sources to describe “pushing” on the key, or other relevant conditions. The left column contains terms used when referring to movements to depress the key. The middle column contains terms used when referring to keeping the key depressed. The right column contains terms that are used either when referring to both conditions or when it is unclear which condition is being discussed.

Playing in a way described using the terms listed above is strongly discouraged in all contexts. One reason for this is that the key hits back at the finger with equal force (see subcategory 5.1.5 above). The same is true for the keybed, which is a hard surface (Taubman Institute, 1995, vol. 1). Therefore, pushing on the keybed will have no impact on the sound produced, and may result in physical problems with no possible technical or musical benefit (see subcategory 5.1.3). Golandsky states that pushing often occurs due to a lack of arm support, and that when pianists are told to put the key down by moving their fingers, they often think of pushing and squeezing (Taubman Institute, 1995, vol. 2). She also compares pushing on the keybed to both standing and walking (Taubman Institute, 1995, vol. 1, 4). She says that when standing, one should not feel that their feet are not pushing on the ground (Taubman Institute, 1995, vol. 1). In the same way, when the finger is on the keybed, the pianist should not feel as though the finger is pushing on the keybed (Taubman Institute, 1995, vol. 1). She compares playing to walking, in which one should not feel that they are pushing off one leg to make the next step (Taubman Institute, 1995, vol. 4). In the same way, when moving from note to note, the

pianist should not push off the standing finger when moving to play the next key (Taubman Institute, 1995, vol. 4).

5.3.3 Don't hover when playing

TA Summary:

While the Taubman Approach sources strongly discourage pushing on either the key or the keybed, they also discourage hovering or holding up (Taubman Institute, 1995, vol. 1, 4, 5; Milanovic, 2012, p. 163). As with the previous subcategory, a number of terms were identified as describing hovering/holding up, both in the context of moving down to play the key, as well as when the key is depressed. When moving to play the key, the Taubman Approach sources state that pianists often “hover” either when trying to play softly (Taubman Institute, 1995, vol. 1) or prevent a harsh sound (Milanovic, 2012, p. 163). Golandsky states that holding up with the arms in octave playing can make it hard to get power (Taubman Institute, 1995, vol. 5). As a result, the fingers will have to force or to push into the keys (from subcategory 5.3.2; Taubman Institute, 1995, vol. 5). Additionally, hovering is also discouraged once the key is depressed. Golandsky and Taubman strongly advise against “releasing the weight from the bottom of the key,” which may cause the key to rise up to a small degree (Taubman Institute, 1995, vol. 2, 4). This can occur when during forearm rotation movements (Taubman Institute, 1995, vol. 2), or when getting too high in shaping (Taubman Institute, 1995, vol. 5). Doing so will cause the upper arm to hold up in order to keep the fingers from falling off the keys, resulting in fatigue and limited speed capability (Taubman Institute, 1995, vol. 4). Holding up on the key bottom can also occur in a way that cannot be seen (Taubman Institute, 1995, vol. 1). For example, the arm can be holding up, which will cause the

finger to have to hold onto the key to keep it down (Taubman Institute, 1995, vol. 4). Hovering can also occur by stopping the finger before it gets to the key bottom, which will also cause holding in the upper arm. This can occur either in soft playing (Taubman Institute, 1995, vol. 1). Playing too lightly can also occur to avoid “Keybedding” (Milanovic, 2012, p. 157). Golandsky describes the feeling of hovering in this way as “like you’re tiptoeing” (Taubman Institute, 1995, vol. 1).

5.3.4 Don’t relax when playing

TA Summary:

Along with pushing and hovering, relaxation is another problem that can result when playing. The excerpts related to relaxation when playing the key(s) indicate that the Taubman Approach sources discourage playing with fingers, hands, or arms that are “floppy” or “dead” (Taubman Institute, 1995, vol. 5; Milanovic, 2012, p. 163). That being said, most excerpts in this subcategory are related to relaxation when reaching the keybed. Golandsky states that when this kind of relaxation occurs, the pianist continues dropping after the key is depressed (Taubman Institute, 1995, vol. 1). She says that when “moving freely” one muscle is relaxed, whereas “relaxing” causes both muscles to relax (Taubman Institute, 1995, vol. 1). Several words are used to describe relaxation on the keybed: “drop,” “collapse,” “sink,” “floppy,” “crumble.” Taubman (1984) states that one reason why relaxation can occur is to fix the problem of tension. Similarly, Milanovic (2012) states that relaxation can occur as part of an attempt to fix the problem of overactive fingers (p. 157). However, both Taubman and Golandsky suggest that relaxation does not remove tension, but rather increases it because it increases the amount of effort needed to move (Taubman Institute, 1995, vol. 1). Golandsky states that the

finger joints should not collapse, and instead you should feel that “there is a knuckle there” at the bridge because it is a fulcrum (Taubman Institute, 1995, vol. 4). She explains that collapsing the bridge can cause back pain (Taubman Institute, 1995, vol. 4). Just as there can be a relationship between hovering and relaxation before playing, Milanovic (2012) suggests that a similar relationship can occur when playing. She describes her own experience of this as holding up her arm and relaxing her wrist upon key contact (p. 163).

Analysis:

The Taubman Approach sources sampled in these categories use a wide variety of terms to indicate different ways to depress the key(s) and keep them depressed. Different terms are used to describe ways of playing that are either recommended or discouraged. There seem to be two general issues related to the forces involved in key depression that are relevant for these categories: 1) The force/velocity at the fingertip; and 2) the muscle contraction(s) used to generate that force/velocity at the fingertip and to stabilize the joints. A number of terms in the above categories are used to indicate how both of these factors contribute to playing in a certain context. Very often, the Taubman Approach sources describe the recommended way of playing in relation to what it is not, as a lack of certain problems. For example, Golandsky describes being “on the bottom of the key” as “you’re just not pressing there, nor are you hovering up” (Taubman Institute, 1995, vol. 1). Therefore, the analysis below was organized in order to better understand the biomechanical implications of certain recommended words by comparing them to potential problems related to a number of factors (e.g. fingertip force, muscle contraction across particular joints, etc.).

“Standing,” “pushing,” and “hovering:” The idea of “standing” on the keyboard seems to be used in the Taubman Approach sources to describe the recommended way of keeping the keys depressed. Other terms used to describe this way of playing, such as “resting,” “easy resting,” “lightly balanced” etc. indicate that the Taubman Approach sources recommend a relatively low fingertip force when keeping the key down. Golandsky differentiates this way of playing from both “pressing” and “hovering up” (Taubman Institute, 1995, vol. 1). These terms are likely used to generally describe using too much (“pressing”) or too little (“hovering up”) fingertip force, respectively. Golandsky compares the correct feeling of keeping the key down (“standing” or “resting”) to the feeling of “resting down” on the keys before playing. When “resting down” before playing, the Taubman Approach sources advise the pianist to allow the keyboard to support a relatively small amount of their upper limb weight, which generates a relatively small fingertip force (see analysis of subcategory 5.2.1 above). In order to prevent the keys from going down, the recommended fingertip force for “resting down” before playing is likely close to, but not above approximately 50-55g per key (see analysis of subcategory 5.2.1 above). Once the key is depressed, however, the situation will be different. Golandsky’s statement that you always have to be “solid on the bottom of the key” indicates that the key should always be fully depressed, regardless of context. The use of words like “settled,” “down,” and “earthbound” give a similar impression. As discussed above, the upweight of a key is typically about 20-22g (see analysis of subcategory 5.1.4 above). This means that the fingertip force must be more than that amount to keep the key fully depressed. If the fingertip force is less than that, then the key will begin to come up. Taubman describes this phenomenon as “finger releases” (Taubman Institute, 1995, vol. 2), which will constitute a form “hovering” as described by the Taubman Approach sources. As with “hovering” before playing (see subcategory 5.2.2 above), the Taubman

Approach sources state that decreasing the fingertip force when trying to keep the key depressed can cause “holding” in the upper arm in order to keep the finger on the key (Taubman Institute, 1995, vol. 4). Again, this likely refers to using increased muscle forces across the shoulder to compensate for the decrease in support from the keyboard (see analysis of subcategory 5.2.2 above). “Holding” the upper arm is just one example of this type of compensation, which may occur using a large variety of possible muscle/joint combinations.

The Taubman Approach sources state that “finger releases” can occur because the pianist “remov[es] the weight off the bottom of the key” (Taubman Institute, 1995, vol. 2). The idea of using “weight” to keep the key depressed will be discussed in further detail below (see analysis of subcategory 5.5.1). As it relates to this subcategory, this statement generally refers to decreasing the amount of fingertip force below 20g when moving to play the next key. When moving to play the next finger, the finger that is keeping the key down will change shape to some degree. Depending on a number of factors, this may adjust the fingertip force in small amounts. If the fingertip force is very close to 20g, then it increases the possibility that those small adjustments will cause the fingertip force to go below 20g and cause the key to start coming up. This will lead to a form of “hovering” as described in the Taubman Approach sources. Understanding “finger releases” in this way offers another possible implication of Golandsky’s statements that the finger should feel “solid on the bottom of the key” (Taubman Institute, 1995, vol. 1). As stated above, the recommended fingertip force is not very high; however, being “solid on the bottom of the key,” may suggest that fingertip force should be high enough that any small changes will not cause the key to start coming up. In order for this to happen, the recommended fingertip force would likely be somewhat below the downweight (50g), but still somewhat higher than the upweight (20g). That way, if the movement to play the

next key decreases the amount of fingertip force, the net force will still be in the downward direction, and the key will not come up. This understanding is consistent with Golandsky's statement that keeping the key(s) down should feel similar to "resting down" on the keys before playing.

"Pushing"/"Pressing:" The many statements in the Taubman Approach sources that discourage "pushing," "pressing," "forcing," etc. indicate that a fingertip force significantly higher than 50g is not recommended once the key is depressed. Golandsky states that "when you land on the bottom and stand solidly on the bottom of the key, you don't continue pushing. You have wood there. It won't help if you keep pushing, but it has tremendous ramifications on the technique as a whole when you do press and push. So it has to be an easy, just resting down, but no more effort. No activity on the key bottom" (Taubman Institute, 1995, vol. 1). As discussed above, the fingertip force needed to depress the key will vary depending on the desired volume (subcategory 5.1.1). If the pianist wants a loud sound, the forces can be quite high relative to the downweight of the key (50-55g). However, Golandsky's statement suggests that once the key is fully depressed, the pianist should not continue applying high fingertip forces, but rather use only the relatively low amount needed to feel "solid" when keeping the key down (described above). By the time the key is fully depressed, the hammer has already been released toward the string, and so continuing to apply a relatively high fingertip force would not impact the volume of the resulting sound (see subcategory 5.1.3). Golandsky's statement suggests that because the keyboard is a hard surface, increased fingertip forces would increase the contact force. This also means that applying more force will require more muscle contraction in order to stabilize the finger joints (and possibly others). If the muscles activated to generate this force cross multiple joints,

then co-contraction will likely increase to prevent those joints from moving.¹⁰⁵ Therefore, a high fingertip force once the key is depressed will increase muscle contraction with no possible musical benefit.

“Push off:” Golandsky states that “when I move a little bit up, it’s not a push off, which will activate the extensors, and then I have to flex to come down, and you have dual muscular pulls.” (Taubman Institute, 1995, vol. 4). In this situation, she is discussing moving from one key to play the next key, which is several notes away from the one currently being played. The term “push off” likely refers to applying increased force to the key that is being depressed in order to help generate the movement to the next key.¹⁰⁶ Her explanation suggests that this increased force will be applied by increasing muscle contraction in the finger extensors, which will lead to co-contraction (“dual muscular pulls”) once the flexors contract to play the next key. Instead of “pushing off,” Golandsky states that “the [recommended] action comes only...from the slight lifting of the finger, hand, and forearm, and swinging. The finger that I finished just rests down and does nothing” (Taubman Institute, 1995, vol. 4). This suggests that the movement to the next key should mainly be executed by more proximal muscles that move the larger segments, such as the elbow (and likely the shoulder to a small extent). In this case, minimal muscle contraction would be used across fingers in order to keep the key down.

“Grabbing” and “gripping:” In addition to high fingertip forces, the terms related to “pushing” on the key when it is depressed also seem to suggest a different meaning in some contexts. For

¹⁰⁵ For example, if the extrinsic finger flexors are activated, they will also tend to flex the wrist. In order to prevent this from occurring, the wrist/finger extensor muscles would need to be activated.

¹⁰⁶ As discussed in the TA Summary of this subcategory, Golandsky compares “pushing off” when playing to walking. According to the scientific literature, there is thought to be a form of “push off” involved in walking (Zelik and Adamczyk, 2016). In this case, Golandsky’s statement more likely refers to the feeling of “pushing off” excessively, which would lead to increased feelings of effort beyond the amount typically experienced when walking.

example, Golandsky discusses incorrect chord playing in the following way: “when the fingers alone try to do it, we end up playing very fast to overcome surface resistance and very hard into the keys. And it feels very hard to keep them down, and there is a great deal of grabbing and gripping that goes with it” (Taubman Institute, 1995, vol. 4). In this context, the fingertip force is likely near the minimum amount to keep the keys down (upweight, 20g); however, this fingertip force is achieved in such a way that the muscles crossing the finger joints are contracting to an extent that it feels effortful. The terms “grabbing” and “gripping” used here do not seem to indicate high fingertip forces, but rather using a high degree of muscle contraction to achieve the necessary fingertip force. The choice of terminology suggests that this muscle contraction will likely occur in the finger flexors, which are associated with motions to “grab” or “grip” objects away from the piano. This may also lead to co-contraction of the finger/wrist extensors to prevent any movement at the wrist (see analysis on “Curling,” subcategory 4.1.4). In contrast to “grabbing” and “gripping,” the Taubman Approach sources seem to suggest that “standing” on the keybed involves using the minimal muscle contraction to achieve the fingertip force necessary to keep the key depressed. Terms like “easy resting,” “solid,” “lightly balanced,” all indicate that keeping the key down properly is associated with feelings of very little effort. This implies that a relatively low degree of muscle contraction is used when playing in this way, particularly across the finger joints. Milanovic’s description of the correct feeling of contacting the keybed as an “anti-climax,” or “like nothing” (2012, pp. 107, 141) gives further evidence to this interpretation. These feelings of effortlessness are likely associated with low muscle contraction, particularly across the finger joints. This may be achieved in part by “balancing” the finger(s) in a similar way to “resting down” before playing. As discussed above, the “correct balance” is accomplished by certain joint geometry and distribution of muscle forces across all of

the upper limb joints (see subcategory 5.1.1 above). When keeping the key depressed, the Taubman Approach sources suggest that it is also produced by using the hand and arm to “support” the finger (Taubman Institute, 1995, vol. 4). This idea will be discussed in more detail below (subcategory 5.5.1).

Feeling “centered:” Golandsky also states that the fingers should feel “centered” when keeping the key down. This likely indicates that the vertical forces acting on the finger bones are close to parallel and in line with one another. The direction of the forces will likely be constantly changing in small amounts while moving to play the next key. Therefore, the term “feeling centered” may describe the feeling of generally having the forces close to parallel and in-line, although they will likely not be exactly so very often. This would tend to minimize the sideways component of the forces acting on each bone, which are known as **shear** forces (Knudson, 2007, p. 69). How this may be achieved and why this may be beneficial will be discussed in more detail below (subcategory 5.5.3).

Playing on the fingertip vs. the “pad:” One additional aspect of “balancing” on the keyboard that is discussed in this subcategory is that the finger should typically contact the key near the fingertip. This could be recommended because it can help the pianist find the position with greater finger flexion angle at the MCP joints necessary to “balancing” the finger. That being said, Golandsky suggests that pianists sometimes need to play more on the “pad,” or the “flesh” of the finger when playing black keys (Taubman Institute, 1995, vol. 2). In this context, these terms seem to refer to the part of the finger that is more on the palmar side of the distal phalanx. Golandsky states that playing slightly more on that part of the finger, as opposed to the fingertip, is sometimes necessary because the black keys are more narrow than the white keys (Taubman Institute, 1995, vol. 2). Because there is less surface area on the black keys, it is easier to play the

black keys more accurately by using a part of the finger that has more surface area. Playing closer to the palmar side of the finger would provide a larger surface area with which to contact the key, which can explain Golandsky's statement that doing so may be helpful to prevent "falling off the keys" (Taubman Institute, 1995, vol. 2).

Hitting hard/fast into the keys: A number of excerpts in this subcategory seem to discourage using excessive fingertip force, velocity, or muscle contraction to depress the key. Generally, the subject of the movement/forces involved in depressing the key is considered to be out of the scope of this analysis. However, "hitting hard/fast" into keys will be discussed only regarding the manner in which it directly impacts the fingertip force when the key is fully depressed and stops moving. Golandsky states that "when we hit the key very, very fast, the key hits us back with equal force. Every action has a reaction equal and opposite to itself (Taubman Institute, 1995, vol. 1). This seems to indicate that moving the finger into the key at high velocity will generate a high force back into the finger. As discussed above, the contact force from the key itself will likely not be high until the key stops moving (see subcategory 5.1.5 above). However, the Taubman Approach sources seem to make a connection between the amount of velocity/force applied to the key and the contact force when the key stops moving. This may be because the key dip is so small (approximately $\frac{3}{8}$ in.) that if the pianist tries to depress the key with very high finger velocity, there will not be time for the finger to slow down before the key is fully depressed, and the contact force will be relatively high. As a result, the Taubman Approach sources strongly discourage hitting hard/fast into the keys.¹⁰⁷ Milanovic (2012) describes the feeling of the relatively high contact force as "stimulating to tactile nerves" (p. 141); however, the Taubman Approach sources state that this can be harmful for both technical and physical

¹⁰⁷ The Taubman Approach sources discourage hitting the keys hard/fast for reasons other than the resulting contact force. However, these issues are outside the scope of this study, which focuses on "Keybedding."

reasons (see categories 6.1-2 below). In contrast, the lack of any particular feeling that is associated with playing correctly likely requires a very low impact force at the fingertip when the key stops moving downward (see below). Taubman's description of the correct feeling of the keybed as "like butter" (Milanovic, 2012, p. 111) suggests that re-imagining the hard surface of the keybed as a softer one (butter) could help the pianist produce this result.

Extraneous movement and "relaxation:" In addition to the terms above related to the force applied to the key, several terms in the Taubman Approach sources seem to suggest that "standing" on the key also includes a lack of unnecessary movement once the key is down. Terms like "settled," "rested," "finished," etc. all indicate that once the key is fully depressed the pianist should not attempt to continue moving in any way that is related to the playing of that key. As discussed above, moving after the key is depressed has no impact on the sound produced by playing that key (see subcategory 5.1.3). Therefore, any movement that occurs after the key is depressed should be in service of playing the next key. Any "expressive" gestures that pianists often make when trying to get a "singing tone" or to "embody" the sound of a long note should be minimized. Taubman discourages one student from doing this in a masterclass excerpt: "Don't come down...see, you think you're making it intense and feeling, and you know, when you come down, after sound has been produced, then she's dropping down to get a beautiful sound when nothing is happening. That is such a waste" (Taubman Institute, 1995, vol. 1). By the time the key is fully depressed, the hammer has already hit the string, and so any movement to try to make it "intense and feeling" or "get a beautiful sound" will not have any impact on the sound produced ("nothing is happening"). For that reason, Taubman considers that kind of movement to be "a waste." Based on this interpretation of her comments, it can be inferred that any movement after the key(s) are depressed should be in service of playing the next key(s).

According to the Taubman Approach sources, another way in which extraneous movement can occur is when the pianist “relaxes” after the key is depressed. As discussed above, one reason that the Taubman Approach sources describe “relaxation” as problematic is that it can disrupt the distribution of muscle contractions across the joints of the upper limb (see subcategory 5.2.2). If one or more joints do not have enough muscle contraction, then compensation will be required elsewhere. This can also lead to a feeling of “falling” that disrupts the “correct balance at the keyboard” (subcategories 5.2.1-2.3). Both the feeling of “falling” and compensation can still be considered potentially problematic when keeping the key depressed. In addition to these problems, the Taubman Approach excerpts related to “relaxation” after the key is depressed indicate that another issue may be relevant in this subcategory. Golandsky defines “relaxation” after depressing the key in the following way:

“A relaxation is going beyond the resting, the lack of tension point. Relaxation is an activity. Relaxation is when I got there [plays chord], I continue dropping, and all the fulcrums begin to fall. Now what happens when we relax, and I have to say something about it because it’s used much as a tool, that when we relax, we relax both muscles. As I told you when you move freely, one muscle is active and the other is passive. When you relax, you relax both” (Taubman Institute, 1995, vol. 1).

According to Golandsky, this type of “relaxation” is problematic because it inhibits movement and can lead to tension:

“If I had to start moving, it would take a tremendous amount of effort to get the muscles to act again, to create movement. And this is why when people are very relaxed, they have a tremendous amount of tension as well...so tension can come from tension, from overusing the muscle, and it can come from tremendous relaxation, where it takes a

tremendous effort...to move again. It takes too much effort, and it ends up as a tension” (Taubman Institute, 1995, vol. 1).

As discussed above, the force of gravity acting on the joints/segments of the upper limb tends to pull them down towards the ground. While the fingertips are supported by the keys, some muscle forces will be needed across the other joints in order to support the remaining upper limb weight. In order to balance out the force of gravity, muscle contraction is mainly needed on only one side of each upper limb joint (see subcategory 5.2.1).¹⁰⁸ Golandsky’s states that “when you move freely, one muscle is active and the other is passive.” This likely indicates that contracting muscles on one side of a joint is recommended as a way to stabilize that joint without creating high levels of stiffness. As discussed above this is possible if the muscles contracting collectively balance out the force of gravity, which is pulling downward (see subcategory 5.1.1). Golandsky contrasts “moving freely” in this way with relaxation: “When you relax, you relax both [muscles]” (Taubman Institute, 1995, vol. 1). This suggests that relaxing muscles crossing both sides of a joint will be problematic because the joint will have very low stiffness, if any. In addition to the problems identified above (feeling of falling and compensation of muscle contraction across other joints), Golandsky points out another potential consequence of “relaxation” as “all the fulcrums begin to fall.”¹⁰⁹ If joints in the upper limb do not have enough stiffness, then the combination of the force of gravity will cause the segment(s) between those joints to fall towards the ground. Once the key is fully depressed, then the segments will continue

¹⁰⁸ The shoulder is an exception because of its “ball and socket” structure.

¹⁰⁹ Here, the term “fulcrum” is being used synonymously with “joint” (Taubman Institute, 1995, vol. 1). This is consistent with the use of the term “fulcrum” in the biomechanical literature (McLester & St. Pierre, 2007, p. 224). Further research will be needed to examine the term “fulcrum” as it is used in the Taubman Approach in other contexts.

falling until either they are acted on by some other force.¹¹⁰ Because of the general position of the limb used in piano playing, this change in joint geometry will occur in at least one of the following ways: finger extension,¹¹¹ wrist extension, elbow extension, and/or shoulder depression. The Taubman Approach sources often refer to these forms of changing joint geometry due to low stiffness as a “collapsed” joint or segment (e.g. Taubman Institute, 1995, vol. 4; Milanovic, 2012, p. 205).

Golandsky states that the problem with “relaxation” (“collapse”) in this way is that “it would take a tremendous amount of effort to get the muscles to act again, to create movement” (Taubman Institute, 1995, vol. 1). Increased effort is typically associated with an increase in muscle contraction. One or more “collapsed” segments may lead to increased muscle contraction when playing for several possible reasons: 1) it may bring the muscles crossing that joint outside their optimal length, which makes them less effective at generating the force needed for movement; 2) it may take the joints out of their “balanced position,” and so more muscle contraction will likely be required to maintain the “collapsed” position; 3) trying to move while maintaining very low stiffness across the “relaxed” joint will require compensation of muscles crossing other joints; 4) if the pianist needs to move the “collapsed” segment(s) to play the next key, it will likely increase the amount of work needed to execute that movement. In mechanics, **work** is the product of force and displacement (Knudson, 2007, p. 155). Work is expressed with the equation $W = FD$. If the limb is “collapsed” in some way, the pianist will have to do the work involved in lifting it up and then across the keyboard in order to play the next key. Because this

¹¹⁰e.g. if stiffness is increased, the joint reaches the end of its range of motion, another muscle is activated, etc.

¹¹¹ More specifically, this extension would typically occur at the MCP and/or DIP joints. As a result of either MCP and/or DIP extension, the PIP joints would likely flex to some degree.

will increase the distance moved (displacement) when playing, the work involved will increase. This work will take more time and more muscle contraction to execute.¹¹² According to the Taubman Approach sources, pianists often “relax” after depressing the key(s) to reduce muscle contraction. While this may be true for a short period of time or for a particular set of muscles, playing in this way will likely lead to an increase of muscle contraction throughout the upper limb. This can help explain Golandsky’s statement that “relaxation” often “ends up as a tension.” In this case, the term “tension” seems to refer to overworking one or more muscles (see subcategory 5.6.1.1 below and “Curling” subcategory 4.3.2 for a discussion of the term “tension” as used in the Taubman Approach sources. Also see Wheatley-Brown, 2011).

Golandsky’s statement that “relaxation is an activity” (Taubman Institute, 1995, vol. 1) likely refers to the fact that allowing a joint/segment to “collapse” in this way will create extra movement after depressing the key(s).¹¹³ This contrasts statements that the pianist should feel “settled,” “rested,” “solid,” etc. on the key bottom. As mentioned above, these terms seem to suggest that the pianist should not use extraneous movements after depressing the key. The way these statements are contrasted with “relaxation” indicates that they also are meant to instruct the pianist to play with enough joint stiffness to stabilize the joints against both the forces of gravity and the contact force from the keyboard. If this is mainly done by contracting muscles on only one side of the joint (“free”), the amount of joint stiffness will still be relatively low. However, that small amount of muscle contraction will help prevent extraneous motion that could be problematic for the reasons listed above.

¹¹² This increase in work would be relative to maintaining a joint position that is not collapsed, in which the pianist would not have to move as far to reach the next key.

¹¹³ It may also refer to the fact that pianists often “relax” in this way intentionally. In this case, calling “relaxation” “an activity would refer to a mental”activity,” rather than a physical one.

Metaphor of “standing:” Golandsky compares the feeling of “resting down on the key bottom” to standing: “When you stand, you don’t press, you don’t push, you don’t feel up. You feel that you’re resting down. Same thing [in piano playing]” (Taubman Institute, 1995, vol 1). The metaphor of standing reiterates several ideas about the difference between “resting down on the key bottom” and “pushing” that have been discussed in the analysis above. First, it suggests that minimal effort should be required to stabilize the joints (not “relaxed”) Second, there should be no feeling of continuing to apply force down into the key once it is fully depressed (not “pushing”). An interesting difference between piano playing and standing is that standing on the ground has no equivalent of the key. This suggests that the force needed to oppose the upweight and keep key down should feel negligible. This will be possible because the upweight is typically quite low (20g); however, the feelings of effort needed to resist this force will vary depending on the position and distribution of force in the upper limb (see subcategories 5.2.1-2.3 above). Therefore, these factors can be considered significant in finding the recommended state of “resting down on the key bottom,” in a similar fashion to “resting down” on the keys before playing. Additionally the metaphor of standing affirms the idea that the key should be fully depressed, as if it were not there at all (not “hovering”).¹¹⁴ This understanding of the metaphor of standing used in the Taubman Approach sources to describe the recommended sensation when the key is depressed explains the potential usefulness of this metaphor in a pedagogical context. It seems to offer the pianist a subjective description that encapsulates both the recommended feeling and the potential problems that may occur (“pushing,” “hovering,” and “relaxation”). Because the idea of standing is a common experience, this metaphor is likely to be meaningful

¹¹⁴ Similarly, Golandsky’s statement that playing should feel like “walking on key bottoms” suggests that the pianist should have a feeling of putting the fingers down on a solid surface, like putting the feet on the floor. This implies that force needed to put the keys down should be subjectively negligible.

for a wide variety of students in a pedagogical context. That being said, a separate analysis of this terminology was necessary to give a more detailed biomechanical description of what may be involved in the recommended way of playing as well as each type of potential problem.

5.3.5 Conclusion: When playing

The categories above were developed in order to analyze the terms related to the feelings/movements relevant to depressing the keys and keeping them depressed. A total of 259 units of coding were used in this category. After a second coding, 251 units of coding were in agreement between the two coding sessions, making for a 96.91% agreement. The following table has been provided to display each subcategory with a brief summary of its biomechanical analysis:

Table 5.4 *When playing*

Subcategory	Biomechanical Analysis	Taubman Sources	Units of Coding
Fingers should stand/walk on the keys/keybed	When the key is depressed, the fingertip force should be fairly low. The forces acting on the finger bones should be parallel and in-line. This is possible because the upweight of a key is typically only about 20-22g. The key should be fully depressed, and so the fingertip force should be high enough that any small adjustments when playing will still maintain a net force downward. The feeling of depressing the key should be similar to that of placing the fingers on the key before playing. Therefore, the fingertip force will likely be below 50g but still somewhat above 20g. This amount of force should be maintained using relatively low muscle contraction across the upper limb joints. The fingers should typically contact the keys close to the fingertip. When playing the black keys, the fingers may contact the keys closer to their palmar side.	Taubman 1984; Taubman Institute, 1995, vols. 1, 2, 3, 4, 5; Milanovic, 2012	105
Do not push on the keys/keybed	The fingertip force should not be significantly higher than 50g once the key is depressed. Because the keybed is a hard surface, doing so will increase the contact force. The muscle contraction used to create that fingertip force should not be high. Also, the fingertip velocity should not be excessively high, which will likely lead to a high contact force once the key is fully depressed.	Taubman 1984; Taubman Institute, 1995, vols. 1, 2, 3, 4, 5; Milanovic, 2012	66
Do not hover when playing	If the fingertip force is too low, the key will start coming up. Also, compensation may be required across other joints to support the upper limb weight that is no longer supported by the keyboard.	Taubman Institute, 1995, vols. 1, 2, 4, 5; Milanovic, 2012	31

Do not relax when playing	The joints should have enough stiffness to stabilize them against the contact force and weight of the upper limb. Without sufficient stiffness, one or more segments will fall towards the ground due to the force of gravity. This may lead to compensation, increased muscle contraction, and/or increase the amount of time, movement, and work needed to play. Generally, the pianist should not move after depressing the key in any way that does not contribute to playing the next key. Any other movements will not impact the sound and will increase the amount of effort when playing.	Taubman 1984; Taubman Institute, 1995, vols. 1, 2, 3, 4, 5; Milanovic, 2012	47
Miscellaneous - when playing	Considered irrelevant for this analysis		10

5.4 Aiming:

The Taubman Approach sources state that the concept of “aiming” is essential to controlling the amount of force generated between the finger and the key and/or keybed. The following categories were developed to summarize Taubman’s ideas about aiming during key depression. 1) Aim to the point of sound; 2) Don’t aim past point of sound; 3) Follow through/don’t stop at the point of sound. Finally, a miscellaneous subcategory was developed to include any statements related to aiming that did not fit in the other three categories.

5.4.1 Aim to the point of sound

TA Summary:

The Taubman Approach sources state that the pianist should aim for the point of sound, which is about $\frac{1}{8}$ inch below the surface of the key (Taubman Institute, 1995, vol. 1). Golandsky states that the pianist should aim their power and energy to that point when playing (Taubman Institute, 1995, vol. 1). According to Milanovic (2012), proper aiming to the point of sound must be learned in order to control the speed of the key and produce the desired tone (p. 111). It also allows the finger to rest on the keybed without pushing, and therefore allows the pianist to avoid “Keybedding” (Taubman Institute, 1995, vol. 1; Milanovic, 2012, p. 141).

5.4.2 Don't aim past point of sound

TA Summary:

According to the Taubman Approach sources, one incorrect way of aiming incorrectly is to aim past the point of sound to the bottom of the key. Multiple sources describe aiming past the point of sound as a potential cause of “Keybedding” (Taubman Institute, 1995, vol. 1, 5; Milanovic, 2012, p. 141).

5.4.3 Follow through/don't stop at the point of sound

TA Summary:

Golandsky states that while the pianist should aim for the point of sound when playing, the finger does not stop moving when it reaches that point (Taubman Institute, 1995, vol. 1). Instead, the finger still continues moving down towards the keybed as part of a follow through (Taubman Institute, 1995, vol. 1). She compares this to hitting a ball, in that “You aim your greatest force at it, and then there's a follow through” (Taubman Institute, 1995, vol. 1). She discourages stopping at the point of sound because it will cause hovering (Taubman Institute, 1995, vol. 1).

5.4.4 Aiming - Miscellaneous

TA Summary:

The miscellaneous subcategory for excerpts related to aiming includes several excerpts. Golandsky generally compares the idea of aiming to that involved in tennis or golf (Taubman Institute, 1995, vol. 1). She states that while it is problematic to aim past the point of sound, it is also problematic to aim before the point of sound (Taubman Institute, 1995, vol. 1). Doing so can lead to preparing or tensing in the air in anticipation of playing the key. Additionally, Milanovic (2012) says that when the pianist has to wait to

play the next key, they should move to it and then wait to control the key descent (p. 174). Taubman states that when moving to the next note, “you cannot miss a note if you’re on it” (Taubman Institute, 1995, vol. 1) Therefore, the pianist should make contact with the key before trying to depress it.

Analysis: Aiming

The issue of aiming may be more significantly related to motor control than biomechanics, and so it is largely outside the scope of this study. However, it was included in this analysis because the Taubman Approach sources make a direct connection between aiming and the amount of fingertip force/velocity used to depress the keys and keep them depressed. The statements in these categories seem to suggest that if the pianist tries to focus on the point of sound when playing, they will generate less fingertip force than if they focus on the keybed. In addition to the aspects of this idea that are related to motor control, one possible mechanical explanation for Taubman’s statements about aiming has to do with the fact that the key moves downward, whereas the finger will not be able to generate a large enough force to move the keybed at all. Because the downweight of a key (50g) is relatively small compared to the total weight of the upper limb, the key will likely move away from the fingertip with enough velocity that there will not be enough time to generate a very high force between them. As a result, if the pianist focuses on aiming their finger at the point of sound (near the middle of the key dip), they may be less likely to generate a large force when coming in contact with the key and eventually the keybed. On the other hand, because the keybed will not move, then the pianist will be able to generate a much higher fingertip force when the key is fully depressed. Therefore, focusing on aiming their finger at the key bottom may cause the pianist to generate a higher fingertip force

than if they focus on the point of sound. The idea of excessive fingertip force (“pushing” as described above in subcategory 5.3.2) will be discussed in more detail below.

“Don’t stop at the point of sound:” Golandsky states that the pianist must not “stop at the point of sound” because it will cause “hovering.” This is related to the fact that the letoff (“point of sound”) is not at the bottom of the key dip. Therefore, even though the pianist should attempt to “aim”¹¹⁵ for the letoff point (“point of sound”) as Golandsky suggests, they should still fully depress the keys when playing. If they stop depressing the key before it hits the keybed, this will cause what the Taubman Approach sources describe as “hovering,” which will be discussed in further detail below (subcategory 5.3.3).

5.4.5 Conclusion: Aiming

The categories in this section suggest that the Taubman Approach sources make a connection between aiming and fingertip force regulation when playing. A total of 26 units of coding were used in this category. After a second coding, 25 units of coding were in agreement between the two coding sessions, making for a 96.15% agreement. Because the content of the excerpts in this section were mainly related to motor control, rather than biomechanics, no table will be provided. However, it may be necessary for further research to explore the implications of this subject in more detail in order to understand the subject of “Keybedding” more fully. The next set of categories will focus on the subject of “hand/arm support” and how it may relate to the amount of fingertip force and muscle contraction used when playing.

¹¹⁵ The term “aim” has deliberately been left without an analysis because it is a term from the field of motor control, which is outside the scope of this study.

5.5 Arm/Hand Support

Introduction:

The analysis of the terms “standing” (recommended) and “pushing” (discouraged) found that one distinction between these terms has to do with the amount of muscle contraction used to generate the fingertip force necessary to keep the key depressed. One aspect of “standing” is that as little muscle contraction as necessary should be used to keep the key fully depressed and stabilize the joints. The categories in this section, which are related to the idea of hand and arm support and how that may impact the amount of finger muscle contraction needed when playing. Several factors will be discussed related to joint position and/or muscle force that are related to this issue. Within the larger context of the Taubman Approach, the issue of “hand and arm support” is very complex. As a result, the categories here included excerpts related to both moving to put the key down and keeping the key down. This was done because terminology used to describe the “correct” and “incorrect” ways of playing often overlaps between these two conditions. In some excerpts, it was not entirely clear if the statement referred to either or both conditions. The biomechanics of moving to depress the keys is a far more complex mechanical problem. Similarly the pedagogical materials that cover this subject in the Taubman Approach sources are more detailed. As a result, a detailed investigation of “hand/arm support” when depressing the keys will require its own separate analysis. In order to limit the scope of the current study, the biomechanical analysis below will only refer to the condition of keeping the key down. Four categories were created to discuss the issue of hand/arm support when playing:

- 1) The hand/arm should support the fingers when playing;
- 2) The fingers should not isolate/play by themselves;
- 3) Playing fingers should be straight down/not tilted;
- 4) Non-playing fingers should hover above/rest lightly on the keys.

A miscellaneous subcategory was then included to

include statements related to the idea of “support” that did not fit into the other categories. Because the biomechanics of these categories are somewhat interrelated, their analyses will be included after they have all been summarized.

5.5.1 The hand/arm should support the finger(s) when playing

TA Summary:

While the finger depresses the key when playing, the Taubman Approach sources state that it must always do so with the support of the hand and forearm in order to avoid finger isolation. This is achieved through a combination of hand and forearm motions that are often described as very small, or even “invisible” (Taubman Institute, 1995, vol. 1). Although they are sometimes exaggerated in training, Golandsky (reading from Taubman’s unpublished writings) generally describes these motions in the following way: “Since the fingers and arms are attached to each other, if the arm is free and unrestrained it naturally reacts with corresponding motions to the direction of the motion of the fingers. It is usually tiny enough to just be an imperceptible shimmer” (Taubman Institute, 1995, vol. 1). The hand and arm motions considered relevant to this analysis were found to be forearm rotation (Taubman Institute, 1995, vol. 2), the Walking Hand and Arm (Taubman Institute, 1995, vol. 4), and the In and Out arm motions (Taubman Institute, 1995, vol. 3).¹¹⁶ A full investigation of these motions is outside the scope of the current study, and so further research will be required to analyze their role in supporting the fingers when depressing the key. Generally, Golandsky states that all of these motions

¹¹⁶ Forearm rotation, the Walking Hand and Arm are the subject of the second, third, and fourth DVD’s, respectively (Taubman Institute, 1995, vol. 1, 2, 3). Taubman considers these movement to be essential elements for a “coordinate technique,” all of which combine allows the hand and forearm to “support” the fingers in key depression (see Taubman Institute, 1995, vol. 1, 2, 3, 4; Milanovic, 2012; see Moran, 2008 for some discussion of forearm rotation). These topics are quite complex, and so a full discussion of them is outside of the scope of this study.

occur in between the playing of each note. Along with other arm motions, they must be combined together (Taubman Institute, 1995, vol. 4). The correct combination and proportion of arm motions brings the finger to where it is going to play and helps the finger put the key down (Taubman Institute, 1995, vol. 4). The result is that the finger(s) can use as little effort as possible, and the pianist can have control over both horizontal and vertical speeds (tempo and dynamics, respectively) (Taubman Institute, 1995, vol. 1-4).

Just as that the hand/arm must support the finger when moving down to depress the key, the Taubman Approach sources state that they must also do so once the key has been depressed. Taubman (1984, p. 147) and Milanovic (2012, p. 112) state that the arm should be balanced behind the playing finger(s). When the arm supports the playing finger, it allows the fingers to feel strong, and eliminates the need for pressing or pushing to keep the keys down (Taubman, 1984, p. 147; Taubman Institute, 1995, vol. 4; Moran, 2008, pp. 27, 29). When moving from key to key, Golandsky (Taubman Institute, 1995, vol. 4) states that enough hand and forearm weight must remain on the playing finger to keep it feeling solid. This support on the bottom of the key occurs even during soft playing, when many pianists have a tendency to hover (Taubman Institute, 1995, vol. 4). Several excerpts in this subcategory are related to chord or interval playing. As described above, Golandsky (Taubman Institute, 1995, vol. 4) states that when playing chords, the fingers should be “like stilts” supporting the arm weight. This allows them to flex only minimally, with the arm weight holding the keys down when they are depressed.

5.5.2 The fingers should not isolate/play without support

TA Summary:

In contrast to playing with hand/arm support, the Taubman Approach sources strongly discourage playing in such a way that the finger(s) put the key(s) down by themselves. Taubman (1984) states that “In a coordinated technique finger movements are never isolated from the hand and arm” (p. 146). According to Milanovic (2012), “A finger is isolated when moving without the support of the hand and forearm” (p. 134). The term “isolation” is used in a number of contexts in the Taubman Approach sources, and so the excerpts in this subcategory were only coded to include statements related to isolation as it relates to finger activity to depress the keys or keep them down. In addition to being “isolated,” and “not supported,” Golandsky states that the fingers should not “try to move by themselves” (Taubman Institute, 1995, vol. 1, 4). Some excerpts in this subcategory also advise against “activat[ing] the muscles,” (Taubman Institute, 1995, vol. 2) and moving the “fingers alone” (Taubman Institute, 1995, vol. 2, 4).

One commonly mentioned cause of finger isolation when depressing the keys is playing with “active fingers,” and keeping the arm “quiet” or “rigid” (Taubman Institute, 1995, vol. 1, 2, 4). When playing in this way, the pianist holds their hand/arm up, while they play down with their finger(s) (Taubman Institute, 1995, vol. 4). As a result, there will not be the necessary “resilience” in the hand and forearm, and the forearm rotation and the vertical Walking Hand and Arm will not be able to function properly (from subcategory 5.5.1; Taubman Institute, 1995, vol. 4). Golandsky states that if the pianist plays with a rigid arm, the fingers will have to move up, sideways, and down by themselves, without the proper support of the arm/hand (Taubman Institute, 1995, vol. 2).

One other example of finger isolation in key depression is what Golandsky calls “playing up,” in which the finger plays down but the arm/hand moves upward (Taubman Institute, 1995, vol. 5). As a consequence of the lack of arm/hand support, she mentions two types of finger movements that may occur. She says that the pianist will often use either the “thrusting” motion (see “Curling,” categories 4.2.1-2), or they will flex their fingers in an isolated way to put the key down (Taubman Institute, 1995, vol. 1). She states that because the fingers are light compared to the arm, and they are moved by relatively small muscles, they will need to move very fast and “push fast and hard into the key to overcome the surface resistance” (Taubman Institute, 1995, vol. 2). These motions will be spasmodic and jerky, and the fingers will feel weak (Taubman, 1984, p. 148). As a result, a number of problems that were identified in subcategory 5.3.2 (“don’t push”) are described as consequences of isolating the fingers: “pushing down,” (Taubman Institute, 1995, vol. 4) “pushing fast/hard into the key,” (Taubman Institute, 1995, vol. 2, 5) “pulling,” (Taubman Institute, 1995, vol. 1) “grabbing to keep the key down,” (Taubman Institute, 1995, vol. 2, 4) “hitting down very hard,” (Taubman Institute, 1995, vol. 2) and “squeezing” (Taubman Institute, 1995, vol. 2). Additionally, if the thumb is playing in an isolated way and with no hand/arm support, it will be moved only by its abductor muscle to play the key (Taubman Institute, 1995, vol. 1). This will result in what Golandsky calls the “snapping thumb,” which causes the other fingers to shoot upward when the thumb hits the keybed (Taubman Institute, 1995, vol. 1).

5.5.3 Finger should be straight down/not tilted

TA Summary:

The Taubman Approach sources state that the fingers should not be tilted when depressing the key(s) in most situations. If the fingers are tilted, the arm weight cannot properly support the fingers, which Golandsky states can cause the fingers to feel weak (Taubman Institute, 1995, vol. 1). She states that when playing more than one note, tilting the fingers can cause the arm weight to be balanced unevenly (Taubman Institute, 1995, vol. 1, 2). While pianists sometimes tilt in order to help with chord voicing, Golandsky claims that this can be problematic, and so voicing should instead be achieved by freeing more arm weight behind the finger that you want to play louder (Taubman Institute, 1995, vol. 2). Instead of tilting, the Taubman Approach sources suggest that the fingers should typically be straight down when depressing the keys (Taubman Institute, 1995, vol. 1, 2, 4). When the finger is straight down, the palm of the hand should be facing the floor, with the forearm parallel to the floor. According to Milanovic (2012), one Taubman teacher described this position as “flat to the floor” (p. 203). This position allows the pianist to feel solid, centered, and supported on each finger (2012, p. 203). Golandsky states that this position is particularly important for the 4th finger, which is often tilted, and can feel weak as a result (Taubman Institute, 1995, vol. 1).

While tilting is typically discouraged, the Taubman Approach sources mention three particular contexts in which some degree of tilting is recommended:

1. **When playing the 5th finger:** Moran (2008) states that students should play the 5th finger a little bit on the side of the fingertip (p. 50). She contrasts this with the

way that fingers 2, 3, and 4 should play straight down, stating that slightly tilting on the 5th finger allows it to feel equally strong.

2. **When playing chords that require a very large hand span:** Milanovic (2012) states that when playing these types of chords, the pianist should use the “scissor position,” in which the fingers are tilted in order to allow them to reach a further distance (pp. 170-1). However, this position is only recommended when necessary, and Milanovic (2012) states that pianists can have a tendency to overuse it (p. 171).
3. **“Single rotations”** (Taubman Institute, 1995, vol. 2, 4, 5; Moran, 2008, p. 55): In these cases, the pianist will tilt the finger that just played in order to facilitate a motion back in the other direction to play the next note (for example in a trill) (Taubman Institute, 1995, vol. 2).

5.5.4 Non-playing fingers should hover closely above/rest lightly on the keys

TA Summary:

In addition to the position of the playing finger, the position of the non-playing fingers can also impact hand/arm support when playing. Golandsky (Taubman Institute, 1995, vol. 2) and Milanovic (2012, p. 155) state that the non-playing fingers should not rest heavily on keys because doing so causes the arm weight to rest on those fingers. As a result, the weight becomes distributed over all of the fingers instead of just the playing finger (Taubman Institute, 1995, vol. 2), which can slow down playing speed (Milanovic, 2012, p. 155). Instead of resting heavily, the non-playing fingers should either barely touch the keys or hover close to them. According to Milanovic (2012), Golandsky

describes the correct state of the non-playing fingers as feeling “down in the air” (p. 155). In this position, the fingers do not lift very high or pull away from the hand (Taubman Institute, 1995, vol. 1), but are also not “completely inert” (Milanovic, 2012, p. 111). This allows for the arm to be balanced behind the playing finger (Taubman, 1984, p. 147). In contrast, Milanovic (2012) says that when playing the thumb, pulling fingers 2-5 away from the thumb can cause the thumb to “crumble” (p. 206). Furthermore, if the non-playing fingers hover just above the keys, they can drop only a very small distance into the key when they need to play, which increases efficiency “as they only have to drop into the next note, as opposed to lifting then dropping into the key” (Milanovic, 2012, p. 111). It also helps those fingers bring the weight of the hand and forearm behind them when they play the next key(s) (Taubman Institute, 1995, vol. 1).

Analysis:

“Hand/arm support” and feeling “strong”/“solid:” Taubman states that “The arm will...accommodate the downward motion by balancing on the playing finger. It has nowhere else to go because it is no longer resting down on the unused fingers. The playing finger now has the full support of the arm. When the arm balances equally on each finger, all fingers will feel strong, free, and controlled” (1984, p. 146-7) Golandsky also states the fingers should be “supported” when the keys are depressed, which makes the fingers feel “solid” and eliminates the need for “pushing” or “pressing” (also in Moran, 2008, pp. 27, 29). As mentioned above, the force needed to keep the key down once it is depressed (upweight, about 20g) is less than the force needed to depress it in first place (the downweight, which is about 50g) (see subcategory 5.1.4). When the finger is keeping the key depressed, the upper limb weight is being supported by forces from a combination of sources: muscle forces across the joints, passive forces from

connective tissues, and the contact force from the keyboard (see subcategory 5.1.5). The contact force creates an equal/opposite force from the fingertip down into the key, which needs to be greater than the upweight to keep it depressed. The upward contact force from keys would tend to push upward on each of the finger bones. However, if the upper limb is in the “balanced” position described above (subcategories 5.2.1 and 5.2.3) the hand will be above the finger bones, and so it will push down on the finger bones to some extent, which will help resist their tendency to extend. In doing so, less muscle contraction of the finger flexors will be needed to stabilize the finger joints. Additionally, the force of the hand pushing down on the finger bones will contribute to the fingertip force used to keep the key depressed. As a result, the hand and arm can be described as “supporting” the finger in both directions: they contribute both to the force that stabilizes the finger joints as well as the fingertip force. Because the upper limb is a kinetic chain, the position of the hand that is necessary for this to occur (above the finger bones) is dependent on the position of the forearm. In this way, the forearm can be considered to “support” the hand, which then “supports” the fingers.

Using “hand and forearm weight” to keep the key down: Golandsky states that when the finger is depressing the key, that finger “remains with enough hand and forearm weight to feel solidly on the bottom of the key, and is not released until it plays the next key.” As discussed above, one meaning of the phrase “feel solidly on the bottom of the key” is that the fingertip force is high enough compared to the upweight so that a small adjustment in force will not cause the key to come up. Furthermore the term “solid” suggests that this should be done using a low degree of muscle contraction, particularly across the finger joints. Golandsky’s statement indicates that this may be possible because the “hand and forearm weight” “remains” on the finger. The number of factors involved in generating fingertip force are quite complex, and so it

is very difficult to determine exactly how one of these factors (e.g. upper limb weight) individually contributes to the resulting fingertip force. However, Golandsky's statement indicates generally that the force of the hand/forearm pushing on the finger bones can be generated to some extent by the weight of those parts. This could occur by having a relatively low amount of contraction in the muscles that tend to support these segments in opposition to gravity (elbow flexors and wrist extensors). Doing so would create a net force downward that causes the hand to push down on the finger bones, which would then push down on the key. Because the weight of the forearm/hand is much larger than the upweight of the key, the muscles supporting these parts will not be completely relaxed (which is considered problematic for other reasons; see analysis of category 5.3). In fact, the amount of weight contributing to fingertip force will likely be a very low proportion of their total weight. However, using some amount of hand/forearm weight to contribute to fingertip force will allow the pianist to keep the key down using relatively low muscle contraction across the finger joints. Taubman's statement that the arm should "balance on the playing finger" suggests that the combination forces acting on the upper limb should not generate a net force in any direction other than straight down from the fingertip into the key. This will give the pianist the sensation that the finger is balanced, without any feeling of "falling" in a particular direction, which will likely be accompanied by increased muscle contraction to stabilize the upper limb joints. As with "balance" before playing, this type of "balance" is likely created by a combination of factors, including the joint position and distribution of muscle contractions across the upper limb (see subcategory 5.2.1 above).

Feeling "strong," without "pressing:" Taubman states that "When the arm balances equally on each finger, all fingers will feel strong, free, and controlled." Moran (2008) states that "Playing the finger with the support of the hand and forearm eliminates any need for pressing" (pp. 27,

29). In these excerpts, the term “pressing” is likely meant to describe high levels of muscle contraction, rather than high fingertip force. The terms “support” and “balance” used in these sources likely refer to the fact that the hand and forearm are positioned in such a way that allows them to contribute to fingertip force using non-muscular forces (e.g. weight). If this occurs, then the pianist will not need to use a high degree of muscle contraction across the finger joints in order to keep the key down (“pressing”). Doing so will likely decrease the subjective feeling of effort needed to keep the key down and make the finger feel “strong” (or “solid”). Furthermore, it will likely make it easier to control the movement and force output of the fingers when playing (“free” and “controlled”).¹¹⁷

Lack of support and pressing: Moran’s (2008) statement suggests that if the fingers do not have the support of the hand/arm, then the pianist will need to “press” in order to generate the necessary fingertip force to depress the key and prevent it from coming up (pp. 27, 29). If the muscles that tend to support the forearm and hand (elbow flexors/wrist extensors) are activated, then this will decrease the amount of net force from the weight of those parts pushing down on the finger bones/key. As a result, this will decrease the fingertip force. In order to generate the necessary fingertip force to keep the key down, the pianist may then need to increase the amount of muscle contraction across the finger joints. This is equivalent to the definition of the term “pressing” described above (subcategory 5.3.2). In this case, activating the muscles that support the forearm/hand would be a form of “hovering,” which as mentioned above, can lead to “pressing.” Because this “pressing” occurs due to improper “hand/arm support,” it can also be described as a form of “finger isolation” as described in the Taubman Approach sources.

¹¹⁷ Keeping the key down in this way may also be beneficial from a motor control point of view because it changes the task of keeping the key down from one that is about maintaining the position of the finger itself to one that is about maintaining contact between the finger and the keybed. Further research will be needed to investigate the implications of these statements in the Taubman Approach sources as they relate to motor control.

Hand/Arm support and chord playing: Golandsky (Taubman Institute, 1995, vol. 4) states that use of “arm weight” is very important in chord playing:

“It is essential that there be as much weight at the disposal of the fingers in key depression of chords as needed. The fingers themselves are light and cannot supply enough weight to play chords with ease, let alone with power, and we know that when the fingers alone try to do it...it feels very hard to keep them down, and there is a great deal of grabbing and gripping that goes with it...So the fingers really are like stilts supporting the weight of the arm, but they hardly have to, they flex very minimally, so there’s really no problem with flexing and extending at the same time...It’s crucial for chords and intervals, if the keys feel heavy, hard to put down, you’re doing it from the fingers. Sometimes you do a certain amount of arm, but perhaps not enough to make it easy to put them down, and to feel that all of them can come down equally. That you can get all the power that you want, and the fingers don’t have to grab to keep the keys down.”

As mentioned above, the total force applied by the pianist to the keys will need to be at least the combined upweight of all the keys being depressed (subcategory 5.1.4). For example, if the pianist is playing a three note chord, the total upweight will be approximately 60-68g. Based on discussion above, in order to feel “solid,” as recommended by the Taubman Approach sources, there should be enough fingertip force at each key that there is no chance of keys coming up. This amount will therefore likely be closer to 40-50g per key, which would make 120-150g total. While the amount of fingertip force is not very high for each finger, trying to generate that force using a great deal of finger muscle contraction may be problematic. When playing a chord, the fingers will be extended and abducted to some degree. This means that contracting the finger flexors to produce the necessary fingertip force will lead to co-contraction (see “Curling,”

categories 4.1.5-6). Furthermore, the finger muscles will be outside of their optimal length, which will make them less effective at generating force. Therefore, trying to keep the keys depressed by using a high degree of muscle contraction in the finger flexors will create the feelings of effort that Golandsky describes as “grabbing” and “gripping” (see subcategory 5.3.2).

In contrast, Golandsky suggests that chords can be played more easily by allowing the arm weight to be “at the disposal of the fingers” (Taubman Institute, 1995, vol. 4). The combined weight of all of the keys being depressed will not be very much compared to the total weight of the upper limb. Therefore, if the muscles that tend to support the forearm/hand have a relatively low amount of contraction, the net force of the hand pushing down on the fingers can generate enough force to keep all the keys depressed using very little effort. In this way the fingers will be “like stilts supporting the weight of the arm,” as Golandsky describes. However, it is important to note that the amount of arm/hand weight supported by the fingers will still be relatively low compared to their total weight. The net force produced by that amount of weight will be distributed across all of the fingers used to depress the keys. This will allow each of the fingers to feel “equal” in their ability to keep the keys depressed.¹¹⁸ The finger flexor activity can be limited only to the amount needed to stabilize the finger joints (“they flex very minimally”). However, Golandsky states that if the pianist is not playing properly, “Sometimes you do a certain amount of arm, but perhaps not enough to make it easy to put [the keys] down.” If the muscles that support the forearm/hand contract to a greater degree, it will reduce the amount of force generated by the weight of those parts that is pushing down on the fingers. If this occurs, the fingertip force will be reduced, and finger muscles will need to contract more to compensate.

¹¹⁸ The exact amount of force from the hand pushing on each playing finger will likely not be exactly equal, but the differences would be negligible enough that they all feel “equal,” as Golandsky describes.

Doing so would constitute a form of “finger isolation” because the fingertip force will have less “support” as described in the Taubman Approach sources.

“Straight down”/not “tilted:” Golandsky says that in order for the finger to be supported, the finger should be “straight down” and not “tilted” when it is on the key. Based on her demonstration (Taubman Institute, 1995, vol. 1), the term “straight down” seems to indicate that the finger(s) should contact the key(s) near the middle of the fingertip. When playing single notes, this means that the MCP joint will likely be directly behind the fingertip. In contrast, “tilted” seems to indicate that the finger contacts the key on either its ulnar or radial side. When playing single notes, this means that the MCP joint will be either to the left or the right of the point of contact between the fingertip and the key. In the Taubman Approach sources, the recommendation of being “straight down” seems to apply only to fingers 2, 3, and 4. Moran (2008) states that the 5th finger should be somewhat “tilted” (p. 29) (discussed below), and the thumb has a different angle of contacting the keyboard altogether.

“Straight down” and feeling “centered:” Golandsky also states that the finger should feel “centered” when depressing the keys. As mentioned above, this term suggests that the forces on each finger bone are generally kept close to in line and parallel,¹¹⁹ which could minimize any shear (sideways) forces acting on each bone (see subcategory 5.3.1). Because the finger bones all push on each other, this would require the finger to contact the key at a point close to the middle of the fingertip (“straight down”). This position would allow each finger bone to push on the joint cartilage of the adjacent bone. If the finger contacts the key on either the ulnar or radial side of the fingertip (“tilted”), the contact force from the keyboard would be directed into the fingertip at an angle, which could then lead to shear forces acting on each finger bone. Instead of

¹¹⁹ As mentioned above, the direction of forces acting on the finger bones would likely change to some degree while moving to play the next key.

the force on each bone pushing on the joint cartilage between them, this could create more force pushing on the ligaments that hold the bones together. One outcome of this could be an uncomfortable feeling when playing, and the ligaments may eventually become damaged. Additionally, shear forces on the finger bones could tend to move the finger sideways (ab/adduct it). In order to prevent sideways movement from occurring, the finger ab/adductor muscles may need to contract to resist the sideways component of the contact force and stabilize the finger joints.

“Flat to the floor:” According to Milanovic (2012), one Taubman teacher stated that the hand and the forearm should be “flat to the floor” (p. 199). Milanovic’s analysis of this term suggests that it means the hand and forearm should be parallel to the floor. Placing the hand and forearm in this position would also place the MCP joint of the finger (either 2, 3, or 4) behind the point of contact with the key, which would also allow the finger to contact the key near the middle of the fingertip (“straight down”). In addition to impacting the direction of forces on the finger bones (described above), it also impacts the position of the downward force generated by the hand/forearm pushing down on the finger bones (“support” described above). If the hand is parallel to the floor, then the force directed from the hand into the playing finger can be close to straight down in the direction of the key. If the hand and forearm are not parallel to the floor, then the force generated by the hand and forearm may push on the finger at an angle. This could tend to cause the forearm to rotate (pronate/supinate). The impact of this would be similar to what would occur when the finger is “tilted.” In order to stabilize the forearm in a position that is not parallel (“flat”) to the floor, some force may need to be generated in the pronator/supinator muscles to resist the force of gravity. Because the position of the upper limb is a kinetic chain, the positions of the joints are interdependent to one another. If the MCP joint is behind the point

of contact between the fingertip and the key being depressed (finger is “straight down”) then the hand/forearm will be parallel (“flat”) to the floor, and vice-versa. Similarly, if the MCP joint is to the right or the left of the point of contact between the fingertip and the key (finger is “tilted”), then the hand/forearm will not be parallel (“flat”) to the floor either. Playing with fingers “straight down” and hand “flat to the floor” may be recommended by the Taubman Approach sources because all of the forces acting on the fingers are close to in-line and parallel. This will have two possible benefits. First, it will likely minimize the amount of force acting on the ligaments of the finger bones. Second, it will potentially decrease the muscle forces needed to stabilize the joints and keep the key down. Low muscle force will add to the feeling of “solidity” described above. In contrast, being “tilted” is considered to be problematic because it would likely increase the amount of sideways forces along the keys, which will increase the forces on the finger ligaments. It may also require extra muscle force in the elbow/forearm, as well as across the fingers joints in order to maintain that position. This may also lead to an increase in muscle force across the finger joints to keep the key depressed (“pushing,” as described in subcategory 5.3.2), which would give the pianist the sensation that the finger is “weak,” as Golandsky describes.¹²⁰

Exceptions to being “straight down:” The Taubman Approach sources identify several exceptions to the idea that the fingers should typically be “straight down.” These exceptions will be discussed next.

5th finger played “on the side:” Moran (2008) states that “since finger 5 is on the side of the hand, it plays a little more on the right side of the tip than fingers 2, 3, and 4 do in order to feel equally strong” (p. 50). Doing so would make the 5th finger “tilted” as described above. One

¹²⁰ It is important to note that this position is only recommended when the key is depressed. The recommended movements/position when depressing the key(s) is considered outside the scope of this study.

reason why this might be necessary to make the 5th finger feel “equally strong” is related to the position of the center of gravity. As mentioned above (analysis of category 5.2), when the fingertips are placed on the keys, the center of gravity for the upper limb is likely to be located somewhere in the forearm that is closer to the elbow than the wrist. It will also likely be located in the middle of the forearm, between the ulna and radius bones. In contrast, the 5th finger is on the side of the hand. This means that when the 5th finger is contacting the key near the middle of the fingertip (“straight down”), the center of gravity will not be directly behind the 5th finger. This will give the forearm a tendency to pronate (rotate toward the thumb side), and further muscle contraction will likely be needed to prevent that from occurring. This may reduce the possibility of allowing some forearm/hand weight to help generate the fingertip force (“support”), and so the 5th finger may feel less “strong.” One possible way to alleviate this issue is to supinate the forearm (rotate toward the 5th finger side) to a small degree, which will also cause the finger to contact the key closer to its ulnar side (“tilting” as described above).¹²¹ Doing so will bring the center of gravity closer to being behind the 5th finger, which will reduce the tendency to rotate. The forearm/elbow muscles can maintain a relatively low level of contraction, and some of the forearm/hand weight can push on the finger bones to contribute to fingertip force. In this way, “tilting” the 5th finger can help make it “feel equally strong” compared to fingers 2, 3, and 4. For fingers 2, 3, and 4, one benefit of contacting the key in the middle of the fingertip is to prevent the tendency for forearm rotation (see above). However, in the case of the fifth finger, doing so would actually increase that tendency, and so being slightly supinated (“tilted”) may actually be beneficial. That being said, Moran’s statement suggests that the

¹²¹ In this context, supinating the forearm is in reference to the typical piano playing position, which involves keeping the forearm almost entirely pronated. Therefore, the more “supinated” position discussed in this context will still be pronated relative to its resting position.

amount of supination will likely be very small. This may be in order to avoid significantly increasing the shear forces acting on the bones of the 5th finger, which may eventually cause damage to ligaments (see above).

“Scissor position:” Milanovic (2012) uses the term “scissor position” to describe playing with the fingers “tilted” in order to reach certain large intervals/chords (p. 170). This is achieved by supinating the forearm to some extent.¹²² When playing in a way that the fingers will contact the keys near the middle of the fingertips (“straight down”), finger abduction is the only way to increase the distance between the fingertips. However, when the forearm is supinated to some extent (“scissor position”), the pianist can also use some amount of finger flexion to help increase the distance between the fingertips. This is helpful because the range of motion for the fingers in the sagittal plane (flexion/extension) is larger than that in the frontal plane (ab/adduction). However, supinating the forearm will change the point of contact between the fingertips and the keys (“tilting” the fingers), and so they will not have the same “support” of the hand/forearm when playing this way. Therefore, more muscle contraction will be required to keep the keys depressed and stabilize the joints. For this reason, Milanovic (2012) states that the “scissor position” is only recommended when the pianist cannot otherwise reach the distance of a particular chord/interval (p. 171).

“Non-playing fingers:” In the Taubman Approach sources, the term “non-playing finger(s)” refers to the finger(s) that are not currently depressing a key (Milanovic, 2012, p. 134). This is contrasted with the finger(s) that are depressing the keys, which are often referred to as the “playing fingers” (Taubman Institute, 1995, vol. 4; Taubman, 1984, p. 147; Moran, 2008, p. 52).

¹²² The exact amount will likely depend on context and individual anthropometry.

“Down in the air:” According to Golandsky the non-playing fingers should “feel down, but they barely touch the keys. They hover very closely to it” (Taubman Institute, 1995, vol. 2). These statements suggest that if the non-playing fingers are not touching the keys, they should be elevated only a very small height above them. This can occur by a small amount of activity in the finger extensor muscles to support the weight of the fingers and bring them to a state of equilibrium. However, as the fingers are extended to a greater degree, more contraction will be needed to maintain their position. This is because co-contraction will be required to simultaneously flex the playing finger and extend the non-playing fingers. Therefore, the Taubman Approach sources discourage the pianist from extending the fingers any more than a small distance above the keys. According to Milanovic (2012), Golandsky describes the correct feeling as “down in the air” (p. 155). This phrase seems to be a pedagogical term to help the student find a position for the “non-playing fingers” that is elevated off the keys, but not to an excessively high degree. Milanovic’s statement is in reference to the recommended position of the thumb when it is a “non-playing finger.”¹²³ Based on Golandsky’s statement above, touching the key(s) with the “non-playing fingers” is considered necessary in some contexts. Further evidence can be found in Milanovic’s (2012) statement that the correct position for the non-playing fingers is “either rest[ing] lightly on the keys, or hover[ing] slightly above...” (p. 111).

“Resting lightly” vs. “resting heavily:” Milanovic (2012) states that if the “non-playing fingers” are touching the keys, they should “rest lightly” on [them]” (p. 111) The idea of “resting lightly” is contrasted with that of “resting heavily,” which Golandsky claims will “[remove] the weight from the [playing] finger” (Taubman Institute, 1995, vol. 2). This will cause the pianist to “feel that the weight is suddenly distributed over all the other fingers, and [the playing] finger

¹²³ This will likely vary to some extent depending on context.

doesn't feel supported enough" (Taubman Institute, 1995, vol. 2). In order to better understand the terms "resting lightly" and "resting heavily," it may be helpful to analyze Taubman's claim that when the arm "balanc[es] on the playing finger," "it has nowhere else to go because it is no longer resting down on the unused fingers. The playing finger now has the full support of the arm." This statement suggests that the state of the "non-playing fingers" impacts the ability of the arm to "support" the fingers. As discussed above, the amount of upper limb weight supported by the keyboard will be relatively small compared to the total upper limb weight. However, if the non-playing fingers are not touching the keys, then all of the weight that is supported by the keyboard will be directed via the fingertip force into the key being depressed. Because the "playing finger" is the only finger in contact with the keyboard, no other fingers/keys can be used to support the upper limb weight ("it has nowhere else to go").¹²⁴ If the non-playing fingers are touching the keys then there are other points of contact between the upper limb and the keyboard. This means that the amount of upper limb weight supported by the keyboard can be distributed among all of the fingers in contact with the keyboard, as Golandsky describes. The term "resting lightly" likely implies that the non-playing fingers are not supporting a very large percentage of the amount of upper limb weight that is supported by the keyboard. In doing so, the playing finger and the key that is depressed will still be supporting the majority of that weight. The fingertip force at the non-playing fingers will be low, and they may feel "light." In contrast, "resting heavily" likely means that the amount of upper limb weight that is supported by the keyboard is more evenly distributed among all the fingers. This will increase the fingertip force of these fingers, which may cause them to feel "heavy."¹²⁵ Golandsky's statement that this

¹²⁴ This refers only to the upper limb weight that is otherwise not supported by muscle contractions or passive tissues.

¹²⁵ The definitions of "resting lightly" and "resting heavily" provided here correspond to the definition of these terms as used in the Taubman Approach sources to describe the amount of upper limb weight supported by the

will “[remove] the weight from the [playing] finger,” and cause it to not “feel supported enough” likely indicates that doing so will decrease the amount of hand/arm weight contributing to the fingertip force of the “playing finger.” The fact that Taubman connects this issue to allowing the arm to “balance on the playing finger” also suggests that if the “non-playing fingers” support too much upper limb weight (“resting heavily”), the net force of the hand/arm pushing downward may lead to a feeling that the playing finger is “falling” in one direction. As a result of these potential problems, allowing the “non-playing fingers” to support too much upper limb weight (“resting heavily”) may require the pianist to use more muscle contraction across the joints of the playing finger to keep the key depressed and stabilize those joints.

5.5.5 Miscellaneous - Support

The miscellaneous subcategory was created to contain any excerpts related to the word “support” that did not directly relate to the hand or forearm. The main finding from these excerpts is that the position of the torso has a role in supporting the upper limb (Milanovic, 2012). The biomechanics of the torso is considered outside the scope of this study, and so further research will be needed to examine this subject in more detail.

5.5.6 Conclusion: Hand/Arm support

The categories above were developed in order to describe the role of the hand and forearm in “supporting the playing finger” as described in the Taubman Approach. A total of 325 units of coding were used in this category. After a second coding, 316 units of coding were in agreement between the two codings, making for a 96.97% agreement. The following table has been provided to display each subcategory with a brief summary of its biomechanical analysis:

keyboard before playing. In that scenario, “resting lightly” referred to the recommended amount of weight supported by the keys, which is relatively low. “Resting heavily” on the keys before playing was defined as supporting too much upper limb weight with the keyboard, which will cause the keys to go down.

Table 5.5 *Hand/Arm support*

Categories	Biomechanical Analysis	TA Sources	Units of Coding
Hand/arm should support the fingers when playing	If the hand is positioned above the fingers, the upward contact force from the keys will push up on all of the finger bones, which will then push up on the hand. The hand will then push down on the finger bones, which will push down on the key. If the muscles that support the forearm and hand contract to only a relatively small degree, the weight of those parts will cause some amount of net force to push down on the finger bones and contribute to the fingertip force that keeps the key depressed. The combination of forces acting on the upper limb should not generate a net force in any direction other than straight down from the fingertip into the key. The factors will reduce the amount of muscle contraction needed to stabilize the finger joints.	Taubman 1984; Taubman Institute, 1995, vols. 1, 2, 3, 4, 5; Milanovic, 2012; Moran, 2008	207
Fingers should not/isolate play by themselves	If the muscles that support the forearm and hand contract to a relatively high degree, more muscle contraction across the finger joints may be used in order to keep the key down. This issue is particularly significant when playing chords because the finger muscles will be less effective at generating force.	Taubman 1984; Taubman Institute, 1995, vols. 1, 2, 3, 4, 5; Milanovic, 2012; Moran, 2008	79
Finger should be straight down/not tilted	The point of contact between the finger and the key should be near the middle of the fingertip. When playing single notes this will likely mean that the MCP joint of the playing finger is directly behind the fingertip. This will likely allow the forces acting on the finger bones to be close to in-line and parallel. It also will likely reduce the amount of shear forces acting on the finger bones. In order for this to occur, the hand and forearm should also be roughly parallel to the floor. This position could decrease the tendency of the fingers to ad/abduct, and for the forearm to rotate. Therefore, it could reduce the muscle contraction needed to maintain this position and keep the key(s) depressed. Exceptions to this may occur when playing the 5th finger, because the center of gravity will not be directly behind that finger. Playing the 5th finger with a slightly supinated position can bring the center of gravity behind that finger and potentially reduce the amount of muscle contraction needed. Other exceptions can occur when playing very large chords/intervals, or when changing directions in the transverse plane (forearm rotation).	Taubman 1984; Taubman Institute, 1995, vols. 1, 2, 3, 4, 5; Milanovic, 2012; Moran, 2008	25

Non-playing fingers should hover above/rest lightly on the keys	When depressing the key(s), the fingers that are not depressing a key should not be extended very high above the keys. Instead, they should either be elevated to a small height above the keys or in contact with the keys. If they are in contact with the keys, those fingers should not be supporting a large proportion of the upper limb weight relative to the total amount of weight that is supported by the keyboard. Almost all of the upper limb weight supported by the keyboard should be directed into the key(s) that are depressed. This will minimize the amount of muscle contraction needed to keep the key depressed and stabilize the joints.	Taubman 1984; Taubman Institute, 1995, vols. 1, 2; Milanovic, 2012	8
Miscellaneous - support	Considered outside the scope of this analysis		6

5.6 Problems Associated with “Keybedding:”

Introduction:

The final group of categories will describe the problems that the Taubman Approach sources state may occur as a consequence of “Keybedding.” The subcategories in this section have been divided into two groups: physical problems and technical problems. In this case, the phrase “physical problems” describes ways in which “Keybedding” can cause problems in the pianist’s body. The phrase “technical problems” was defined as ways in which “Keybedding” inhibits the pianist’s ability to produce a desired musical result (e.g. tempo, dynamics). Three categories of physical problems were identified: 1) Tension; 2) Calluses/bleeding fingertips; 3) Pain/injury/tendinitis. Two categories of technical problems were also developed: 1) Harsh sound; 2) Limited playing speed/rebound. A miscellaneous subcategory was then created to include any physical or technical problems that did not fit into these categories.

5.6.1 Physical problems

5.6.1.1 “Keybedding” can cause tension

TA Summary:

One physical consequence of “Keybedding” described by Golandsky and Milanovic is tension (Taubman Institute, 1995, vol. 1; Milanovic, 2012, p. 141). Taubman (1984) states that pressing too hard on the keys can cause tension in the wrist (p. 151).

Analysis:

“Keybedding” and Tension: The analysis on "Curling" (subcategory 4.3.2) and previous research (Wheatley-Brown, 2011) have found that the Taubman Approach sources seem to use the term “tension” to refer to one of two possible meanings in different contexts: 1) excessively high muscle forces; 2) excessively high stiffness across a joint, typically produced by co-contraction. The current analysis on “Keybedding” has found that this term is generally defined either as using excessive fingertip force or using excessive muscle force to produce the necessary fingertip force for playing. In both aspects of this definition, “Keybedding” would lead to excessive muscle force in some capacity. In the case of high fingertip force, high muscle forces could occur in order to generate that fingertip force; it could also occur to stabilize the finger joints against the high contact force that would be directed back into the fingertips. In the case of high muscle force used to create the necessary fingertip force, this definition of the term “Keybedding” would be analogous with the first definition of “tension” listed above. Therefore, any combination of excessive fingertip and/or muscle forces used for key depression would lead to “tension,” as defined by excessively high muscle forces. The definition of “Keybedding” provided above could also lead to excessively high stiffness/co-contraction across one or more joints. The most direct way this would occur would be that co-contraction is often used to

stabilize joints against a high degree of contact force. Using high fingertip force either to depress the keys, or when the key is fully depressed would generate a high contact force, and would therefore likely lead to co-contraction across the finger joints to stabilize them (maintain equilibrium). This understanding of the terms “Keybedding” and “tension” can help explain the statements in the Taubman Approach sources that they are related to one another.

5.6.1.2 “Keybedding” can cause calluses/bleeding fingertips

TA Summary:

Another set of problems that the Taubman Approach sources relate to excessive force/speed into the keys are callused, cracked, and bleeding fingertips (Taubman Institute, 1995, vol. 1, 5). Golandsky associates these symptoms with pushing fast and hard into the keys, which causes the key to hit back with equal force (from subcategory 5.1.5; Taubman Institute, 1995, vol. 1).

Analysis:

Calluses/bleeding fingertips: Golandsky states that playing with excessive fingertip force/velocity can lead to fingertips that are “callused,” “cracked,” or “bleeding.” Calluses or callosities are defined as thickening of the outer layers of skin in order to cover and protect the more vulnerable layers underneath (Gambichler, Boms, & Freitag, 2004). Calluses can occur due to repeated stress and trauma on the skin, such as excessive pressure or friction (Crepy, 2015; Cohen, 2008). Among musicians, calluses tend to be more common in players of string or percussion instruments (Patrino et al., 2016; Gambichler, Boms, & Freitag, 2004; Baccouche et al., 2007; Onder et al., 1999), and can appear in the early stages of learning or during intensive periods of practice (Crepy, 2015; Baccouche et al., 2007). If enough stress is put on the tissue, the skin may tear and cause bleeding (Crepy, 2015). Since there is little research documenting

these issues among pianists, it is not entirely clear specifically from the excerpts in this study why the Taubman Approach sources state these problems could occur. Golandsky claims that it may be due to the fact that “the key hits us back with equal force” (Taubman Institute, 1995, vol. 1). This seems to indicate that the high contact force could cause repetitive stress on the skin. One other possibility is that playing with excessive fingertip force/velocity may increase the force(s) of friction between the fingertips and the keys, particularly if the pianist slides their fingers on the keys excessively when playing. This could also constitute a form of repetitive stress on the skin that is thought to cause the problems mentioned above.

5.6.1.3 “Keybedding” can lead to pain/injury/tendinitis

TA Summary:

In addition to the specific skin-related symptoms discussed above, Taubman states that excessive force into the keys can generally lead to injury (1984, p. 148). Milanovic (2012) provides more detail about the injuries associated with “Keybedding,” claiming that it “can cause pain on the underside of the forearm, and has been linked with tendinitis and other injuries” (p. 141).

Analysis:

Pain/injury/tendinitis: The Taubman Approach sources indicate that excessive finger force/velocity can lead to pain and injury. One example may be the skin conditions described above in the previous subcategory. Additionally, Milanovic (2012) points out two potential problems: “pain in underside of forearm” and “tendinitis” (p. 141).

“Pain in underside of forearm:” The term “underside of forearm” likely refers to the side that is facing the ground when playing the piano. In the anatomical literature, this is sometimes referred to as the “volar” side of the forearm (Boles et al., 1999). This side of the forearm is

where finger/wrist flexor muscles are located. Therefore, a possible explanation for Milanovic's (2012) statement is that exerting high fingertip force once the key is depressed is associated with excessive force in the finger/wrist flexor muscles (see subcategory 5.3.2). If these muscles are used to generate high forces repeatedly for a sustained period of time, they may get overworked. As noted above, the Taubman Approach sources also associate a relatively high degree of fingertip force/velocity when depressing the keys to a high degree of contact force when the key stops moving ("Keybedding") (see subcategory 5.1.5 above). This means that depressing the keys using high degrees of finger flexor contraction may also contribute to this problem. Excessive muscle contraction is thought to be a potential cause of muscle fatigue and pain, among other symptoms (see analysis on "Curling," subcategory 4.3.1), and so this could explain Milanovic's statement.

Tendinitis: According to the scientific sources used in this study, the term "tendinitis" can be used in a number of ways. It is literally defined as "inflammation of a tendon" (Watson, 2009, p. 76). The tendon is the part of the muscle that attaches it to a bone (Cael, 2010). When the muscle contracts, its tendon transmits force to the bone (Freivalds, 2004). The mechanisms of tendon injuries are thought to be diverse, but they are often believed to be linked to the repetition of "high intensity" movements (Watson, 2009, p. 76; see also Narducci, 2020, p. 205; Freivalds, 2004, p. 204). For this reason, they are found to be a relatively common form of playing-related musculoskeletal disorders (PRMD's) among musicians, and are sometimes linked to poor biomechanics when playing (Watson, 2009, p. 76-7; Narducci, 2020, p. 203). In addition to tendon inflammation, the term "tendonitis" can also be used to refer to several other tendon conditions, such as inflammation of the tendon sheath (sometimes called "tenosynovitis"), and degradation of the tendon over time due to improper healing (sometimes called "tendinosis")

(Watson, 2009, p. 76; Narducci, 2020, pp. 205-6). Among musicians, tendon injuries typically occur in a number of different areas of the upper limb: the fingers, thumbs, wrists, forearms, and elbows (Watson, 2009; Narducci, 2020, pp. 206-7). Symptoms of tendonitis can include swelling, tenderness, as well as pain in and around the impacted areas; decreased ability to withstand force can also occur (Watson, 2009, p. 77; Narducci, 2020, pp. 204-5; Freivalds, 2004, p. 204). A number of tendon conditions are also given separate names based on the impacted area (Watson, 2009, p. 77; Narducci, 2020, pp. 206-7).¹²⁶ As a result of these terminological complexities, tendon issues can sometimes be difficult to label (Watson, 2009, p. 76). Milanovic (2012) states generally that excessive force on the key when it is depressed can lead to tendonitis (p. 141). This likely means that if the pianist repeatedly used high muscle forces to depress the keys and keep them depressed, a tendon issue may eventually occur. This will be exacerbated by the increased contact force that occurs in conjunction with increased fingertip force. As a result of that increased contact force, the pianist will need to further increase muscle forces to stabilize the joints. If the same muscles are used to depress the key, keep it depressed, and stabilize the joints, then they will be generating relatively high forces over a sustained period of time, and a tendon problem may occur. The particular area that is affected will likely vary depending on a variety of biomechanical factors.

5.6.2 Technical Problems Associated with “Keybedding”

5.6.2.1 “Keybedding” can cause harsh sound

TA Summary:

As discussed above, the Taubman Approach sources state that the piano is a speed tool, and that tone quality is dependent on the vertical speed of the key (see subcategory 5.1.1).

¹²⁶ For example, lateral epicondylitis is sometimes known as “tennis elbow,” and tenosynovitis of the thumb is known as “de Quervain’s syndrome” (Watson, 2009, p. 78).

Golandsky states that the faster the key speed, the louder the sound (Taubman Institute, 1995, vol. 1). She also says that “if you go beyond a certain speed of the key, the tone begins to be very harsh” (Taubman Institute, 1995, vol. 1). Similarly, Milanovic (2012) states that “the excessive force associated with “Keybedding” can result in harsh sound” (p. 141). Furthermore, she adds that “if the key is struck forcefully, the tone decays more quickly than if played with a more moderate descent” (p. 141).

Analysis:

Harsh sound: Golandsky states that “as you go beyond a certain speed of the key, the tone begins to be very harsh” (Taubman Institute, 1995, vol. 1). As discussed above, key velocity is proportional to the volume of the sound produced (subcategory 5.1.1). Therefore, as key velocity increases, so does the volume of the sound. Golandsky’s use of the term “harsh” likely refers to a sound that has a very unpleasant quality. This would not solely be a product of the volume; it would also relate to timbre, which is the term typically used to describe sound quality (Palmieri, 2003). Timbre is often described as determined by the overtones of a sound; however other factors are also believed to be involved (Sethares, 2005).¹²⁷ In this context, a “harsh” sound likely refers to one in which many of the higher partials are audible (Arencibia, 2020). Because louder sounds typically have more overtones, they can generally be considered more “harsh” than soft sounds (Arencibia, 2020). This may occur as a result of excessive finger velocity when playing. As mentioned above, excessive finger velocity may lead to excessive fingertip force/impact force once the key is depressed (“Keybedding”). However, Golandsky’s statement that “there must be other ways of how to get power without going beyond a certain key speed” (Taubman Institute, 1995, vol. 1) indicates that she believes the manner in which the key is

¹²⁷ A full discussion of timbre is outside the scope of this study. See Sethares, 2005 and Letowski, 1992 for more detailed discussions of this subject.

depressed can impact the timbre in a way that is independent from volume. Many researchers and experts believe that it is not possible to directly change timbre independent of volume (Arencibia, 2020). However, there is some evidence to the contrary (e.g. Suzuki, 2007), and this subject is generally not very well documented in the piano mechanics literature. Therefore, further research will be needed to investigate it more fully. Furthermore, the subject of tone production in the Taubman Approach is discussed in more detail in DVD 10 (Taubman Institute, 2003, vol. 10), which was not included in this study. An analysis of that DVD will likely be necessary to more fully understand the Taubman Approach sources' beliefs on the more nuanced aspects of this subject. For these reasons, the relationship between key velocity and timbre will not be discussed here in any more detail.

5.6.2.2 “Keybedding” can limit playing speed

TA Summary:

According to the Taubman Approach sources, another consequence of playing with too much vertical speed is that it can limit tempo, which Taubman (1984) refers to as “horizontal speed” (p. 147). Several Taubman Approach sources state that while pianists often try to play at a faster tempo by increasing their vertical speed, rather than their horizontal speed, the force of the keys hitting back against the fingers will actually produce a rebound, limiting horizontal speed and slowing the playing down (Taubman, 1984, p. 147; Taubman Institute, 1995, vol. 1; Milanovic, 2012, p. 147). Therefore, excessive vertical speed can actually be counterproductive when trying to increase horizontal speed.

Analysis:

“Keybedding” can limit playing speed: Taubman states that if the finger is moved towards the key with too much velocity, the finger “actually bounces away from the key several times before the key is fully depressed” (Taubman, 1984, p. 147). As a result, she states that playing with too much finger velocity will cause the finger to “rebound” in a negative way. She cites Ortmann’s experiments as her source for these statements. This idea may be related to the contact force directed from the key into the finger. However, a detailed analysis of this idea would require an analysis of Ortmann’s study and a sophisticated discussion of the piano mechanism.¹²⁸

Therefore, it has been considered outside the scope of this study. That being said, if rebounding does occur, one reason it could slow down playing speed is that it would take more time for the fingertip to translate from its starting position to the time that it reaches a state of rest when the key is fully depressed. One other possibility is that the generally higher muscle forces associated with playing in this way will limit the pianist’s ability to move quickly due to the force-velocity relationship (see analysis on “Curling,” subcategory 4.1.3). That being said, further research will be needed to explore the subject of “rebounding” more fully.

5.6.3 Miscellaneous - Problems associated with “Keybedding”

TA Summary:

A miscellaneous subcategory was developed to contain excerpts that discuss problems associated with “Keybedding” that do not fit into any of the above categories. Because the line between physical and technical problems was not always clear for these excerpts, they were placed in a miscellaneous subcategory related to problems generally, rather than one specifically related to either physical or technical problems. Some of the

¹²⁸ For more information on Ortmann’s work, see his two published books: *The Physical Basis of Piano Touch and Tone* (1925) and *The Physiological Mechanics of Piano Technique* (1929).

excerpts in this subcategory contain general statements that excessive force into the key or the keybed can act “as a destructive feedback to the pianist’s hands,” and have “tremendous ramifications on the technique as a whole” (Taubman Institute, 1995, vol. 1). Golandsky states watching someone play in this way gives the impression that the pianist is fighting the instrument, which “is a losing battle that usually ends in the destruction of the pianist’s hands” (Taubman Institute, 1995, vol. 1). Other excerpts in this subcategory relate to the sensations associated with “Keybedding.” In one masterclass, a student complains of a “crammed feeling,” which Taubman associates pushing on the keybed (Taubman Institute, 1995, vol. 1). Milanovic (2012) points out that one of the reasons pianists often engage in “Keybedding” is that the feeling can be “addictive, stimulating to tactile nerves,” and “[promote] a false impression of involvement in the music and musical intensity through physical tension” (p. 141). While she says this can provide “carnal gratification,” it cannot alter the tone produced, and should be avoided (2012, p. 141). No analysis will be included for these excerpts, which were considered outside the scope of this study.

5.6.4 Conclusion: Problems associated with “Keybedding”

The categories above were developed in order to summarize the potential physical and musical problems that the Taubman Approach sources associate with “Keybedding.” A total of 34 units of coding were used in this category. After a second coding, 33 units of coding were in agreement between the two coding sessions, making for a 97.06% agreement. The following table has been provided to display each subcategory with a brief summary of its biomechanical analysis:

Table 5.6 *Problems associated with “Keybedding”*

Subcategories	Biomechanical Analysis	TA sources	Units of Coding
“Keybedding” can cause tension	Excessive fingertip force may lead to increased muscle contraction and/or increased stiffness across one or more joints.	Taubman Institute, 1995, vol. 1; Taubman, 1984; Milanovic, 2012	4
“Keybedding” can cause calluses/bleeding fingertips	Excessive fingertip force or finger muscle force when playing may increase the friction forces between the fingertips and the keys. This may cause repetitive stress on the skin of the fingertips. If this amount of stress is excessively high, it may cause the skin to tear, or lead to the development of callosities.	Taubman Institute, 1995, vol. 1, 5	2
“Keybedding” can cause pain/injury/tendinitis	Excessive fingertip force or finger muscle force when playing may cause the extrinsic finger muscles to become overworked. It also may lead to a tendon disorder, characterized by inflammation, tenderness, and/or decreased ability to withstand force. Generally, these issues may also lead to pain in the volar side of the forearm.	Taubman 1984; Milanovic, 2012;	3
“Keybedding” can cause harsh sound	Excessive finger velocity when depressing the key may be associated with high fingertip/impact force once the key is fully depressed. Because high finger velocity can lead to high key velocity, it will also cause the resulting tone to be loud. Louder sounds typically have more overtones than softer sounds, and so a tone that is very loud due to excessive fingertip velocity may be perceived as having a timbre that is harsh. The idea of manipulating timbre independent of volume in piano playing has not been well researched, and therefore cannot be discussed in detail in this study.	Taubman Institute, 1995, vol. 1, 4; Milanovic, 2012	6
“Keybedding” can cause limited playing speed/rebound	Excessive finger velocity may cause the finger to rebound off the key before it is fully depressed. A full investigation of this subject is outside the scope of this study. However, if this does occur then rebound may decrease playing speed (tempo) because each finger will take more time to reach a state of rest. Another possible reason that excessive fingertip velocity may lead to a decrease in playing speed is that it may increase muscle forces more generally throughout the upper limb.	Taubman 1984; Taubman Institute, 1995, vol. 1, 5; Milanovic, 2012	9
Misc. Problems associated with “Keybedding”	Excessive fingertip force, velocity, and/or muscle contraction when playing may lead to a number of issues in addition to those listed above. Most of the issues found in this subcategory are subjective feelings, such as feeling “crammed,” “stimulated,” and “involved in the music” through “physical tension.”	Taubman Institute, 1995, vol. 1; Milanovic, 2012	10

5.7 “Keybedding” Misc.

TA Summary:

A final miscellaneous subcategory was created to include any excerpts related to the subject of “Keybedding” that did not fit in any of the categories created for this study. Only one excerpt was included in this subcategory, in which Milanovic (2012) states that Golandsky used the technique of “playing” on her forearm so that she could feel the appropriate amount of force under each fingertip (p. 157). From this experience, Milanovic states that she realized that her touch had become too light in order to avoid her previous habit of “Keybedding.” This would likely lead to a form of hovering, as described above in subcategory 5.3.3.

5.8 Conclusion: “Keybedding”

A total of seven categories and 32 subcategories created to analyze the term “Keybedding” as used in the Taubman Approach sources. The first main category (5.1) discussed several concepts related to the piano mechanism that were considered necessary to understanding “Keybedding.” The second main category (5.2) outlined important elements of the setup before playing which may impact force and muscle contraction used when playing. The third main category (5.3) focused on terms used to describe the feelings that may occur when playing. Subcategories were organized to contain certain classes of feelings that may share certain biomechanical characteristics. Category 5.4 described recommendations related to the concept of “aiming,” and category 5.5 considered the idea of “hand/arm support” when playing. The sixth and final category (5.6) explored several physical and technical problems that may occur as a result of “Keybedding.” A total of 775 units of coding were found in this analysis. Of those units of coding, 758 were found to be in agreement between both coding sessions, making

for a coefficient of agreement of 97.17%. The discussion section of “Keybedding” will follow the same format as the one provided for the analysis on “Curling.” Because a table was included to summarize the findings of each subcategory in a particular main category, only general details related to the findings in this chapter will be discussed here. The potential implications of these findings will also be discussed in the context of the entire analysis. Next, a discussion of the process of analyzing the pedagogical language included in this section will follow. Finally, the potential implications of this study for further research will be detailed

Overview of biomechanical analysis and its implications:

The only Taubman Approach source in this study that uses the term “Keybedding” is the thesis by Milanovic (2012). Her description of the term suggests that it refers to a state of excessive fingertip force once the key is fully depressed (p. 204). This idea is discussed throughout the other Taubman Approach sources used in this study, even if the term “Keybedding” is not explicitly used. A number of other related activities are also discouraged. For example, pianists are advised against using excessive fingertip force/velocity when depressing the key. Also, any excessive muscle contraction when playing is said to be generally inadvisable. As mentioned in the discussion on “Curling,” Taubman’s rationale for what constitutes “correct” and “incorrect” ways of playing is partly determined by considering the various task constraints. In the case of “Keybedding,” she seems to consider the design of the piano mechanism to be an essential constraint. Namely, she believed it was essential for the pianist to know how sound is produced, and how the pianist can or cannot control that sound when playing (category 5.1). Several important mechanical factors were found relative to sound production and key depression. First, dynamic variations are mainly produced by manipulating key velocity when it passes the letoff point (“point of sound;” subcategories 5.1.1-2). Once the

key passes the letoff point, the hammer has been released toward the string, and so the pianist cannot do anything to change the resulting sound (subcategory 5.1.3). An additional factor is that a certain amount of force is necessary to depress the key (downweight), and a certain amount of force is necessary to keep the key depressed (upweight); in a typical piano, these quantities will be different (subcategory 5.1.3). When playing, the force used to depress the key will vary depending on the desired dynamics. However, the upweight will be constant at a relatively low amount (about 20g). While there may be a benefit to maintaining a fingertip force that is somewhat higher than the upweight, there does not seem to be any musical/technical benefit to using a significantly larger force (see analysis of subcategory 5.1.3). Furthermore, any amount of fingertip force directed into the key(s) will also be reciprocated into the finger(s) (subcategory 5.1.5). As a result, excessive fingertip force is thought to be a potential cause of physical and technical problems (see category 5.6). Without this understanding of the piano mechanism, Taubman found that many pianists attempt to manipulate sound by engaging in behaviors that do not actually have any such impact (subcategories 5.1.3 and 5.3.4). Her perspective seems to have been that a clear understanding of the constraints provided by the piano mechanism is essential for the pianist to play with the minimal physical effort required. In contrast, acting on false or incomplete assumptions about those constraints can often lead the pianist to deliberately engage in activities that are ineffectual, or even harmful.

According to the analysis of category 5.2, the setup before playing will impact factors like muscle contraction, force, and stiffness (among others) once playing begins. Statements in the Taubman Approach sources suggest that the recommended fingertip force and muscle contraction used when placing the hands on keys before playing is comparable to that recommended when keeping the key(s) depressed. Generally, the degree of both these

parameters should be kept relatively low. This is thought to be achieved in part by using a combination of contact force from keys and distribution of muscle contractions to support the upper limb weight (analysis of subcategory 5.2.1). Additionally, the analysis of this category found that many different biomechanical factors (joint position, sitting height/distance, balance, distribution of muscle forces, etc.) can impact the amount of muscle contraction/fingertip force. Many possible combinations of interaction between these factors can occur. The recommendations of the Taubman Approach sources suggest that finding a proper setup can allow for minimal muscle contraction and relatively low stiffness across all of the joints (see analysis of category 5.2). They claim that such a setup will result in the pianist feeling that the fingers are “resting down lightly” on the keys (see analysis of category 5.2).

Once the pianist starts playing, a number of subjective terms are used to describe feelings that are either recommended or discouraged (category 5.3). While excerpts were coded that pertain to both the act of key depression and keeping the key depressed, the analysis of this category focused solely on the latter. From a biomechanical point of view, there are many factors that contribute to the subjective feeling of the upper limb when keeping the key depressed (e.g. force, position, muscle contraction, stiffness, etc.). The language of the Taubman Approach sources used in this study often focuses on the subjective experience, rather than the individual biomechanical factors themselves. One reason for this may be that it would be highly impractical for the pianist to attempt to consciously monitor and control all of these factors when playing. In fact, the interaction of these factors is so complex at any given moment that conscious control would likely be impossible. Therefore, within a pedagogical context, the most practical way to describe the recommended/discouraged ways of playing could be to describe the feeling that results from them. One subcategory (5.3.1) was created to outline the terms used to describe

various feelings associated with the recommended way of playing, while three others (5.3.2-4) were developed for ways of playing that should be avoided. In the analysis of these subcategories, biomechanical explanations were then proposed for various terms based on the particular context in which they are used. Because these terms are inherently relative, the Taubman Approach sources often describe them in relation to other feelings that are considered to be problematic. For example, the pianist is told that they should not feel as though they are “pushing,” “hovering,” or “relaxing,” but rather that they are “resting” on the key. Without using the negative terms as points of reference, it would likely be much more difficult to determine what is meant by the term “resting.” Using the negative terms in this way to more clearly define positive ones can be considered a form of triangulation, in which the correct feeling is situated between two problematic extremes. In a practical context, it would likely be difficult for the pianist to find the so-called “effortless” ways of playing without some relationship to the feelings that are absent in this condition (“pushing,” “hovering,” “relaxing,” etc.). Therefore, triangulation of this kind may allow the pianist to identify what is “correct” by viewing it as the absence of feelings that are “incorrect.” In the analysis of category 5.3, the comparison of positive and negative terms suggested that certain biomechanical characteristics are associated with the recommended way of playing (see conclusion of category 5.3). In a pedagogical context, the Taubman Approach sources encapsulate all of these factors using a single metaphor: that of “standing” on the key. As with the pedagogical language found in category 5.3, the biomechanical descriptions provided in the analysis of this category are still relative. Because of the wide variety of possibilities among individuals and pianistic contexts, it would likely be difficult and even inadvisable to try and set a clear quantitative standard that could be practically applied. Instead, the use of a metaphor based on a common experience could allow the pianist to

find the recommended feeling, while also limiting the need for conscious control of many interdependent biomechanical parameters.

Category 5.4 was created to outline the ideas relevant to the subject “aiming,” which the Taubman Approach sources clearly connect to “Keybedding.” The subcategories related to “aiming” suggest that the amount of force exerted on the key when it is fully depressed is directly linked to the point at which the pianist “aims [their] force” when playing (Taubman Institute, 1995, vol. 1; subcategories 5.4.1-2). That being said, the issue of “aiming” was determined to have a significant motor control component. As a result, it was considered to be largely outside the scope of this study.

Category 5.5 was developed to deal with the issue of “hand and forearm support.” As category 5.3, excerpts were coded pertaining to both the act of key depression and keeping the key depressed. Again, the analysis of this category focused solely on keeping the key depressed. The analysis of category 5.3 found that the Taubman Approach sources advocate for generally low muscle contraction across the finger joints in order to achieve the fingertip force necessary for playing. One possible way to achieve this is to allow some weight from the hand/forearm to push down on the finger bones (see analysis of subcategory 5.5.1). Doing so requires the muscles that support these parts to have relatively low contraction. The ability to “support” the finger(s) with the hand/forearm seems to be affected by the degree of contraction in muscles crossing the elbow/wrist joints. The position of the upper limb joints is also likely a significant factor because the hand/forearm must be above the finger bones to some extent in order to push down on them. Furthermore, the MCP joint should be positioned behind the playing finger (if playing one of fingers 2-4), allowing the finger to contact the key near the middle of the fingertip (subcategory 5.5.3). This will likely reduce the amount of shear forces acting on the finger bones, potentially

decrease the strain on soft tissues, and allow for reduced contraction of certain muscles. A final issue that was found to be related to “hand and forearm support” is that if the “non-playing fingers” are touching the keys, they should not support too much upper limb weight (subcategory 5.5.4). That way, a large percentage of the weight supported by the keyboard can be directed into the key(s) being depressed via the playing finger(s). According to the Taubman Approach sources, significantly changing any of these factors could lead to an increase in muscle contraction across the finger joints, which may constitute a form of “isolation” and lead to a feeling that the finger is “pushing” or “pressing” on the key(s) (subcategories 5.3.2 and 5.5.2). The connection between a lack of hand/arm “support” and “pushing” suggests that this issue is indirectly related to “Keybedding.” That being said, the ideas of “support” and “isolation” are central concepts to the recommendations provided by the Taubman Approach that are used in many different contexts, so further research will be needed to fully unpack the biomechanics related to these terms.

Analysis of Language:

In contrast to the analysis on “Curling,” the analysis on “Keybedding” did not contain a large number of anatomical terms that needed to be translated. Muscles were often referred to generally (e.g. “flexors” or “extensors”), but specific muscles were not typically mentioned. Some joints were mentioned that had been previously analyzed in the “Curling” analysis (e.g. “main knuckles” as the MCP joints). That being said, the “Keybedding” analysis did include the additional task of translating a number of terms related to the piano mechanism. However, most of these terms were explicitly defined in at least one of the Taubman Approach sources, and so they could be substituted for the scientific terminology without much difficulty. One concept that required slightly more analysis was that of “weighted keys,” which had to be separated into two

different terms from the piano technology literature: “upweight” and “downweight.” The difference between the two quantities was accounted for in the Taubman Approach sources, and so all that was needed was to apply the appropriate scientific terms.

Additionally, a number of linguistic issues that occurred in the “Curling” analysis also came up in a similar fashion relation to “Keybedding.” One such challenge was that of subjective language, which was anticipated based on the research problem (see Chapter 2). However, this issue posed some more complex challenges related to the subject of “Keybedding” compared to “Curling.” The main way in which “Keybedding” is described is as an “embodied experience” (Milanovic, 2012, p. 257), namely that of “press[ing] on the key” (Milanovic, 2012, p. 141). While the experience of “pulling in” the fingers (“Curling”) could be defined by a single biomechanical event (DIP/PIP flexion), explaining the idea of “press[ing] on the key” can be much more complex from a biomechanical perspective. Some references to this term in the Taubman Approach sources seem to describe an objective application of force, but there are many factors that can contribute to how that force is achieved. Furthermore, some references in the Taubman Approach sources are more likely to be discouraging the subjective experience of “pushing,” which may imply increases in fingertip force and/or muscle contraction. While the Taubman Approach sources seem to discourage an increase in both of these two factors, they do not necessarily occur concurrently when playing. This led to some challenges during the process of analysis. To alleviate this problem, the analysis provided in this study attempted to identify certain cases where various possible mechanical situations may be implied. This choice was made in an attempt to demonstrate that there are several possible types of biomechanical conditions that may result in the feeling of “pushing.” Similarly, many different conditions may be implied from the use of that term in a given context. From a pedagogical perspective, any

combination of factors resulting in that feeling is considered problematic, and so one term may suffice in that context. However, from a biomechanical perspective, this term does not allow for a clear and consistent translation across contexts.

A similar problem occurred with the other subjective terms contained in category 5.3. As discussed above, these terms were analyzed by referencing their implications against one another to determine their relative significance. Because of the wide number of factors that may contribute to a single experience and the relative nature of the terminology used, it was difficult to attribute specific qualitative terminology for many of those concepts. For example, the analysis of the concept of “standing” on the key suggested that a relatively low stiffness should occur across all joints. However, too little stiffness would fall under the category of “relaxation,” and would as a result be problematic as well. Therefore, the correct amount of stiffness was identified as relatively low, but not excessively low. Analogous situations occurred regarding relative fingertip force and the concepts of “standing,” “pushing,” and “hovering.” Similar to the pedagogical terms, the biomechanical descriptions provided for these terms were necessarily relative. However, one advantage of applying even relative scientific language is that it indicates a clearly defined biomechanical concept, even if a clear quantitative distinction between “correct” and “incorrect” was not easily discernible.

An added complication of subjective terminology was that some of the terms used in the Taubman Approach sources to describe the feelings when playing are also used in the scientific literature to describe objective biomechanical concepts. For example, the term “support” has a biomechanical meaning, which was discussed in category 5.2 as it related to “resting down” on the keys before playing. Similarly, the word “force” can be used as a noun in mechanics, but also as a verb in a more colloquial context. In the Taubman Approach sources, it is used in both ways

in different contexts. The term “weight” is also an objective mechanical term that is used in pedagogical contexts. In the latter situation, it is often used to describe the experience of increasing fingertip force by decreasing muscle contraction. As discussed in the analysis above, weight may be a contributing factor to producing that fingertip force, but it is one of many complex interacting factors. Using the term “weight” to describe the experience may simplify the issue to make the task more easily achievable for a pianist, but from a biomechanical perspective it may cause confusion about what is actually being described.

Another challenge in translation was found in analyzing the terms “relaxation” and “holding up”/“hovering,” which are sometimes used to refer to a muscular state and sometimes used to refer to a position. For example, “relaxation” can refer to having too little muscle contraction across a joint, and it can also refer to a joint that is positioned closer to the floor than the recommended position (the opposite is true for “hovering” or “holding up”). Both the low muscle contraction and lower position can also happen at the same time, which further complicates the issue. For the purposes of this study, it was clear that in all circumstances, these terms are being used pejoratively. However, in some specific contexts it was unclear what exact biomechanical condition was being described.

Consistency among sources:

As with the analysis on “Curling,” the concepts related to “Keybedding” are generally fairly consistent among the Taubman Approach sources (see the tables provided at the conclusion of each category). The largest exception to this is actually the use of the word “Keybedding,” which has been discussed above. Another exception was that some of the aspects of the piano mechanism, the “point of sound” (subcategory 5.1.2) and the “weighted keys” (5.1.4), were only discussed in the DVD’s, and not in the other sources. Moran’s (2008) method

book was not found to include any details of the piano mechanism relevant to this subject; this could be the case because such concepts might be considered too technical for a beginner book that contains little discussion of tone production. Moran does regularly warn the student to avoid “pressing” on the keys, but she does not mention the justification for doing based on the piano mechanism, which is included in some of the other sources. Generally, too many excerpts were contained in categories 5.3 and 5.5 to accurately measure the consistency among the terms used without quantitative measurements. In this study, the focus was placed on finding qualitative nuances in meaning for certain terminological choices. Further research could examine the consistency of each individual term throughout different contexts. Terms that are idiosyncratic to the Taubman Approach, like “isolation” and “support” were used in all the sources, and therefore can be considered central to the Taubman Approach lexicon. As discussed above, certain mechanical terms like “weight,” “force,” and “relaxation” seem to imply either objective and/or subjective definitions in different contexts; the variations in the use of these terms may ultimately lead to some confusion.

Recommendations for further research:

Further research could examine several of the topics related to “Keybedding” discussed in this study in more detail. First, the issue of tone production could be examined, which would likely require an analysis of DVD 10 (Taubman Institute, 2003, vol. 10). Second, the subjective terms used in category 5.3 could be analyzed for more nuances in meaning that were not covered in this study. Furthermore, the excerpts coded in categories 5.3 and 5.5 related to the act of key depression could be analyzed to determine their biomechanical implications. Doing so could also supply a biomechanical explanation for the terms “isolation” and “support,” which are highly significant in the Taubman Approach. Finally, the motor control implications of any of the topics

discussed in Chapter 5 would be useful. Any of these investigations would provide a more comprehensive understanding of the scientific basis for the concepts related to “Keybedding.” As with the analysis on “Curling,” this study did not attempt to make a full evaluation of the claims laid out in the Taubman Approach related to the subject of “Keybedding,” and so further research is needed to more fully evaluate those claims. Previous studies have been done to investigate the fingertip force involved in piano playing, and a variety of different technologies have been developed to increase the accuracy of such measurements (e.g. Grosshauser et al., 2012; McPherson, 2012; Parlitz, et al., 1998). Further research could examine how the recommendations of the Taubman Approach discussed in this analysis relate to the findings of previous studies. Other quantitative measurements related to the statements in this study will also be beneficial, such as those related to joint stiffness, and muscle contraction used to “rest down” on the keys, keep the keys depressed, and maintain certain joint positions. That being said such studies may be challenging due to the wide ranging of interdependent factors involved.

Conclusion

This study was a first attempt at analyzing the ideas put forth in a pedagogical approach by using the language of modern biomechanical science. The findings of the two analyses in this study suggest that this can be done if terminology is examined within the larger context of the approach itself. That being said, a number of challenges were encountered during the process of each analysis (see conclusions of “Curling” and “Keybedding”). The most significant challenges were found when trying to analyze subjective terminology that was not explicitly defined in the pedagogical source materials. Scientific terms were also sometimes used to describe subjective phenomena, which caused some difficulty. One significant result of this study is the need to take into account the context in which language is used before its meaning can be ascertained. Language used to describe piano playing generally tends to occur in one of three different contexts: 1) Performance contexts, in which the pianist may use language to describe their own experience or engage in self-talk to better execute the task; 2) Pedagogical contexts, in which a teacher will often need to use language to help someone else execute the task; 3) Scientific contexts, in which language can be used to describe what is objectively occurring during the execution of the task. The goal of each of these tasks is distinct, and therefore a different set of language may be more effective for achieving one task compared to another. For example, one advantage of scientific terminology is its precision and consistency of meaning across contexts. However, the goals of performance and pedagogy are purely practical, and so the most precise language may not necessarily be the most useful for every situation; in some practical contexts, it may in fact even be counterproductive. For this reason, the biomechanical language produced by this study is not meant to be considered optimal in all possible contexts. The pedagogical language of the Taubman Approach has been codified over many years through trial and error. It

has been anecdotally successful from a pedagogical point of view, and it continues to be adapted with more widespread use. A number of biomechanical terms supplied in this study may in fact be more objectively precise than Taubman's language. However, she may have found that the subjective implications of using certain terms (e.g. "tension," "relaxation," "force," etc.) may lead students to engage in ways of playing that she considered to be problematic. This experience may have led her to avoid using these terms altogether in a positive context. While doing so may have benefited her students, it also seems to have created problems for situations in which precision and consistency are essential: scientific description, evaluation of ideas, and knowledge transfer, among others. In all of these contexts, pedagogical language can be problematic, and so the scientific language proposed in this study will likely be a helpful alternative.

Because of the varying circumstances in which language may be used, it may be beneficial for pedagogues to have separate lexicons of relevant terminology that can be applied in various contexts. One lexicon could consist of precise, scientific terminology for the purpose of describing what is thought to be objectively occurring; others could use more subjective, colloquial, and/or metaphorical language designed for pedagogical contexts. Pedagogical lexicons would also need to be diverse enough to accommodate students of different ages, comprehension levels, learning styles, and cultural backgrounds. Ideally, the scientific and pedagogical lexicons would have distinct terminology in order to avoid potential confusion during knowledge transfer. However, this may be somewhat difficult because scientific terms are also used colloquially. Regardless, it is important to have some way of clearly distinguishing when terms are being used to describe subjective experiences, as opposed to objective phenomena. The results of this study are a first step in providing an explicitly scientific lexicon

for the concepts discussed. The goal of doing so was to assist with clarity, as well as to facilitate discussion and evaluation of these ideas across disciplines.

Limitations and recommendations for further research:

One of the aims of this study was to provide a basis for future research. The terminology used in this study could provide a basis for operationalizing and then testing some of the claims made in the Taubman Approach. In addition to other ideas proposed in the conclusion of each analysis, future research could continue to investigate the large amount of subject material in the Taubman Approach that was not examined here. One limitation of this study was that it was unable to include many materials on the Taubman Approach that continue to be produced to this day. Further research could take more source materials into account, which may provide further clarity on pedagogical ideas. Future studies could also examine the concepts outlined here with more attention to the issue of motor control, which was generally not discussed in detail. Another limitation of this study was the use of only a single coder, which occurred due to the large amount of data and need for prior experience with the pedagogical material. The subjective nature of analyzing terminology placed some inherent limitations on the accuracy of the analysis; however, this was considered somewhat unavoidable under the chosen methodology (QCA). Subjective perspective was more likely to impact some parts of the analysis than others (see above). This issue was mitigated by consulting experts in both the scientific and pedagogical fields. That being said, it is likely that further nuances in meaning could be identified through additional research, which could also create opportunities for increased discussion among more practitioners of the relevant fields. Finally, this study could be used as a model for analyzing language in other approaches to piano technique. Doing so would make it easier to evaluate the ideas put forth in various approaches, both in comparison to the scientific literature, as well as to

each other. Without a common set of terms, substantive discussions of that kind can be extremely challenging, and so studies built on the model provided here will likely benefit both the pedagogical and scientific fields.

Appendix A: Coding frame for “Curling” analysis

4.1 What is Curling?

4.1.1 Curling is pulling fingers in from nail joint

- a. **Description** - Statements that define curling as pulling the fingers in from the ‘nail joint’ (DIP). Any reference to flexing or pulling in this joint is appropriate in this category.
- b. **Examples** - “When I talk about curling I’m talking about doing this pulling in this phalange here at the nail joint (points to DIP) so that this (DIP) is sticking out practically.” (Taubman Institute, 1995, vol. 1)
- c. **Decision rules** - None.

4.1.2 Curling/fixating creates activates opposing muscles

- a. **Description** - Any reference to how curling the fingers activates opposing muscles or creates “dual muscular pulls.” Also includes any time that “opposing muscles” are discussed in relation to curling. In addition to curling, this category can include the occurrence of dual muscular pulls related to fixating/molding/preparing the fingers.
- b. **Examples** - “Fixating is usually achieved by the use of contrary muscle such as flexing and extending at the same time which creates those dual muscular pulls.” (Taubman Institute, 1995, vol. 1)
- c. **Decision rules** - Do not include statements that the combination of curling and stretching activates opposing muscles. These statements have their own category.

4.1.3 Curling uses the long flexor muscle that pulls tightly under/over wrist/fingers

- a. **Description** - Any reference to the muscle used to curl the fingers (long flexor). Also includes references to how that muscle “pulls tightly” over/under either the wrist and/or fingers.
- b. **Examples** - “The long flexor is being used. It pulls tightly under the fingers and the wrist.” (Taubman, 1984)
- c. **Decision rules as needed** - Only include references to the muscle used and that it pulls tightly. Do not include parts of statements that reference other impacts of using that muscle (i.e. - the long flexor causes the restriction of motion). Those parts of the statements belong in their own respective category.

4.1.4 Curling restricts hand/finger motion

- a. **Description** - Any reference to how curling prevents/limits/restricts/inhibits the hand/finger motions up or down (flexion/extension). This can also include inviting audience members to try and move the fingers/hand up/down with the fingers curled to feel the restricted movement.
- b. **Examples** - “(It pulls tightly under the fingers and the wrist.) “This creates the restriction of motion you experienced in both the finger and hand motions.” (Taubman, 1984); ‘And then if you try, if you curl your fingers again and try to move your fingers very quickly, very hard, very restricted” (Taubman Institute, 1995, vol. 1)
- c. **Decision rules** - This is distinct from ‘curling prevents opening the hand,’ which only refers to opening up the hand/fingers (abduction). The current category only refers to restriction of the up/down motions of the fingers (flexion/extension). Use this category for any reference to restriction of motion in the context of curling vs. the natural curve.

4.1.5 Curling prevents opening the hand

- a. **Description** - Any reference to how curling prevents/limits the hands ability to open or the fingers’ abduction.
- b. **Examples** - “(Another traditional way in which artists have been taught was to curl the second finger in order to tighten and keep the other fingers from hitting the keys in the way. If you do that, again, you have a curled finger, an over-curved finger, again it’s already very tight,) and it limits the span of the hand.” (Taubman Institute, 1995, vol. 5); “(So it’s a very tight, over-curved position that pulls again on the long flexor. It makes it very tight) and makes it impossible to open the fingers.” (Taubman Institute, 1995, vol. 3)
- c. **Decision rules** - This is different from ‘curling restricts hand/finger motion,’ which only refers to the up/down motions (flexion/extension). Use the current category for ways that curling restricts the opening (abduction) of the hand only.

4.1.6 Curling and Stretching together activates opposing muscles

- a. **Description** - Any statement that curling the fingers and opening the hand/stretching activates opposing muscles, or creates “dual muscular pulls”.
- b. **Examples** - “Now you play very much curled with your fingers down. Now when you’re stretching your fingers, you’re using an extensor, which is on top of the finger, and when you play down you’re using a flexor. So you’re making claws.” (Taubman Institute, 1995, vol. 1)
- c. **Decision rules** - Do not include statements that curling alone (without stretching) activates opposing muscles. These statements have their own category.

4.1.7 Don’t curl the thumb

- a. **Description** - Any statement that discusses/advises against using curling/flexing the thumb at the IP joint. Includes curling the thumb as a basic position (generally) or in other contexts (after releasing the key with the thumb).
- b. **Examples** - “The thumb should never be curled this way (flexed IP).” (Taubman Institute, 1995, vol. 1)
- c. **Decision rules** - do include physical impacts of curling the thumb here, but instead put them in the relevant subcategory of “physical impacts.” Do not include the curling of the thumb related to octave playing, which has its own category.

4.2 Curling in Context

4.2.1 Don’t line up all fingers to be the same length as a starting position

- a. **Description** - Any statement that discusses/advises against using curling to make all of the fingers the same length, or form a straight line (horizontally).
- b. **Examples** - “Unfortunately, there are exercises in popular piano method books encouraging students to curl by lining up their fingertips on a pencil.” (Milanovic, 134)
- c. **Decision rules** - Do not include positive statements that encourage keeping fingers at their natural length, which have their own category.

4.2.2 Don’t play in horizontal key spots/key spots must have in and out relationship

- a. **Description** - Any statement that advises against playing in key spots (the place where the finger makes contact with the key) that form a horizontal line when playing consecutive notes. Also include the inverse statement that key spots must have an in/out relationship to one another.
- b. **Example** - “Because of the different finger lengths, the fingers should not place themselves in a straight, horizontal line on the keys when played consecutively.” (Taubman Institute, 1995, vol. 3); “The fingers generally must fall in key spots with an in and out relationship to each other, both in the black key and the white key area.” (Taubman Institute, 1995, vol. 3)
- c. **Decision rules** - Distinct from lining up all the fingers as a starting hand position, which refers to the position of the hand before playing. This category refers to the spots in which the finger touches the keys when playing consecutive notes.

4.2.3 Curling occurs when you bring the finger out instead of the arm

- a. **Description** - Any statement that describes an instance of curling to move the finger out by itself instead of the whole arm when connecting notes. This is separate from “curling to play a long finger on white keys” because it describes an action independent of the reason/context behind. It also describes how curling can occur due to an incorrect way to move out.
- b. **Examples** - “If the arm is not going to come out to bring you to where the finger has to play, that finger is going to bring itself out. And then you’re going to be curling.” (Taubman Institute, 1995, vol. 3)
- c. **Decision Rules** - Do not include statements about proper in/out motion of the finger/hand/arm unit.

4.2.4 Don’t curl longer fingers to play white keys/to avoid the black key area

- a. **Description** - Any statement that discourages or describes curling longer finger(s) to play on white keys, or curling longer fingers to keep them out of the black key area. This can refer to 1) curling longer fingers that are moving to play in order to avoid playing white notes in the black key area; 2) curling non-playing fingers to prevent them from touching the black keys; 3) curling non-playing fingers to prevent them from being in the black key area for any other reason. Also includes statements that the tendency to curl a long finger(s) is common.
- b. **Examples** - “When playing all white keys, and the in and out arm movements are lacking, the long fingers, 2, 3 and 4, will be forced to curl to avoid playing in the black key area.” (Taubman Institute, 1995, vol. 3)

- c. **Decision Rules** - Do not include statements about correctly playing in the black key area. Do not include statements related to “bringing the finger out” instead of the arm, which have their own category.

4.2.5 Curling can cause the finger(s) to feel(s) too long

- a. **Description** - Any statement that indicates curling can occur because a finger feels too long.
- b. **Examples** - “The wrong in and out motions will make fingers feel either too long or too short, and I’ll give you several examples just before I do the scale.” (Taubman Institute, 1995, vol. 3)
- c. **Decision Rules** - Do not include positive statements that the correct in/out motions can prevent this sensation. Those statements belong in the “correct in/out motions can prevent curling” category.

4.2.6 Don’t curl to prevent broken nail joint

- a. **Description** - Any statement that discusses/advises against using curling to prevent breaking/collapsing the nail joint (DIP). Also include statements that compare curling to “breaking” the nail joint in terms of their level of harmfulness to technique.
- b. **Examples** - “One of the main reasons I should say for curling the fingers is to avoid or prevent or cure the broken nail joint, especially with kids who come with the break here (DIP), so the teachers tell them to do that (curl) in order to prevent that kind of a break, but the fingers should never go to that extreme.” (Taubman Institute, 1995, vol. 1)
- c. **Decision rules** - None.

4.2.7 Don’t curl when plucking in octave playing

- a. **Description** - Any reference to curling when doing the ‘plucking motion’ described for proper octave playing.
- b. **Examples** - “What you add is a slight plucking action in the fingertip. Now I say the fingertip because if you’re going to pluck this way (flexes DIP), you’re going to end up with the over-curved fingers.” (Taubman Institute, 1995, vol. 5)
- c. **Decision rules** - None.

4.2.8 Curling can occur because the wrist is too low

- a. **Description** - Any reference to how curling can occur when the wrist is too low. This can include statements that curling due to a low wrist happens in order to prevent falling of the keys. Other words that may be used include clenching, grabbing, or other related synonyms.
- b. **Examples** - “Also the feeling is that you’re falling off the keyboard so the fingers into clench and to grab and to hang on to the keys.” (Taubman Institute, 1995, vol. 1); “See, when your wrist is low, this is what happens to the finger (shows flexed fourth). This is very common. You see pianists do this.” (Taubman Institute, 1995, vol. 1)
- c. **Decision rules** - None.

4.3 Curling leads to physical/musical problems

4.3.1 Curling can lead to pain/injury

- a. **Description** - Any statement that curling can lead to injury in a general sense.
- b. **Examples** - “Although I will say that the people who come in who were injured (and with fingers that are clenched, many for years, have come in from the very round finger training.)” (Taubman Institute, 1995, vol. 1)
- c. **Decision rules** - None.

4.3.2 Curling/fixating creates tension/tightness

- a. **Definition** - Any time the words ‘tension,’ ‘tightness,’ are used in reference to curling or fixation.
- b. **Examples** - “(again the feeling is that of falling off and the fingers again clench to hold onto the keyboard.) So that’s one way of creating tension right away.” (Taubman Institute, 1995, vol. 1)
- c. **Decision rules** - None.

4.3.3 Curling can cause fingers to stay curled

- a. **Definition** - Any statement that curling can cause fingers to stay curled or clenched.
- b. **Examples** - “I constantly see that fourth finger being pulled under like this (demonstrates flexing fourth finger toward the palm). One day that’s going to stay that way.” (Taubman Institute, 1995, vol. 1)
- c. **Decision rules** - Also include references to “clenching” or dystonia caused by curling.

4.3.4 Miscellaneous - Problems associated with “Curling”

- a. **Definition** - Any physical/musical problem resulting from curling the fingers that is not covered in the other subcategories

- b. **Examples** - Numbness, memory issues, spasm, weakness, fatigue, limitations, etc.

4.4 Miscellaneous - “Curling”

- a. **Definition** - Any statement related to curling the fingers that is not covered in the other main categories

4.5 Fingers should have natural curve/neutral hand position

4.5.1 Natural curve/optimal finger position is the same as when hand is at the side

- a. **Description** - Any statement that refers to finding the proper hand position or “natural curve” by putting the hand at your side and then putting the hand on the keyboard.
- b. **Examples** - “Curving, which is just the normal curve of the fingers when the hand is at your side and you put on the keyboard this is the normal curve that’s correct.” (Taubman Institute, 1995, vol. 1)
- c. **Decision rules** - Do not include statements that the nail joint should be relatively straight, which has its own category. Do not include negative statements that the knuckles should not curl, collapse, etc.

4.5.2 Finger lengths should stay in the same relationship to each other

- a. **Description** - Any statement related to maintaining the relationship of the finger lengths that occurs in the natural hand position.
- b. **Examples** - “And if you notice also, my fingers always stay in the same relation to each other.” (Taubman Institute, 1995, vol. 5); “Also if you look at your hands, if you haven’t looked lately, you’ll see that some fingers are long and some are shorter, and that we always have to keep that relationship.” (Taubman Institute, 1995, vol. 3)
- c. **Decision rules** - Distinguish this from above categories which refer to negative statements (don’t curl/make them the same length). The current category only applies to positive statements (keep them all at their natural lengths).

4.5.3 Nail joint should be relatively straight

- a. **Description** - Any statement claiming that the nail joint (DIP) should be relatively straight, rather than curled (flexed) or broken (extended). Also include statements that the thumb should be relatively straight.
- b. **Examples** - “And when the child was told, if they did this (“broken” DIP), I said ‘no, it has to be straight,’ and they straightened it out. And before you know it they were playing with a perfectly nice straight nail joint, and that’s the way it’s supposed to be.” (Taubman Institute, 1995, vol. 1)
- c. **Decision rules** - This is separate from “curling to prevent the broken nail joint,” which only refers to the negative statements (don’t curl to prevent the broken nail joint). This category refers only to positive statements that the joint should be relatively straight.

4.5.4 Miscellaneous - Natural curve

- a. **Description** - Any other statements related to the natural hand position that are not included in the above subcategories

4.6 Movements that prevent curling

4.6.1 Fingers should only move from the main knuckle

- a. **Description** - Any reference that encourages moving the fingers only from the main knuckle (MCP). This includes statements about moving the fingers ‘in one piece.’
- b. **Examples** - “(Fingers 2, 3, 4, and 5 each have three knuckles.) They move from the main knuckle” (Moran, 2008); “this will be a coordinate way to move when we move just in one piece from the knuckle (MCP).” (Taubman Institute, 1995, vol. 1)
- c. **Decision rules** - None.

4.6.2 Finger motions should use short flexors that don’t cross/pull tightly over the wrist

- a. **Description** - Any reference to the muscles in the hand (‘short flexors’ or ‘quick flexors’) that can flex the fingers or “facilitate” finger movement. Also includes references to how those muscles do not cross or “pull tightly” over/under the wrist.
- b. **Examples** - “This motion is done by the short flexor, the muscle that does not extend over the wrist. The short flexor moves the fingers only downward, not exerting any pull on the fingers or wrist.” (Taubman, 1984)
- c. **Decision rules** - None.

4.6.3 Natural curve allows fingers/hand to move freely

- a. **Description** - Any statement that the natural curve position allows for the fingers and hand to move freely. This can also include inviting audience members to try and move the fingers/hand up/down to feel the freedom when not curling the fingers.
- b. **Examples** - “(This will be a coordinate way to move when we move just in one piece from the knuckle (MCP) this way,) it’s just the freest way to do it.” (Taubman Institute, 1995, vol. 1); “Now open your fingers as they fall naturally and move your fingers up and down. You will feel the difference in the freedom of motion.” (Taubman, 1984)
- c. **Decision rules as needed** - None.

4.6.4 Correct in/out movements can prevent curling

- a. **Description** - Statements that discuss using in and out motions to avoid curling, to maintain the “natural curve” of the fingers, or to maintain the relationship of the finger lengths. Also include statements that in/out can avoid the feeling of fingers being too long/short.
- b. **Examples** - “So in order to avoid that and to keep the finger always, the hand in its optimum position, which is the natural curve, I would have to move out.” (Taubman Institute, 1995, vol. 3)
- c. **Decision rules** - This refers only to positive statements about moving in/out to avoid curling. This is separate from statements that curling can occur without the proper in/out movements, which will belong in a different category (i.e. when playing on all white keys, etc.). Do not include statements about bringing the finger out by itself, which is discouraged, and has its own category. Do not include statements that curling can occur because a finger feels too long, but only that the correct in and out motions can correct this issue. Do not include statements that incorrect in/out can give the sensation of fingers being too long, which also belong in the “curling can occur because finger(s) feel(s) too long.”

4.6.5 Playing in the black key area can prevent curling

- a. **Description** - Statements that discuss the necessity of playing in the ‘black key area’ to avoid curling.
- b. **Examples** - “I’m not moving in and out, but the point is that I’m talking now about when do we have to stay in the black key area? There are some situations where we have to move in and out, and situations where you’re there and you should stay there. OK? So that here, the third and fourth finger shouldn’t be playing out this way. That’s the point that I’m making. That you’re playing really in the black key area. You see that? (Because the most common thing is for the finger, for the third finger to pull out this way).” (Taubman Institute, 1995, vol. 3)
- c. **Decision rules** - Only refers to positive statements encouraging playing in the black key area when necessary. Do not include statements discouraged curling to avoid the black key area.

Appendix B: Coding Frame for “Keybedding” analysis

5.1 Piano characteristics

5.1.1 Piano is a speed tool

- a. Definition - Any statement that the piano is a speed tool or that the speed of key depression impacts the dynamics of the sound. Also include statements that differentiate vertical and horizontal speed. Include statements that must be way to get loud sound without going beyond certain key speed
- b. Examples - “The piano is a machine that is governed by its own laws. It is a speed tool that requires perfect timing” (Taubman Institute, 1995, vol. 1); “That if we know that when we go slowly into the key, we get a softer sound. That’s all we have to know.” (Taubman Institute, 1995, vol. 1)
- c. Decision Rules - None.

5.1.2 Point of sound is where hammer hits string

- a. Definition - any statement that defines the term “point of sound” as the place where the hammer hits the string. Also include other statements related to the definition of the point of sound, such as where it is located ($\frac{3}{8}$ below the key surface), that it feels like a “bump,” etc.
- b. Examples - “And if you put the key down very slowly, you’ll feel a little bit of a bump. And it’s at that point of the bump that the hammer hits the string and falls back. We call it the point of sound.” (Taubman Institute, 1995, vol. 1)
- c. Decision Rules - do not include statements about “aiming” related to the point of sound. These statements belong in the categories related to aiming.

5.1.3 There is no sound on the bottom of the key

- a. Definition - statements that refer to the idea that once the hammer has hit the string, the pianist can no longer do anything to impact that sound. This includes statements related to there being “no sound on the bottom of the key,” or other related statements.
- b. Examples - “The first thing is that when we put a key down, if you look inside the keyboard, you’ll see that by the time we get to the bottom of the key, the hammer has already hit the string and fallen back.” (Taubman Institute, 1995, vol. 1)
- c. Decision Rules - None.

5.1.4 The keys are weighted

- a. Definition - any statements related to the keys as “weighted.” Also include excerpts related to “overcoming surface resistance.”
- b. Examples - “If you place a, if you put pencil over several keys, you’ll feel how heavy it is. In other words, several notes, 2, 3, 4, 5 notes, will be clearly much heavier than playing one note. The keys are weighted.” (Taubman Institute, 1995, vol. 1)
- c. Decision Rules - None

5.1.5 The keys hit back with equal force

- a. Definition - Any statement that the keybed hits back at the pianists’ fingers with equal force to that which is applied in depressing the key.
- b. Examples - “Also when we hit the key very, very fast, the key hits us back with equal force. Every action has a reaction equal and opposite to itself.” (Taubman Institute, 1995, vol. 1)
- c. Decision Rules - This includes statements that use the term “push off” in a positive sense. Those statements do not belong in the “don’t push” category.

5.1.6 Miscellaneous - Piano characteristics

- a. Definition - any statements related to the physical mechanism of the piano that are not included in the above categories.

5.2 Before playing

5.2.1 The fingers should rest down on keyboard

- a. Definition - any statement that is related to the concept of “resting down” on the keys before playing. Also include statements related to finding the “correct balance” on the keyboard.
- b. Examples - “And in order to create the correct balance at the keyboard, one should feel that they are resting down without the keys going down” (Taubman Institute, 1995, vol. 1)
- c. Decision Rules - Do not include statements about resting on the key bottom when playing. Only includes statements on what happens before playing

5.2.2 Don't hover/relax before playing

- a. Definition - any statement that discourages holding up, hovering, or relaxing before playing.
- b. Examples - “[The shoulders are stable points] which are not held up or relaxed down. Holding up and/or relaxing down would hinder the motion of the playing apparatus.” (Moran, 2008)
- c. Decision Rules - Only refers to statements related to hovering/relaxing when playing. Do not include statements related to hovering before playing. If it is not clear whether a statement refers to hovering before or during playing, it belongs in the relevant category that describes the “during playing” condition.

5.2.3 Correct position/sitting height impacts resting down

- a. Definition - any statement that is related to how joint position/sitting height relates to the pianist's ability to rest down on the keys. This includes statements about both the correct and incorrect sitting heights.
- b. Examples - “If I'm sitting very high and by the way I have to say something about people often think that the height of the chair has to do with the size of the person. But it doesn't have to do with the size of the person. It has to do with the length of the upper arm. If the upper arm is short clearly you have to bring yourself to a level where again the elbow will be on the same level as the keys. If you have a very long upper arm that extends all the way down the chair will have to come up. Whatever it is you have to end up with an elbow that extends on the street plane this way. Now if I'm sitting up immediately if we're talking about unifying all the parts and feeling that we can rest down” (Taubman Institute, 1995, vol. 1)
- c. Decision Rules - Only include the statements related to the sitting height or position. Do not include statements related to the concept of “unity,” unless they are mentioned in relation to sitting height or position. Do not include statements related to “support” regardless of whether or not they relate to sitting/position.

5.2.4 Miscellaneous - Before playing

- a. Definition - any statements related to joint position or muscular state before playing that are not included in the above categories.

5.3 When playing

5.3.1 Finger should stand on ke(y)/keybed

- a. Definition - Any statement about the correct feeling or state of the finger when it is keeping a key depressed. Words for this correct feeling/state can include resting, balancing, standing, settling, or being solid on the keybed. Also include comparisons to standing or walking away from the piano as they apply to the standing finger/foot. Also include statements about limiting finger speed.
- b. Examples - “When you come to the bottom, just feel very easy and rested.” (Taubman Institute, 1995, vol. 1)
- c. Decision Rules - Only refers to statements about the correct approach to being on the key bottom. Do not include statements about the incorrect form of keeping the key depressed (i.e. pressing, pushing, etc.), which have a separate category. For statements including the word “standing,” this category only applies to standing on the key, not comparisons to standing on one's feet. Those references belong in the category “comparisons to standing/sitting.”

5.3.2 Do not push on the key(s)/keybed

- a. Definition - Any statement that describes applying too much force to the keybed (bottom of the key). These statements do not have to use the word “keybedding,” but may use other, descriptive terms instead. Relevant terms can include: pressing, forcing, squeezing, exerting, pushing, etc. Also include statements that discourage excessive finger speed.
- b. Examples - “There is no pushing and forcing...at the bottom of the key” (Taubman Institute, 1995, vol. 1); “When you're playing loud, you're squeezing on the bottom...Stop pushing so hard.” (Taubman Institute, 1995, vol. 1)
- c. Decision Rules - only refers to statements about the incorrect approach to being on the key bottom. Do not include statements about the correct way of keeping the key depressed (i.e. balancing, standing, etc.), which have a separate category. If a statement about fast fingers is compared to horizontal speed, it belongs in the “speed tool” category. If it generally discourages high finger speed it belongs in this category. Fast finger exercises (related to strength) belong in the isolation category.

5.3.3 Do not hover when playing

- a. Definition - any statement that discourages hovering while on the keybed or when depressing the key. Also include statements that discourage releasing the key to some degree before playing the next note.
- b. Examples - “Sometimes the problems, I will hear someone play, and I see a lot of the playing is very coordinated, except in the soft playing. When everything tends to feel like that (holds arms/shoulders up): hovering up.” (Taubman Institute, 1995, vol. 1)
- c. Decision Rules - Only refers to statements related to hovering when playing. Do not include statements related to hovering before playing. If it is not clear whether a statement refers to hovering before or during playing, it belongs in this category.

5.3.4 Do not relax when playing

- a. Definition - any statement that discourages relaxing while on the keybed when depressing the key. Also include statements related to collapsing, sinking, or any other related terms.
- b. Examples - “I will constantly tell you it’s not a relaxation. A relaxation is going beyond the resting, the lack of tension point. Relaxation is an activity. Relaxation is when I got there (plays chord) I continue dropping, and all the fulcrums begin to fall. Now what happens when we relax, and I have to say something about it because it’s used much as a tool, that when we relax, we relax both muscles. As I told you when you move freely, one muscle is active and the other is passive. When you relax, you relax both.” (Taubman Institute, 1995, vol. 1)
- c. Decision Rules - Only refers to statements related to relaxing when playing. Do not include statements related to relaxing before playing. If it is not clear whether a statement refers to relaxing before or during playing, it belongs in this category.

5.3.5 Miscellaneous - When playing

- a. Definition - any statements related to joint position or muscular state while playing that are not included in the above categories.

5.4 Aiming

5.4.1 Aim to the point of sound

- a. Definition - any statement that encourages aiming to the point of sound during key depression.
- b. Examples - “Just aim for the point of sound.” (Taubman Institute, 1995, vol. 1)
- c. Decision Rules - None.

5.4.2 Don’t aim past the point of sound

- a. Definition - any statement that discusses aiming past the point of sound or aiming to the bottom of the key during key depression.
- b. Examples - “Matthay was the first to describe the phenomenon of aiming past the point of sound to press on the key, which he named keybedding.” (Milanovic, 2012, p. 141)
- c. Decision Rules - None.

5.4.3 Follow through/don’t stop at the point of sound

- a. Definition - any statement that discourages stopping at the point of sound. Also include statements that discuss the necessity of “following through” after passing the point of sound during key depression. This includes comparisons to other, non-pianistic activities that require a similar follow through.
- b. Examples - “Now it’s very important to realize though that we don’t stop at the point of sound, because we will be hovering.” (Taubman Institute, 1995, vol. 1)
 - i. “there’s a follow through as with any movement. You can time a ball coming at you, but you don’t stop there. You aim your greatest force at it, and then there’s a follow through.” (Taubman Institute, 1995, vol. 1)
- c. Decision Rules - None.

5.4.4 Miscellaneous - Aiming

- a. Definition - any statements related to aiming that are not included in the above categories.

5.5 Arm/hand should support finger when playing

5.5.1 Arm/hand should support the finger(s) when playing

- a. Definition - Any statement related to the idea of the hand/arm supporting the finger when keeping the key down. Include statements that involve using weight or having weight resting down in order to keep the key down.

- b. Examples - “The finger going down, and the hand and the forearm invisibly support the finger as it goes down” (Taubman Institute, 1995, vol. 4).
- c. Decision Rules - Do not include statements related to weight that are not related to key depression (for example related to sitting height and weight falling). Do not include statements about too much or too little weight on the bottom of the key (pushing and hovering respectively). Include statements about unity that are compared to isolating. Do not include the feelings (solidity, easy, evenness) that result from support, which go in the “finger should stand” category.

5.5.2 Finger should not isolate/play without support

- a. Definition - Any statement that the finger should not isolate when putting the key down or put the key down by itself. Include any statements that describe the finger as not having hand/arm support.
- b. Examples - “In a coordinated technique finger movements are never isolated from the hand and arm” (Taubman, 1984, p. 146).
- c. Decision Rules - Do not include consequences of isolating related to pushing, pressing, grabbing tc., which belong in category... Also, do not include statements related to isolation in lifting the fingers, which belong in the non-playing fingers category.

5.5.3 Finger should be straight down/not tilted

- a. Definition - Any statement that the finger should be straight when putting the key down or that the fingers should not be tilted. Include statements related to tilting when it is considered correct.
- b. Examples - “As you see, when I land on it, I don’t land tilted, as I said yesterday about hand positions, that if you end of tilted, the weight is not supporting those fingers” (Taubman Institute, 1995, vol. 2).
- c. Decision Rules - Include statements that discuss “support” related to tilting in this category.

5.5.4 Non-playing fingers should hover closely above/rest lightly on keys

- a. Definition - Any statement that the non-playing fingers should hover close to keys or rest on them lightly. Also include any other statements discouraging the pianist from resting heavily with the non-playing fingers or lifting them very high.
- b. Examples - “The other thing is that the fingers that don’t play, should not rest heavily on the keys. In other words, if I’m moving from 1 to 2 and I played The 2 and 3, 4, and 5 rest heavily, the keys are not going down, but there’s a great deal of resting down on 3, 4 and 5, the resting on those fingers removes the weight from the second finger. So it will still feel isolated to truly be over that second finger, those fingers, they feel down, but they barely touch the keys. They hover very closely to it, this way” (Taubman Institute, 1995, vol. 2).
- c. Decision Rules - Include statements that discuss “isolation” related to lifting the fingers in this category. Also include statements that discuss to “supported” related to the non-playing fingers in this category.

5.5.5 Miscellaneous - Support

- a. Definition - Any statement related to support of the finger that is not included in the above category.

5.6 Problems Associated with Keybedding

5.6.1 Physical Problems

5.6.1.1 Keybedding can cause tension

- a. Definition - Any statement that keybedding (or related terms) causes tension. Statements can be about tension in a general sense, or related to a specific body part.
- b. Examples “(What’s important about it is that we still land on the bottom of the key, but that there is no pushing and forcing...at the bottom of the key) which creates a tremendous amount of tension” (Taubman Institute, 1995, vol. 1); “Tension in the wrist may be caused by [pressing the fingers too hard into the bottom of the keys].” (Taubman, 1984, p. 151)
- c. Decision Rules - None.

5.6.1.2 Keybedding can cause calluses/bleeding fingertips

- a. Definition - Any statement that keybedding (or related terms) causes bleeding fingertips
- b. Examples - “When it does that, we end up with calluses and bleeding tips. That’s what happens from hitting a surface so hard.” (Taubman Institute, 1995, vol. 1)
- c. Decision Rules - None.

5.6.1.3 Keybedding can cause pain/injury/tendinitis

- a. Definition - Any statement that keybedding (or related terms) causes tendonitis or pain

- b. Examples - "Further, keybedding can cause pain on the underside of the forearm, and has been linked with tendinitis and other injuries" (Milanovic, 2012, p. 141)
- c. Decision Rules - None.

5.6.2 Technical impacts of excessive speed/force

5.6.2.1 Keybedding can cause harsh sound/faster decay

- a. Definition - Includes any statement that keybedding creates a harsh sound. Also include statements that harsh sound is caused by going to fast into the key. This includes references to how hitting the keybed too hard/fast can cause a negative "rebound,. Do not include statements regarding a positive "rebound" in octave playing.
- b. Examples - "unless they are going very fast into the key, and there are technical problems that happened as a result, and also the sound is very harsh" (Taubman Institute, 1995, vol. 1)
- c. Decision Rules - None.

5.6.2.2 Keybedding can limit playing speed

- a. Definition - Any statement that keybedding or excessive force applied to the key reduce the player's capability to play quickly.
- b. Examples - Ortmann's studies proved that playing a key with excessive force actually limits overall speed as the key rebounds before resting on the keybed" (Milanovic, 2012, p. 141)
- c. Decision Rules - None.

5.6.3 Miscellaneous - Problems associated with "Keybedding"

- a. Definition - any statements regarding the tactile feeling of keybedding (or related terms) that can be physically enjoyable, even though this is considered an incorrect/harmful way to play.
- b. Examples - "Keybedding is addictive, stimulating the tactile nerves, and promoting a false impression of involvement in the music and musical intensity through physical tension" (Milanovic, 2012, p. 142)
- c. Decision Rules - Do no include the positive feelings associated with the correct way of playing, which belong in the category "Correct feelings on the key bottom"

5.7 Miscellaneous - "Keybedding"

- a. Definition - Any statements related to "Keybedding" that do not fit into the other categories.

Appendix C: Photos of finger/hand positions related to “Curling” analysis

Figure A1. *“Curling”*



Figure A2. *“Natural Curve”*



Figure A3. *“Lining up” the fingers*

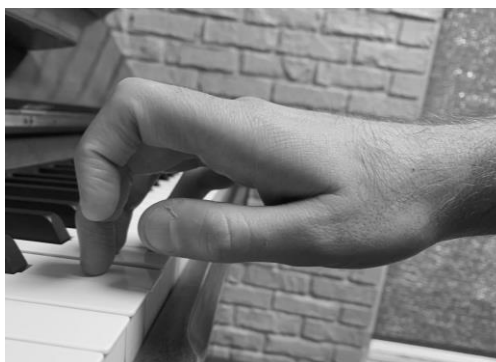


Figure A4. *“Curling” and MCP extension*



Figure A5. *Extension from the “main knuckle”*



Figure A6. *“Curling” to play out with a longer finger*



Figure A7. *“Broken nail joint”*



Figure A8. *“Curled nail joint”*



Figure A9. *“Straight nail joint”*



Figure A10. *“Curling” with a low wrist*



Figure A11. *“Curled” thumb*



Figure A12. *Thumb in “Natural Curve”*

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