

Warm-ups for musicians: Systematized and Terminology Reviews

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Abstract

Context: Many musicians experience playing-related pain and injuries. One of the recommended injury prevention strategies is to warm-up prior to playing¹ a musical instrument. However, this recommendation is not always supported with empirical data. Additionally, multiple terms are used to describe warm-ups and may differ between authors, creating confusion around this injury prevention strategy. **Objectives:** The objectives of this thesis are to search for evidence-based studies that would support the benefit of warm-ups for musicians, reduce the confusion around musicians' warm-ups, and bring clarity to the definition of warm-up. **Methodology:** In order to do so, this thesis presents two studies. The first study consisted of doing a systematized review of English published articles in order to identify if there was evidence to support the statement that warm-ups prevent injury. The methodology and results of each included article were evaluated using the American Academy for Cerebral Palsy and Developmental Medicine (AACPDM)'s levels of evidence. The second article consisted of a terminology review and taxonomy in order to identify terms, organize them into categories and define warm-ups. The corpus contained the same articles that were included in the systematized review. Terms were identified from the corpus and the most frequently mentioned terms were used for the definition of warm-up. Terms were also categorized in a taxonomy in order to illustrate the different types of warm-ups that are recommended to musicians. **Results:** Twenty-nine studies were included in the analysis of the systematic review. Of these 29 studies, only one ranked at level I, which is the highest level of evidence, and most studies ranked at level V. The one study that was ranked at level I indicated that all three tested warm-up conditions did not have a muscular effect. Therefore, at the moment, there seems to be no evidence that supports the statement that warm-ups prevent injury.

¹ Throughout this thesis, the phrase "prior to playing" refers to prior to playing repertoire or learning new material which reflects the use of this phrase in the literature.

The terminology review led to the following definition of warm-up: “A routine, habit or exercise(s) that is/ are completed prior to playing repertoire or learning new material on a music instrument in order to prepare physically and mentally the musician. The following can be included as part of a musician’s warm-up: physical warm-up (completed without the instrument, for example stretches), musical warm-up (completed with the instrument, for example: scales, familiar tune/ favorite tune, long tones), and psychological warm-up.” It was also determined that stretching should also be defined as it is not always perceived as a warm-up. Stretching was defined as “Slow, controlled and progressive movements that are maintained for at least 20-30 seconds. These are done at various intervals throughout the day such as prior, during (breaks), and after the practice of a music instrument. They are referred to as physical exercises (away from the instrument). The following are some examples of stretching exercises: wrist rotations, forward neck roll, oppositional finger-wrist press, hand-finger extensions, fist clench and unclench, arms-bicep curls, handshakes, arms-triceps extension, and fingers clenched and unclenched.” The taxonomy indicated three warm-up categories: physical, musical and psychological. The physical and musical warm-ups were then subcategorized. It was not possible to subcategorize psychological warm-ups due to a lack of definition and examples in the literature. This study was a first step towards standardization, but further research is necessary in order to standardize a methodology and protocol.

Keywords: warm-up, stretching, musicians, music, injury prevention

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Introduction

Musicians experience occupational pain and injuries, which can be grouped in three categories: musculoskeletal disorders and overuse syndromes, entrapment and peripheral neuropathies and focal dystonias (Tubiana and Amadio, 2000; Foxman & Burgel, 2006). The most prevalent diagnoses among musicians are musculoskeletal disorders (Tubiana and Amadio, 2000; Foxman and Burgel, 2006; Burkholder and Brandfonbrener, 2004). According to Punnett and Wegman (2004), musculoskeletal disorders are defined as “a wide range of inflammatory and degenerative conditions affecting the muscles, tendons, ligaments, joints, peripheral nerves, and supporting blood vessels” (p. 13) and according to Burkholder and Brandfonbrener (2004), musculoskeletal pain syndrome refers to “pain, tightness, stiffness, or tenderness in the muscle-tendon unit (also called *overuse syndrome*)” (p. 117). According to many authors (Brandfonbrener, 1997; Barton and Feinberg, 2008; Spahn, Hilderbrandt, and Seidenglanz, 2001; Spahn, Richter, and Zschocke, 2002; Zaza, 1993; Zander, Voltmer, and Spahn, 2010) a possible solution to reduce musicians’ musculoskeletal disorders is to offer injury prevention strategies or programs. Many researchers (Spaulding, 1988; Zaza, 1994; Brandfonbrener, 1997; Parry, 2003; Tubiana and Amadio, 2000) have recommended warming-up prior to playing an instrument as a prevention strategy. This thesis will therefore investigate the concept of warming up prior to playing a musical instrument. In order to address this topic and explain the need for our research, the literature review will report on the rate of musicians’ musculoskeletal disorders and the current injury prevention programs and strategies for musicians. Then, it will inform on the recommendation of warm-ups as an injury prevention strategy. This will be followed by some background information on the chosen methodology for two studies and then presenting the studies in their entirety. The first study is a systematized review that evaluated the evidence to support the statement that warm-ups prevent musicians’ playing-related injuries. The second

study is a terminology review and taxonomy to provide a list of terms, categorizing them into a taxonomy and synthesizing them into a definition.

Chapter 1

Review of Literature

Musculoskeletal pain and injury among musicians

Professional musicians

Professional musicians experience occupational pain and injuries due to the high demand of the profession on the musculoskeletal system including posture while playing the instrument, repetitive movements and the intensity of practice routines (Ackermann, Adams and Marshall, 2002; Abreu-Ramos and Micheo, 2007; Chan et al., 2014; Dawson, 2008; Zaza and Farewell, 1997). Fishbein and colleagues (1988) provided an overview of a national survey of professional orchestra musicians. The procedure consisted of distributing a questionnaire on medical problems, musculoskeletal symptoms, musculoskeletal diagnoses and medical treatments to the musicians of the 48 orchestras affiliated with the International Conference of Symphony and Opera Musicians (ICSOM). Two thousand two hundred and twelve musicians participated in the study, which represents 55% of the ICSOM musicians. Seventy six percent of the performing musicians among the orchestras reported having a severe medical problem that affected their performance. The neck and back were the most mentioned for musculoskeletal problems. The medical problems were related to various characteristics such as gender, age and instrument group.

Lederman (1989) evaluated instrumentalists for playing-related symptoms. His method consisted of physically assessing musicians from January 1, 1979, to December 31, 1987. He examined each participant while playing his or her instrument and most of the instrumentalists underwent additional tests such as blood analysis, X-ray, neuroimaging studies, electrodiagnostic studies and electromyography. Lederman assessed 226 musicians: 103 string instrumentalists (bowed and plucked strings); 73 keyboard instrumentalists; 44 wind instrumentalists (woodwind

or brass); and 6 percussion instrumentalists. Of these participants, 139 musicians, representing 62% of the assessed instrumentalists, had diagnoses characterized as musculoskeletal and a majority had a form of muscle-tendon overuse.

Yeung and colleagues (1999) studied the prevalence and possible risk factors of playing-related musculoskeletal complaints among musicians of the symphony orchestras in Hong Kong. The method was to distribute a questionnaire to the professional musicians during a rehearsal and to collect the completed questionnaires within fourteen days after the rehearsal. The questionnaire was designed based on previous surveys (Zaza, 1992; Zaza and Farewell, 1997). One hundred seventy questionnaires were distributed to musicians of three professional orchestras in Hong Kong and 39 professional musicians completed the survey (Yeung et al., 1999). The results indicated a one-year playing-related musculoskeletal complaint prevalence of 64% and two predictive factors were identified: less experience in playing and lack of regular exercise.

Abreu-Ramos and colleagues (2007) established the prevalence of musculoskeletal problems that affect the performance ability of professional musicians and the relation of these problems to gender, age and instrument. The method consisted of distributing a questionnaire on the history of musculoskeletal problems to volunteer musicians from the Puerto Rico Symphony Orchestra. The participants were then asked to complete a neuromusculoskeletal upper-body examination. Seventy musicians participated in this study and 81.3% of the participants reported having an upper-body musculoskeletal problem that affected their ability to play over the course of their lifetime. Of these musicians, 83.6% reported that their musculoskeletal problem was directly associated to playing. According to these researchers, the contributing factors for

musculoskeletal problems were hours of exposure, technical expertise, female gender, age and instrument played.

Ackermann and colleagues (2012) studied performance-related musculoskeletal disorders of professional musicians in symphonic and pit orchestras. The procedure consisted of distributing a survey to musicians from eight Australian orchestras. The questionnaire was divided into three main sections: physical and demographic data, psychological stressors and symptoms, and validation tests to compare the results from the first two. According to these researchers, 377 musicians provided useable data. The results indicated that 84% of the participating musicians had experienced pain or injuries that had interfered either with playing their instrument or participating in rehearsals and performances.

Silva and colleagues (2015) investigated the prevalence of pain among different musician groups, sex and body regions with a systematic review. The method consisted of searching the following databases from the 1st of January 2000 until December 2012: PubMed, Web of Science, Academic Search Complete, Science Direct, and Scielo. Studies' titles and abstracts were screened by two reviewers and a meta-analysis of pain prevalence was performed when possible. Eighteen studies were included in this review and were all based on a self-report methodology. The results indicated that pain is prevalent over periods of one week, one month, one year or even a lifetime. The prevalence of pain for musicians varied between 29% and 90%, and pain affecting playing capacity varied between 25.8% and 84.4%. It was also found that the lower back (9.8% to 66.7%) and neck (9.8% to 48.5%) were the most affected body regions. Silva and colleagues concluded that "pain prevalence is high among musicians, independent of the pain definition and time period used."

Music students

High rates of injury and pain are not limited to professional musicians, they may also be experienced by music students. Hagglund (1996) studied the general physical and mental habits of music students and the associated risks for music-related injuries. The method consisted of asking participants to complete a questionnaire. This questionnaire was divided into three main sections: practice habits and past or present injury; injury treatment; various physical and mental aspects of musicians. For this study, 137 music students from the New England Conservatory and 45 music students from the Boston University of Music School participated. Eighty-four students (61%) from the New England Conservatory and twenty-eight students (65%) from the Boston University reported having music related injuries; however, only thirty-eight New England Conservatory students and eighteen Boston University students pursued diagnoses. This study also indicated that the first occurrence of the injury appeared during high school or during undergraduate studies. Of the New England Conservatory participants, 30% reported the first occurrence of injury during high school and 32% during the freshman and sophomore years of college. Of the Boston University participants, 17% indicated that their music related injuries occurred during high school and 82% that it occurred during their undergraduate studies.

Zaza (1992) studied the extent to which music students experienced playing-related health problems and assessed their knowledge of playing-related health problems. She also studied the practice habits and familiarity with techniques for body awareness, relaxation and body movement. The method consisted of distributing a questionnaire at the end of the following ensemble rehearsals: symphony orchestras, concert band, university choir chamber singers, women's chorale, men's chorale, jazz ensembles and baroque ensembles. Three hundred students participated in this study. Forty-three percent of the students reported having been affected by a

playing-related health problem and 69% stated that they knew the meaning of tendinitis, however only 39% gave the correct definition.

Guptill and colleagues (2000) examined the prevalence among music students of playing-related injuries, their opinions on the need for professionals with specialized knowledge of music and musicians, and their satisfaction with received treatments. The method consisted of surveying three instrumental ensembles at a large mid-western university. The questionnaire included three major sections: demographic information, treatment history/ perceptions of professionals, and treatments. One hundred and eight participants completed the questionnaire. However, two were excluded as they were not majoring in music. Ninety-three of one hundred and six participants (87.7%) experienced playing-related injuries and 44% of these students reported that they had consulted health professionals, though only 24.7% sought treatments. Most participants (86.9%) were satisfied with their treatments and 79% of the respondents felt that musical knowledge was important for health professionals that are treating musicians.

This high rate of pain and injury was also reported by children and teenagers who are studying music. Shoup (1995) studied the prevalence of musculoskeletal problems in junior high school and high school students who were enrolled in the school band or orchestra. The method consisted of creating a survey which included questions on practice habits, warm-ups, attitude regarding playing through pain, medical history, performance anxiety and treatments for symptoms. Four hundred and twenty-five high school students answered the questionnaire. The results indicated that 33.2% of the participating students had suffered from a musculoskeletal problem at some point since they began to play their musical instrument. Of these students, 51.9% reported the problem as current. Therefore, the high rate of injury and pain is not limited

to professional musicians or university music students and can be experienced as a teenager learning a musical instrument.

Rannelli and her colleagues (2008) researched the prevalence of playing-related musculoskeletal problems of children enrolled in instrumental music programs in primary and secondary schools in Australia. The methodology consisted of asking children of 7 years or older to complete a modified version of the Young Peoples Activity Questionnaire. This modified survey included music-specific questions and the main focus was playing-related musculoskeletal problems. The locations of symptoms were reported with a visual analog scale. A total of 731 children participated in this study. Sixty-seven percent of the participating children reported experiencing playing-related musculoskeletal symptoms and more than half of these children (56%) reported the occurrence of these symptoms on a monthly basis. Of those who experienced symptoms in the last month, 5% took medication to relieve the problem and 4% sought advice from health professionals.

Injury prevention strategies and programs

Overview of research on injury prevention

In order to address the high rate of musculoskeletal injury among musicians, many authors of published articles, such as Zaza (1993), Brandfonbrener (1997), Barton and Feinberg (2008), Spahn and colleagues (2001; 2002) and Zander and colleagues (2010) suggest the use of injury prevention strategies and/ or programs. Zaza (1993) provided a rationale for the prevention of playing-related health problems based on the guidelines of the Precede-Proceed Health Promotion Framework by Green and Kreutzer of 1991 (as cited in Zaza, 1993). According to Zaza's diagnostic analyses (1993), there are various extrinsic risk factors for musicians' injuries that are behavioral and changeable such as stress, technique, or practice

habits, therefore a prevention program for musicians is realizable. This researcher also states that a program for musicians is in demand due to the populations' concern for playing-related health problems. Another reason for a prevention program's necessity is that music students are not consistently aware of the possible health conditions related to being a musician or on how to prevent them. Therefore, according to Zaza, injury prevention programs are possible and valuable for musicians.

Brandfonbrener (1997) studied the implementation of specific intervention strategies in order to determine whether occupational injuries of musicians are preventable. The method consisted of developing a prevention program based on musculoskeletal education and specific exercise protocols. Participating orchestras were visited 3 times (at the start of the fall season, midseason and the following fall) and musicians were asked to complete a questionnaire on demographics, instruments, playing habits, pain, medical care sought, health habits, stress and attitudes about health. After a didactic lecture, musicians were assigned one of two types of exercises: strengthening or flexibility, switching at the midseason. Physical assessments including the range of motion of all upper-extremity joints, individual manual muscle testing, and objective measurements of grip and pinch strength were completed at each visit. The participants for the experimental group were volunteers from 6 orchestras and the control group consisted of musicians from 3 orchestras. The controls did not receive the didactic lectures nor were they assigned one of the exercise protocols. This study was not able to conclude if musicians' injuries were preventable due to a high attrition rate in participation, however both control and experimental groups indicated an improvement in musculoskeletal symptoms which suggests a positive effect of allowing musicians to focus on their problems. It would have been helpful, though, to solicit the opinions of those who dropped out in order to understand what

could have been done to retain their participation. This approach was validated as three-quarters of the respondents indicated that they would consider participating in a similar study and that they would continue some of the exercises on their own. The health insurance carrier of one of the experimental orchestras even reduced its rates due to fewer claims being made, but the data were insufficient to determine whether or not this was due to the intervention.

Spahn and colleagues (2001) investigated the effectiveness of a 17-week summer course on the prevention of playing-related health problems which combined lectures and practical exercises. Standardized questionnaires were completed at the beginning and at the end of the course. The forty-four participating students of the Zürich Conservatory were divided equally into two groups: experimental and control. The controls volunteered for the study but did not attend the classes. The results indicated that the playing-related symptoms, general symptom frequency, emotional disturbances, and anxiety level decreased for the experimental group. This group also experienced an improvement in general coping with work as a musician. However, the authors suggested that “the effects measured in this study need to be confirmed by further studies with a randomized design” (Spahn et al., 2001, p. 24).

Spahn and colleagues (2002) studied music students’ health attitudes, preventive behaviors when using body-oriented training and playing related symptoms. These researchers also investigated if students consulted with health professionals for their musculoskeletal symptoms. The method consisted of distributing the following standardized questionnaires to students at the Freiburg Conservatory: *The Epidemiological Questionnaire for Musicians* and the *Questionnaire to Measure Illness and Health Locus of Control*. One hundred ninety-seven music students participated in this study. As demonstrated by the results, students believed that health can be influenced by their behavior. However, body-oriented training was not practiced for

preventive reasons as it was instead motivated by a need for therapy. Two thirds of the music students indicated that they had suffered from playing-related problems and half of the musicians had sought professional help. The authors' concluded: "There is minimal consciousness regarding questions of health problems, so that few music students have taken preventive measures up to the present time" (p. 22) and that preventive courses should be offered in order to motivate the music students for a proactive health-promoting behavior (Spahn et al., 2002).

Barton and Feinberg (2008) examined the effectiveness of an eight-week course in health promotion, injury prevention strategies and common injuries among musicians. The method used was a series of questionnaires on the use of health and injury prevention measures. These were answered before class, right after and six weeks later. The participants were 26 freshman music students of a private Midwestern university. The students improved in their overall knowledge of the subject and retained the information six weeks later. However, the execution of health promotion and injury prevention strategies only improved 6 weeks after the end of the course.

Zander and colleagues (2010) studied health among music students and the effectiveness of a preventive curriculum. The method consisted of a longitudinal observational study during the first 2 years of university training. The authors compared data from the group who had followed the prevention program in the form of a one-year course (two semesters) with data of a comparison group of students who had not followed the program. Data was measured with standardized questionnaires which were completed during three testing periods: before the intervention, at the end of the intervention and at the end of the second year. The intervention group had 144 participants and the control group without the intervention had 103 participants. The results indicated that "the prevention program had a preventive effect on the students'

psychological health” (Zander et al., 2010, p. 54). However, the prevention program did not reduce physical symptoms.

Lack of empirical data on injury prevention

According to Dr. Chesky, *Cofounder and Director of Education and Research, Texas Center for Music and Medicine, University of North Texas, Denton, Texas*, and colleagues (2006), “performance injuries are preventable” (p. 142) and “prevention education is the foundation for injury prevention” (p. 143), however, these statements are not supported by empirical data. In the studies presented above, it is interesting to note that these studies were not able to clearly establish if musicians’ injuries are preventable. Brandfonbrener (1997) was not able to determine whether injuries are preventable due to the high attrition rate of her participants. Zander and colleagues (2010) found that their injury prevention program had a psychological effect but did not affect the physical symptoms. Spahn and colleagues (2001)’s results indicated that playing-related symptoms and their frequency decreased for musicians who attended a course, but the researchers concluded that further studies were required in order to confirm their results. Burkholder and Brandfonbrener (2004) also recommend preventative behaviors as they can have a beneficial effect for musicians, however they specified that “further investigation is needed to develop and evaluate such strategies” (p. 122). Other authors of published articles suggest the use of injury prevention strategies, but do not provide their own empirical data on the subject (Chesky, Dawson and Manchester, 2006; Guptill and Zaza, 2010; Spaulding, 1988; Parry, 2003). Research results are not conclusive and there is a clear need for further studies.

It is also important to establish the limitations of the existing literature in order to identify research gaps. Firstly, most studies (Barton and Feinberg, 2008; Spahn and colleagues, 2001;

Spahn and colleagues, 2002) relied on self-reports and only Brandfonbrener's (1997) included physical assessments with inconclusive results. Self-reports provide useful information to researchers on the perceptions of the participants, however they are subject to bias and should not be used as the sole data collection method. It would also be useful to have studies that include physical assessments of musicians before and after the use of an injury prevention strategy. According to Adams and colleagues (1999) from the Department of Ambulatory Care and Prevention of Harvard Medical School and Harvard Pilgrim Health Care and the Canadian Health Services Research Foundation, one of the possible participation biases in self-reports is social desirability, where the participant reports what is socially desirable. For example, a participant might describe that his rate of injury diminished following an injury prevention course as this could be perceived as the socially desirable outcome of this study rather than actually observing this outcome. Secondly, most studies (Brandfonbrener, 1997; Barton and Feinberg, 2008; Spahn et al., 2001; Spahn et al., 2002; Zander et al., 2010) are based on volunteer participation and are therefore prone to volunteer-based bias. According to Spahn and colleagues (2001), students with playing-related symptoms were more likely to participate in a study on injury prevention than students without symptoms. Brandfonbrener (1994) also reported that there were a greater number of musculoskeletal symptoms in the experimental group of her injury prevention study than in the control group. Finally, the injury prevention strategies or programs being studied are not standardized and each study had its own method to convey preventative measures to musicians. For example, Brandfonbrener (1997)'s study made use of didactic lectures and an exercise protocol, Barton and Feinberg (2008) examined the effectiveness of an eight week course in health promotion, injury prevention strategies and common injuries among musicians, and Spahn and colleagues (2001) investigated the

effectiveness of a 17 week summer course on the prevention of playing-related health problems which combined lectures and practical exercises. The results of these studies are therefore difficult to compare as some included practical exercises and others did not, and the length of time for the theoretical component was different for each study.

Warm-ups as an injury prevention strategy

Many authors propose specific injury prevention measures. In Tubiana and Amadio (2000), these measures could include: good posture and gesture, breathing while playing, warm-ups, frequent breaks, cognitive rehearsal such as reading or singing without an instrument, and task variability, for example, a variation of repertoire being practiced (Tubiana and Amadio, 2000). Among all these measures, warm-ups is a strategy mentioned by many authors of published academic articles in the field of injury prevention for musicians (Brandfonbrener, 1997; Guptill and Zaza, 2010; Parry, 2003; Spaulding, 1988; Zaza, 1994). Brandfonbrener (1997) included warm-ups as part of the exercise protocol in her study on injury prevention; participants were encouraged to warm-up for five minutes before playing and before doing the assigned strengthening and flexibility exercises. Parry (2003) also mentions that warm-ups may prevent injury: “musculoskeletal symptoms are greatly diminished by obeying the cardinal rules of a sound practice regimen: proper warm-up, not just scales or exercises but stretching, breathing, full body flexibility exercises, in fact, a whole body warm-up” (p. 19). Guptill and Zaza (2010) mentioned warm-ups as a strategy for the prevention of injury and indicate that “students should be advised against playing with cold hands in a cold room, for reasons of intonation and instrument care as much as for injury prevention” (p. 29).

Lack of empirical data on warm-ups

There is a lack of data in the literature that recommends warm-up as an injury prevention strategy. Zaza (1994) recommends warming-up prior to playing a music instrument in order to prevent playing-related injuries and provides a reference to empirical research. She mentions that “many experts agree that warming-up helps to reduce risks of strains” (p. 3) and quotes Safran and colleagues’ (1988) study to support this statement. Safran and his colleagues’ (1988) study concluded that warming up prior to an exercise may prevent muscular injury by increasing the elasticity of the muscle and the force and change of length required to tear the muscle. However, this research studied muscle tearing of ten rabbits, which might not be applicable to musicians. Therefore, the empirical justification for warm-ups for musicians is questionable.

Some authors of textbooks on musicians’ wellness also recommend warm-ups. According to Paull and Harrison (1997), a warm-up routine should be completed by musicians in order to counteract playing-induced injuries, however, these authors do not cite empirical research that indicates if a warm-up routine does counteract playing-induced injuries. Other authors such as Horvath (2009), and Tatz and Mayoroff (2010) also believe that warm-ups are necessary for the wellbeing of musicians. Warming-up is the first of Horvath’s five essential practice rules in order to reduce the risk of injury and she justifies their importance because “warmed muscles are more efficient, strong and resilient” (p.198). She also indicates that a warm-up “increases blood and lymphatic circulation, increases cellular metabolism, loosens fascia and tendons [and] aids the joints to move with greater ease” (p. 113), however she provides no research data to support this statement. Tatz and Mayoroff (2010) recommend that musicians’ warm-up prior to playing challenging and technical passages as demonstrated by the following quote: “never start working on double stops and chords without properly warming up

the hands” (p. 90). This recommendation is justified with the following: “A ‘warmed up’ muscle can work for longer periods of time and had less danger of overworking and strain” (p. 90).

However, no research data is provided to support such statements. It seems that these statements are based on clinical experience, rather than empirical results. Clinical experience provides useful information but can be insufficient if the observer only relies on these types of data.

Another author who mentions warm-up as injury prevention is Watson (2009) who wrote the book *The biology of musical performance*. He mentions that “the first stage for preventing injury is to warm-up the muscles to be used” (p. 86), quotes Paull and Harrison (1997) and Horvath (2009) as some of his sources, and does not provide any research based information of his own.

Warm-ups are frequently recommended for musicians by various experts of musicians’ wellness as a method of reducing the risk for occupational pain and injuries. Authors quote each other and support their claims by what others have said, but it is difficult to find strong empirical research data.

Confusion around the concept of warm-up

While the recommendation for warm-ups as a prevention measure for musicians is not clearly supported by empirical research, another issue with the current literature is the lack of well-defined terminology. In various articles, the definition of warm-ups differs between authors and the concept is rarely clearly defined. Guptill and Zaza (2010) mention that “many teachers advocate a musical warmup, which is important in preparing the body and mind for performance” and that in order to prevent injuries, students should do a physical warm-up. Parry (2003) also says that a proper warm-up should include physical exercises such as stretching and full body flexibility exercises and that it should not be limited to music scales alone, the latter being a musical warm-up. Spaulding (1988) states that the daily warm-up routine of the

Trondelag Musikkonservatorium in Norway includes music composition, technical warm-up with instrument and physical warm-up.

In textbooks on musicians' wellness, Paull and Harrison (1997) indicate that a "warm-up means using muscles gently and smoothly for a few minutes to increase the blood flow through them without stressing them" (p. 110). Their recommended pre-practice routine includes a body warm-up with an aerobic activity such as cycling and dancing, followed by pre-practice stretches and another warm-up on the instrument which can include technical exercises and repertoire as long as it is moderately demanding and varied. Horvath (2009) also identifies a similar routine: "start with a five-minute brisk walk, or other aerobic activity. Next stretch (p. 196)." She then identifies the need to warm-up at the instrument but to "avoid strenuous technical exercises or phrases when you first begin" (p. 196). Watson (2009) specifies: "warm-up the muscles to be used, something which is done without the instrument. [...] Warm-up is best followed by the playing of some easy pieces or exercises concentrating on accuracy" (p. 86). Therefore, there seems to be at least two separate types of warm-ups with their respective terms: without the instrument, which may include the terms "stretching," "aerobic activity" and "brisk walk," and with the instrument, which may include the terms "technical exercises," "repertoire" and "pieces."

There are various possible terminology issues concerning the use of multiple terms. Firstly, not every term is defined. Watson (2009) does not define "warming-up the muscles". He indicates that a "warm-up is best followed by the playing of some easy pieces or exercises concentrating on accuracy" (p. 86), but no example of a warm-up which would not include the instrument is provided. Secondly, some terms are defined differently. For example, Horvath (2009) includes stretching as part of a warm-up as demonstrated by the following sentence:

“Stretching before you begin to play is essential to begin warming you up for the challenge of playing” (p. 196). However, she cites Peter DeLuca, M. D., clinical associate professor of orthopedics at Drexel University which contradicts her other definition:

One of the misconceptions is that stretching is a warm up, and it’s not.... You need to increase your core temperature so that all your muscles and tendons are being profused with blood.... Whatever you do to increase your body temperature is helpful whether it is jogging in place, or getting on a stationary bike for a couple of minutes. After warming up, then stretch. This will decrease any potential overuse injuries. (as cited in Horvarth, 2009, p. 117)

This would suggest that, stretching may be considered as a warm-up or as an activity to be done after warm-ups have already been completed. Finally, some terms are used in various contexts depending on the author. For example, Tatz and Mayoroff (2010) use the term “finger exercise” for different types of warm-up: physical warm-ups such as “finger exercise 1 warms up the muscles responsible for finger action in the hand and arm. Count to three in your head. “1, 2” – clench your fist- “3”- unclench your fist, letting your fingers half-bent” (p. 162), and musical warm-ups such as “finger exercise 10 shake your hands around. Stay relaxed as you do these examples [...] example VI play this chromatic scale up and down” (p. 165). The term “finger exercise” was not used by Paull and Harrison (1997), Horvath (2009), Guptill and Zaza (2010), Spaulding (1988) and Parry (2003). It is also interesting to note that Tatz and Mayoroff (2010) used terms interchangeably such as “morning warm-up” and “gymnastic exercises”. It seems like for these authors “morning gymnastics” is a synonym of “morning warm-up” which involves stretching exercises, however the use of these terms may be interpreted differently from one individual to another as there is no clear definition of both terms.

Research problems and purpose of the proposed studies

Professional musicians and music students are at high risk of developing occupational pain and injury (Ackermann et al., 2002; Abreu-Ramos & Micheo, 2007; Dawson, 1999; Dawson, 2008; Guptill et al., 2000; Hagglund, 1996; Lederman, 1989; Ranelli et al., 2008; Shoup, 1995; Zaza and Farewell, 1997). Warm-ups are frequently recommended in order to prevent musicians' injuries and are considered an essential part of preparation before playing a musical instrument (Paull and Harrison, 1997; Horvath, 2009; Tatz and Mayoroff, 2010; Watson, 2009; Zaza, 1994). However, there is little empirical research to support that recommendation. The first research problem is summarized by the following: **warm-ups are frequently recommended to musicians for injury prevention, but there is currently no assessment of the evidence supporting the use of warm-ups for the prevention of injury in music performance.** In order to address this problem, the first study for this thesis will be a systematized review on music and warm-ups. This review will present and rank the scientific evidence with the purpose of optimizing decision-making when suggesting injury prevention strategies for musicians. A number of research reviews have been done on the subject of warm-up and sports (McCrary, Ackermann and Halaki, 2015; Woods, Bishop and Jones, 2007; Bishop, 2003a; Bishop, 2003b; Safran, Seaber and Garrett, 1989; Sherlock and Prentice, 1985), however a word search of these articles revealed that these reviews did not include the terms "musicians", "instrumentalists" and "music". Therefore, no review currently summarizes and ranks the evidence supporting the use of warm-ups by musicians.

As demonstrated by the literature review, warm-ups are frequently recommended and considered, however, there are some terminological issues. Multiple terms are used by authors when describing the recommended exercises in a warm-up routine and many of these terms are

not defined or the definitions are different between authors. As such, the second research problem for this thesis is summarized with the following: **the terminology used when recommending warm-ups as an injury prevention method is sometimes unclear, which can create confusion because of multiple term use, lack of defining context, and unclear term relationships.** In order to facilitate more effective communication in this field, the purpose of this second study is to identify and define key terms such as warm-up, stretching, technical exercises and physical exercises based on existing empirical studies on the subject.

Chapter 2

Study design for study 1: Systematized review

The Cochrane Community (2019) defines systematic review as “a review of a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research, and to collect and analyze data from the studies that are included in the review.” (S section) Therefore, this type of review is useful as it summarizes the outcomes of the research on a specific subject, which can help inform other researchers or clinical practitioners (Liberti et al., 2009; Moher et al., 2009). Systematic reviews are also useful in helping to identify gaps in our scientific knowledge and can be required by granting agencies as a justification for further research in a particular field (Liberti et al., 2009; Moher et al., 2009). The PRISMA Statement is a guideline for systematic review which consists of a 27-item checklist and a flow diagram for the presentation of the included studies. This guideline was developed as the quality and transparency of reports prior was not always optimal (Liberti, 2009).

The first study for this thesis follows the PRISMA Statement guidelines for systematic review in order to summarize current research in the field of warm-ups and musicians, to present and rank the evidence, and to identify areas for future research. However, this review is categorized as a systematized review as the work was completed by one reviewer rather than the usual two for a systematic review (Grant and Booth, 2009): “Systematized reviews are typically conducted as a postgraduate student assignment, in recognition that they are not able to draw upon the resources required for a full systematic review (such as two reviewers)” (pp. 102-103).

Background on systematic reviews and the PRISMA guidelines

As mentioned previously, systematic reviews are useful as they summarize and analyze the data related to a specific field of study, however the clarity and transparency of these reports are not always optimal (Liberti et al., 2009). Mulrow (1987) studied the methodology of review articles. His procedure consisted of selecting peer-reviewed articles which were published from June 1985 to June 1986 and were obtained from the following four medical journals: *Annals of Internal Medicine*, *Archives of Internal Medicine*, *The Journal of the American Medical Association* and *The New England Journal of Medicine*. The review articles were then assessed with eight explicit criteria adapted from published guidelines for information syntheses: “Was the specific purpose of the review stated? Were sources and methods of the citation search identified? Were explicit guidelines provided that determined the material included in and excluded from the review? Was a methodologic validity assessment of material in the review performed? Was the information systematically integrated with explication of data limitations and inconsistencies? Was the information integrated and weighted or pooled metrically? Was a summary of pertinent findings provided? Were specific directives for new research initiatives proposed?” (Mulrow, 1987, p. 485) Fifty reviews were included in the analysis and the results indicated that “17 satisfied three of the eight criteria; 32 satisfied four or five criteria; and 1 satisfied six criteria.” (Mulrow, 1987, p. 485) Mulrow also mentioned that only one review had “clearly specified methods of identifying, selecting, and validating included information” (Mulrow, 1987, p. 485). He therefore concluded that medical reviews do not systematically use scientific methods to identify, assess and synthesize the information.

Sacks and colleagues (1987) also evaluated the quality of reviews. The procedure consisted of searching the databases of the National Library of Medicine and Bibliographic

Retrieval Services, Inc for English meta-analyses which were published from January 1966 through October 1986. These articles were then evaluated by two independent investigators with a scoring method of 23 items representing six major areas: study design, combinability, control of bias, statistical analysis, sensitivity analysis, and application of results. Eighty-six meta-analyses were evaluated, and the results indicated that only twenty-four reviews addressed all six areas. The 23 individual items were not all addressed; at best, only between one and fourteen. The researchers of this study concluded that “an urgent need exists for improved methods in literature searching, quality evaluation trials, and synthesizing of the results” (Sacks et al., p. 450).

In order to address the standards for improving the quality of reporting of reviews, an international group developed the QUOROM Statement (QQuality Of Reporting Of Meta-analyses), which was later on updated and renamed the PRISMA Statement (Preferred Reporting Items for Systematic reviews and Meta-Analyses) in order to include the term systematic review (Moher et al., 1999; Liberati et al., 2009). The methodology to develop the PRISMA Statement consisted of in-person and online discussions of a committee of 29 experts which included review authors, methodologists, clinicians, medical editors, and consumers (Moher et al., 2009). The members of the committee were asked to complete the following tasks prior to a three day meeting in Ottawa in 2005: “a systematic review of studies examining the quality of reporting of systematic reviews, and a comprehensive literature search to identify methodological and other articles that might inform the meeting” (Moher et al., 2009, p. 1007). An international survey was also completed in order to ascertain views of QUOROM and the existing checklist items. This survey and essential review items were discussed at the Ottawa meeting. Following the

meeting, the PRISMA checklist and flow diagram were distributed to the members of the committee and were revised by the members eleven times.

The result of this procedure was a 27-item checklist and a four-phase flow diagram. These items are divided in seven categories: title, abstract, introduction, methods, results, discussion and funding. The first item indicates that the title should include the terms systematic review, meta-analysis or both and should include PICOS information (participants, interventions, comparators, outcomes and study design). The second item is a structured summary with the following information: background, objective, data sources, study eligibility criteria, participants, interventions, study appraisal, synthesis methods, results, limitations, conclusions, implications of key findings, funding for the systematic review, and the systematic review registration number. For the introduction, the third item is a rationale described in the context of prior knowledge and the fourth item on objectives indicates that they clearly state the research questions and reference PICOS information. The category on methods includes items five to sixteen: protocol and registration, eligibility criteria, information sources, search, study selection, data collection process, data items, risk of bias in individual studies, synthesis of results, risk of bias across studies and additional analysis. These items indicate a need for thorough information when reporting the methodology of a systematic review. The category for results includes items 17 to 23: study selection, study characteristics, risk of bias within studies, results of individual studies, synthesis of results, risk of bias across studies, and additional analysis. Therefore, the results should include the number of studies screened, assessed for eligibility and included in the review; these numbers should be presented with the flow diagram. The discussion includes items 24 to 26: summary of evidence, limitations and a conclusion that should provide a general

interpretation of the results. The last item is funding as the review should disclose the sources of funding and the role of the funders for the study.

Data collection

Studies for this research project were obtained through database and bibliographic search results. An initial screening of article titles and abstracts helped to identify relevant studies. This was followed by a full text review of all articles that were initially deemed relevant and then included based on their adherence to inclusion criteria. Databases which are relevant to the field of research on warm-ups for musicians, such as in health, kinesiology, music and music education, were considered. The following databases were included in this study: CINAHL, MedLine, SPORTDiscus, Sports Medicine and Education Index, Web of sciences, Music Periodical Database and RILM. These databases were grouped into two categories: medical databases which included databases on sports medicine and arts databases which included databases in music. Keywords were identified by searching the glossary of the selected databases and identifying relevant subject headings.

The inclusion criteria were the study must be in English, must include warm-up or stretching as keywords, discuss the effect or use of warm-ups for or by musicians and have a clear methodological outline. The studies must be published in a journal. This review did not include theses and dissertations in order to limit the scope of the research project. All ages of participants were included in this review. This review did not include articles related to vocalists due to the following three reasons. Firstly, instrumentalists and vocalists do not use the same techniques in order to produce music. Secondly, both groups seek different types of health experts; instrumentalists may attend a physiotherapy clinic and vocalists may instead book an

appointment with an Ear, Nose and Throat Clinic. Lastly, the exclusion of vocalists will limit the scope of the research.

This study follows the guidelines of the PRISMA statement in order to present the relevant information in a clear and transparent manner (see Appendix A for the PRISMA checklist). Therefore, this research project extracted the PICOS information (participants, interventions, comparators, outcomes and study design) of all included studies. The summary for this study did not include a systematic review registration number, as this study was a systematized review. The results present the number of studies screened, assessed for eligibility and included in the review and these numbers were presented in a flow diagram.

Data analysis

The results were presented with the flow diagram of the PRISMA Statement and the data were analyzed with the levels of evidence classification in order to rate the evidence of the included studies. The levels of evidence provide a way for the reviewer to rank the research designs of the articles by assessing the thoroughness of previously conducted studies (Butler and Darrah, 2001). The rating of articles in this review will be based on the American Academy for Cerebral Palsy and Developmental Medicine (AACPDMD) levels of evidence where the level 1 studies have the most credible evidence and the level 5 studies have the lowest level of evidence (Butler and Darrah, 2001; Crosbie et al., 2007). This method was chosen as it includes five levels which are not limited to randomized controlled trials. This analysis was completed via Microsoft Excel.

Chapter 3

Study design for study 2: Terminology review and taxonomy

The design of this study is based on methods used in professional terminology work: “Work concerned with the systematic collection, description, processing, and presentation of concepts and their designations, for the purpose of documenting and promoting correct usage” (The Pavel, 2011, Glossary-terminology work section). The goal is to produce a terminological entry: “medium containing the terminological data pertaining to one concept” (The Pavel, 2011, 3.4.2. Entering Terms on Records section). The terminological data that will be recorded is the following: entry term, definitions, contexts, sources, and subject fields as it will help to define warm-ups in music.

According to The Pavel (2011), modern terminology work has various purposes and benefits such as sharing knowledge, teaching vocabulary of a specialized subject and supporting translation of a document in a specialized field. Therefore, the purpose of terminology work is clear communication based on a structured approach.

Background information on the field of terminology

According to Cabré and Sager (1999), the need for the field of terminology began in the 19th century and was discussed at international meetings of specific fields of study: botany (1867), zoology (1889) and chemistry (1892). The scientific experts in these fields felt that there was a need for a set of rules for formulating terms. In the 1930s, the Austrian E. Wüster, which is considered the founder of modern terminology, presented arguments for the systematization of terminology work and proposed a methodology for processing terminological data. The development of modern terminology is described by Cabré and Sager (1999) in four basic periods. The first period is referred as the origins (1930-1960) and “was characterized by the

design of methods for the systematic formation of terms” (Cabré and Sager, 1999, p. 5). The second period, the structuring of the field (1960-1975), was characterized by the innovation of the mainframe computer, the first databanks and the first approaches to standardize terminology within a language. The third period, the boom (1975-1985), had a “proliferation of language planning and terminology projects” (Cabré and Sager, 1999, p. 6). The fourth period, known as the expansion (1985-present), is marked by international cooperation.

According to The Pavel (2011), modern terminology work has various purposes and benefits such as sharing knowledge, teaching vocabulary of a specialized subject and supporting translation of a document in a specialized field. It also supports language planning which is used to improve relationships between two dialects and international communication. Terminology work can also identify the localization of a term where the term is linked to a language and a culture as it might have a different cultural meaning. Therefore, the purpose of terminology work is clear communication based on a structured approach.

Data collection

Subject field

The methodology for this second study was based on the Government of Canada’s Translation Bureau’s methodology for terminology research as described in The Pavel, an online tutorial course in terminology research (The Pavel, 2011). This tutorial was created from the *Handbook of Terminology* by Pavel and Nolet (2001). The first step is to delimit and structure the subject field. This is considered an important step according to The Pavel as “concepts and terms are studied in relation to their subject field” (The Pavel, 2011, 1.2.4. Term versus Word Section). This process will also organize and limit the terminology project and

terminology data collection. Therefore, the chosen field for this terminology work on warm-ups is music performance.

Corpus

The next step is to identify the corpus and prepare an inventory of written sources that will be scanned for content and terms. A corpus is “a collection of selected written texts assembled for the purpose of performing terminological analysis” (The Pavel, 2011, Glossary-corpus section). For this study, the corpus consists of empirical research that was published in journals. As recommended by The Pavel (2011), it only includes the original usage of terms and does not include translations in order to note the authentic usage of the term. Therefore, the inclusion criteria for this study is English documents.

In order to limit the number of sources for this master’s thesis, the sources that were scanned for terms were obtained from the databases in study 1. Therefore, both studies for this thesis used the same empirical material.

Term extraction

The term extraction step consists of scanning the corpus for terms. There are various methods that can be used such as manual highlighting or computerized term extraction which relies on semi-automatic or automatic software. Computerized extraction is possible if the text is available in computer-readable form. The chosen method was manually highlighting by using the highlighter function in Adobe Reader. The extraction also consists of manually marking the beginning and the end of each term’s context. This data (terms and their context) was subsequently transcribed on a terminology record for analysis in order to define warm-ups in the context of music performance. According to The Pavel, one of the advantages of the manual method versus the computerized software is that the researcher acquires knowledge about

“the subject field, related concepts, and term usage while reading the text” which leads to a better understanding of the concept (The Pavel, 2011, 3.3.3. Scanning for Terms Section). As recommended by the Pavel (2011), terms are identified through their frequency of use, contextual surroundings and typographical enhancements such as italics, boldface print, or quotation marks.

Data analysis

The goal of this study is to create a terminological entry that is similar to the Government of Canada’s terminological record, which is known as Termium (see Appendix B for an example of a terminological entry in Termium). The terminology entry for this study was created with Microsoft Word and includes the following information: definitions, contexts, remarks, usage samples, and key terms. The information for this terminology product was collected from the corpus as identified during the term extraction phase.

A taxonomy was also created with a tree diagram in Microsoft Word in order to categorize the terms used to define warm-ups. This taxonomy followed Bloom’s guiding principles for developing a taxonomy as his major purpose for constructing a taxonomy of educational objectives was to facilitate communication (Bloom, 1956). The first principle consists of basing the taxonomy on existing studies while reflecting the distinctions that were made by the researchers. The second principle indicates the importance of a logically developed and internally consistent taxonomy. The third principle specifies that the taxonomy is consistent with present understanding of the phenomena. The fourth principle is the importance of presenting the taxonomy in a purely descriptive and neutral fashion.

Chapter 4 - Study 1

Systematized review: Warm-ups' effectiveness for musicians

Abstract

Warm-ups are often recommended to musicians in order to prevent playing-related injuries. However, there is currently no assessment of the evidence supporting this recommendation. This study's purpose is therefore to answer the following research question: Is there enough evidence to support the statement that warm-ups prevent playing-related injuries? To answer this research question, this study summarizes, presents and evaluates the scientific data on musicians' warm-ups in the form of a systematized review which followed the PRISMA guidelines. The following databases were searched: Medline; SportDiscus, Sport Medicine and Education Index; Web of Sciences; Music Periodical Database; RILM. The inclusion criteria were English, published articles, had to have a clear methodological outline in order to evaluate the articles systematically, must include warm-up or stretching as keywords, and discuss the effect or use of warm-ups for or by musicians. The evidence of each study was evaluated with the AACPDm's levels of evidence. A total of 29 studies were included in this review and most studies (n=21) were ranked at level V, the lowest level of evidence. Therefore, it is not possible to empirically support the statement that warm-ups help to prevent playing-related injuries.

Keywords: warm-up, musicians, stretching, injury prevention, systematized review

Introduction

Musicians and music students are at high risk of developing playing-related pain or injuries (Ackermann, Adams and Marshall, 2002; Abreu-Ramos and Micheo, 2007; Chan et al., 2014; Dawson, 2008; Zaza and Farewell, 1997). Based on the research studies by Fishbein and colleagues (1988), Lederman (1989), Yeung and colleagues (1999), Abreu-Ramos and

colleagues (2007) and Ackermann and colleagues (2012), the prevalence of playing-related issues varied between 62% and 84%. Silva and colleagues (2015) completed a review on the prevalence of pain for musicians which indicated that it varied between 29% and 90%, and pain affecting playing capacity varied between 25.8% and 84.4%. The playing related injuries are also highly prevalent in music students, Hagglund (1996)'s research indicated that students suffered between 61% and 65%. Zaza (1992) revealed that students were affected by playing-related injuries at 42%. Guptill and Zaza (2000) indicated that 87.7% of the participating students experienced playing-related injuries.

Some studies conclude that musicians should practice injury prevention techniques in order to prevent playing-related issues (Zaza, 1993; Brandfonbrener, 1997; Barton and Feinberg, 2008; Spahn et al., 2001; Spahn et al., 2002; Zander et al., 2010). For example, Zaza (1993) concluded that injury prevention programs are possible and valuable for musicians and Zander and colleagues (2010) concluded that their prevention program had a preventive effect on students. A common injury prevention strategy is to warm-up prior to playing an instrument as mentioned by many authors of published academic articles (Brandfonbrener, 1997; Guptill and Zaza, 2010; Parry, 2003; Spaulding, 1988; Zaza, 1994). Furthermore, multiple books on musicians' injury prevention recommend the practice of warm-up or stretching exercises prior to playing their instrument (Paull and Harrison, 1997; Horvath, 2009; Tatz and Mayoroff, 2010; Tubiana and Amadio, 2000; Watson, 2009). However, these sources do not refer to any empirical research in order to support their statements and as indicated by Brandfonbrener and Lederman (2002, p. 1020) few studies have shown the effectiveness of specific preventative techniques.

Therefore, warm-ups are frequently recommended to musicians for injury prevention, but there is currently no assessment of the evidence supporting the use of warm-ups for the

prevention of injury in music performance. In order to address this problem, this study's purpose is to answer the following research question: What is the evidence to support the statement that warm-ups prevent playing-related injuries? To answer this research question, this study summarizes, presents and evaluates the scientific data on musicians' warm-ups in the form of a systematized review. For the purpose of this study, stretching exercises were considered part of warm-ups as stretches are often recommended as a possible warm-up exercise.

Methodology

From January 29th, 2020, to February 20th, 2020, a total of 7 medical (n=5) and arts (n=2) databases were searched as indicated in table 1. Search terms were mapped to subject headings in CINAHL, Medline, Sport Discus, Music Periodical Database and RILM. The search string was modified, by removing or adding terms, on two occasions in order to refine it and make it more suitable for this study. Table 2 includes the previous search strings and reasons for modifying them. The resulting search terms were combined as outlined in Figure 1. Reference lists of selected papers were scanned to identify other relevant papers. All available years (the oldest included article for this study was published in 1997) were searched for each database. The inclusion criteria were English, published articles, had to have a clear methodological outline in order to evaluate the articles systematically, must include warm-up or stretching as keywords, and discuss the effect or use of warm-ups for or by musicians. This review did not include articles related to vocalists.

Table 1*Databases searched*

Database type	Database name	Number of Citations without filters	Number of Citations with filters (journals, dissertations, English)
Medical databases	1) CINHALL	62	43
	2) Medline	84	84
	3) SportDiscus	154	45
	4) Sports Medicine and Education Index	491	297
	5) Web of sciences	219	205
Arts databases	1) Music Periodical Database	Anywhere except full text: 1993	268, added an additional filter to remove editorial previews: 86
	2) RILM	322	177
Grand Total		3325	937

Table 2*Search string and reasons for modifying it*

Version	Search string	Reason for modifying it
1	instrumentalist* or musician* or performer* or performing artist* AND “warm up*” or “warm-up*” or warmup* or stretching* or stretch* or “warm-up exercise*” or “warming technique*” NOT Singing or vocal or choir* or singer* or choral* or chorus or choruses or voice or vocalist	-Dancers are also performing artists. Too many articles including dancer, dance or dancing. Therefore, needed to modify search string with NOT dancer* or dancing or dance*.
2	instrumentalist* or musician* or performer* or performing artist* AND “warm up*” or “warm-up*” or warmup* or stretching* or stretch* or “warm-up exercise*” or “warming technique*” NOT Singing or vocal or choir* or singer* or choral* or chorus or choruses or voice or vocalist or dancer* or dancing or dance*	-removed performer due to too many results in sports -added music due to subject headings and keywords of databases -removed phrases as databases using ovid (medline and Cochrane) does not recognize “x”, only kept performing artist as it is a subject heading that is used often - Possibility of adding specific instruments as keywords FOR EXAMPLE: violinist* or violin* or violist* or viola* or cellist* or cello* or bassist* or "double bass" or "strings" or woodwind* or percussion* or percussionist* or brass or flute* or flutist* or piccolo* or oboe* or oboist* or clarinet* or clarinetist* or bassoon* or bassoonist* or trumpet* or trumpetist* or harp* or harpist* or trombone* or trombonist* or horn* or hornist* or piano* or pianist* or organist* or keyboardist* or saxophone* or saxophonist* or tuba* or tubist* or tubaist* or marimba or xylophone or drum or drummer or timpani or celeste or triangle HOWEVER: too many possibilities to open the search to other domains in medical databases such as organ can be perceived as a body organ, keyboard as a computer keyboard or brass as the metal. ALSO: May be useful for arts databases

Figure 1

Resulting search terms

Medical databases:

instrumentalist* OR musician* OR "performing artist*" OR music

AND

warm-up* OR warmup* OR stretching* OR stretch*

NOT

Singing OR vocal OR choir* OR singer* OR choral* OR chorus OR choruses OR voice OR vocalist
OR dancer* OR dancing OR dance*

Arts databases:

musician* OR instrumentalist* OR "performing artist*" OR violinist* OR violin* OR violist* OR
viola* OR cellist* OR cello* OR bassist* OR "double bass" OR strings OR woodwind* OR
percussion* OR percussionist* OR brass OR flute* OR flutist* OR piccolo* OR oboe* OR oboist* OR
clarinet* OR clarinetist* OR bassoon* OR bassoonist* OR trumpet* OR trumpetist* OR harp* OR
harpist* OR trombone* OR trombonist* OR "french horn*" OR hornist* OR piano* OR pianist* OR
organist* OR keyboardist* OR saxophone* OR saxophonist* OR tuba* OR tubist* OR tubaist* OR
marimba OR xylophone OR drum OR drummer OR timpani OR celeste OR triangle

AND

warm-up* OR warmup* OR stretching* OR stretch*

NOT

Singing OR vocal OR choir* OR singer* OR choral* OR chorus OR choruses OR voice OR vocalist
OR dancer* OR dancing OR dance*

The included studies were grouped into the following categories: Practice or Teaching Habits, Psychological and/ or Physiological Correlation or Effect, Experts' opinion, Performance Quality Correlation or Effect, and Other: X. The following information was extracted from eligible papers when available: study population (population size, response rate, level of experience, randomized or volunteers, instrument, gender, age), intervention, comparison, outcomes related to warm-ups or stretching, study design, measuring instruments/tests used, statistical tests used, validity, and reliability. This extracted data followed the PICOS framework (participants, interventions, comparators, outcomes and study design) and included additional relevant information for the evaluation of the quality of the studies.

The data were synthesized in a table format using Microsoft Excel. The collected data was then used to create pilot tables in order to quantify the levels of evidence, the study designs

and the categories. The collection and presentation of the data followed the PRISMA guidelines for systematic reviews which consists of a 27-item checklist and a flow diagram for the presentation of the included studies in order to improve the quality and transparency of reviews (Liberti et al., 2009).

In order to rank the research designs of the articles by assessing the thoroughness of previously conducted studies, all studies were analyzed using the American Academy for Cerebral Palsy and Developmental Medicine (AACPDMD)'s levels of evidence where level V is the lowest level of evidence and level 1 is the highest. The criteria for levels of analysis is summarized in table 3. In order to minimize reliability and validity issues, the data collection was repeated twice during the month between January and February 2020 by the first author. The data were ranked by a second objective evaluator, another student at the Piano Research Laboratory at the University of Ottawa. This study was funded by the Canada Graduate Scholarship (NSERC-CIHR). No additional source of funding was used to complete this research.

Table 3*AACPDM's levels of evidence*

Level	Non-empirical	Group Research	Outcomes Research	Single subject research
I		Randomized controlled trials All or none case series		N-of-1-randomized controlled trial
II		Non-randomized controlled trial Prospective cohort study with concurrent control group	Analytic survey	ABABA design Alternating treatments Multiple-baseline across participants
III		Case-control study Cohort-study with historical control group		ABA design
IV		Before and after case series without control group		AB design
V	Descriptive case series/ case reports Anecdotes Experts opinion Theories based on physiology, bench, or animal research Common sense/ first principles			

Note. From Butler, C., & Darrah, J. (2001). Effects of neurodevelopmental treatment (NDT) for cerebral palsy: an AACPDm evidence report. *Developmental Medicine & Child Neurology*, 43, 778–790. <https://doi.org/10.1111/j.1469-8749.2001.tb00160.x>

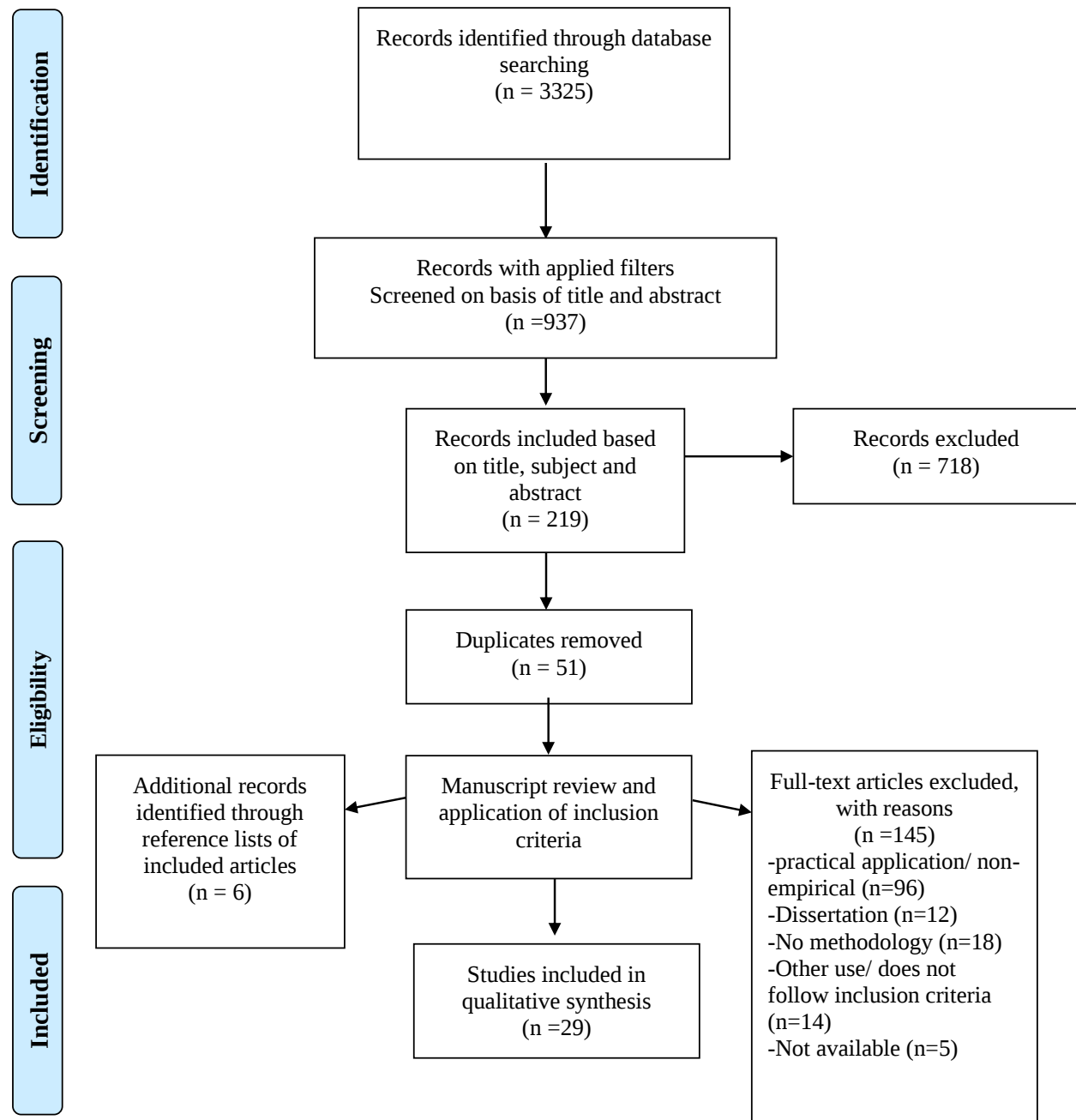
Results

The search of 7 databases with filters, such as journals, dissertations and English, retrieved 937 references. Citations and papers were assessed for eligibility in several stages as outlined in figure 2. The most frequent reason for initial exclusion of papers (based on title, abstract and subject) was use of terms in an irrelevant context to this study such as time stretch, harmonic stretch, and concert or conference reviews. The most frequent reasons for exclusion of full-text papers were practical application/ non-empirical (n=96) and no outlined methodology (n=18). Based on the inclusion criteria, 23 studies were selected from the databases. Of these 23 studies, reference lists were screened for additional articles that might align with the inclusion

criteria of this review. This process led to select 6 additional studies. Therefore, the total number of included studies for this review was 29.

Figure 2

Flow diagram of stages for assessment of eligibility



All studies were grouped into the following categories or a combination of two categories as listed in Table 4: Practice or Teaching Habits (n=10), Psychological and/ or Physiological Correlation or Effect (n=8), Experts' opinion (n=2), Performance Quality Correlation or Effect (n=2), Other: scoping review (n=1), Psychological and/ or Physiological Correlation or Effect AND Practice or Teaching Habits (n=4), Psychological and/ or Physiological Correlation or Effect AND Performance Quality Correlation or Effect (n=1), and Practice or Teaching Habits AND Experts' opinion (n=1). The study designs (see table 5) were: questionnaire (n=10), questionnaire and physiologic measurements (n=5), pre-test, intervention, post-test(s) (n=4), pre-test, intervention, mid-intervention tests, post-test (n=3), questionnaire and observations by a specialist (n=1), questionnaire and performance examination (n=1), questionnaire, interview and physical examination (n= 1), questionnaire and interview (n=1), questionnaire and pilot study for electromyographic analysis (n=1), and other (n=2).

Table 4

Categories of included studies

Categories	Count of References
Practice or Teaching Habits	10
Psychological and/ or Physiological Correlation or Effect	8
Psychological and/ or Physiological Correlation or Effect AND Practice or Teaching Habits	4
Experts' opinion	2
Performance Quality Correlation or Effect	2
Psychological and/ or Physiological Correlation or Effect AND Performance Quality Correlation or Effect	1
Practice or Teaching Habits AND Experts' opinion	1
Other: scoping review	1
Grand Total	29

Table 5*Study design of included studies*

Study Design	Count of Reference
questionnaire	10
questionnaire and physiologic measurements	5
pre-test, intervention, post-test(s)	4
pre-test, intervention, mid-intervention tests, post-test	3
questionnaire and observations by a specialist	1
questionnaire and performance examination	1
questionnaire, interview and physical examination	1
questionnaire and interview	1
questionnaire and pilot study for electromyographic analysis	1
other	2
Grand Total	29

One of the methodological limitations identified in a majority of papers was presence of sampling and measurement biases such as lack of randomization, lack of control group, small sample size, and volunteer based. Only 2 studies of 29 mentioned the randomization of participants. Only 6 studies included a separate control group and two studies mentioned participants acting as their own control group. Seven studies had fewer than 30 participants and of these studies, 2 papers had 16 participants, 1 had 14, 1 had 10 and 1 had 7. Nine papers indicated that their participants were recruited as volunteers. Furthermore, response rate for the studies were highly variable, with a range of 28 to 90.4% and there was considerable variability in population characteristics (age, instruments, experience level such as professionals, amateurs or students). Another methodological limitation that was identified in a majority of papers was inadequate reliability and validity, or omission of reporting of reliability and or validity. Twelve studies did not report on validity and reliability, one study did not report on reliability and two studies did not report on validity. Some studies used surveys that were previously piloted but were not necessarily tested for validity or reliability.

As summarized in Table 6, papers were ranked by two evaluators based on the AACPDm's levels of evidence. Most studies (n=21) were ranked as level V and some (n=3) were ranked as level IV. Three studies were ranked as level II and only 1 study as level I. Zero study was ranked as level III and one study was non-applicable due to the study design of scoping review. The inter-rater reliability was 93.10% and both evaluators met in order to reach a consensus when studies were ranked differently which only occurred twice and the difference was between two adjoining levels. A summary of the collected data of included papers is outlined in table 7. The data in table 7 includes the following for each of the studies: PICOS, category by grouping, instrument/ test, analysis, validity and reliability, and level of evidence.

Table 6

Ranked evidence of included studies

Levels of Evidence	Count of References
I	1
II	3
III	0
IV	3
V	21
N/A	1
Grand Total	29

Table 7

Summary of data per paper

Reference	Category by grouping	Participants	Intervention	comparison	outcome	study design	method/ statistical tests	levels of evidence	comments
Abreu-Ramos et al_2007	Psychological and/or Physiological Correlation or Effect AND Practice or Teaching Habits	83 professional orchestra musicians of the Puerto Rico Symphony Orchestra Volunteers Response Rate: 90.4%	none	N/A	The results indicated that 90.7% of the participants had a warm-up routine. Of these participants, the breakdown per instrument is the following: 90.3% violin/viola (n=28), 93.3% cello/bass (n=14), 100% brass (n=13), 90.0% woodwinds (n=10) and 100% percussion (n=3). The comparison for warm-up routine by age group is the following: 94.4% of 22-29 years old (n=17), 88% of 30-39 years old (n=22), 95.2% of 40-49 years old (n=20) and 90.9% of 50-61 years old (n=10). Stretching and warm-up were reported as factors for alleviating musculoskeletal symptoms at 37.7% (n=23) and 21.3% (n=13) respectively.	questionnaire and physiologic measurements	Instrument/ test: Questionnaire items were playing habits, instrument played, position or seat within the orchestra, medical history, pain and symptoms. Participants also completed a neuromusculoskeletal physical examination of the neck, back, and upper extremities with the primary author of this study. Analysis via Excel and SPSS: descriptive analyses, Pearson parametric and Spearman's p logistic regression analyses, statistical significance or p value < 0.05 and p < 0.01. Validity/ Reliability: Questionnaire previously tested in a pilot study of 10 musicians	V	
Ajidahun and Philipps_2013	Experts' opinion	7 experts in performing arts from the PAMA directory (20 initially invited to participate) -3 medical doctors -2 physical therapists -1 occupational therapist -1 freelance musician Volunteers	none	N/A	All participants agreed that a warm-up program should be taught as an injury prevention strategy and should be completed prior to playing a music instrument. The focus of the warm-up program should be on the whole body. Participants agreed that the content of the program includes musical warm-up and stretching but excludes aerobic exercises as consensus was not reached. Consensus was not reached on the duration of the warm-up program, but the result suggests that the duration could be within 5 to 15 minutes. Additionally, the results indicate that strengthening and conditioning should be done thrice a week.	Delphi Study with 3 phases to obtain an informed consensus from a group of experts via a questionnaire consensus set at 65%	Instrument/ test: Questionnaire conducted using an online survey site, Survey Monkey. The items were years of experience, primary occupation, specialty of participant, type of exercises for a warm-up program, warm-up program duration, area of body to be warmed up, inclusion of musical warm-up in the program and education on injury prevention strategies. Analysis via Survey Monkey: Consensus set at 65% and analysis completed after each Delphi phase (3 phases). Validity/ Reliability: Questionnaire was reviewed by two independent researchers for content validity. No mention of reliability.	V	no mention of reliability

Reference	Category by grouping	Participants	Intervention	comparison	outcome	study design	method/ statistical tests	levels of evidence	comments
Ajidahun et al_2019	Other: scoping review	Searched Databases: Physiotherapy Evidence Database (PEDro); MEDLINE via PubMed; Cumulative Index to Nursing and Allied Health Literature (CINAHL); Cochrane Controlled Trials Register in the Cochrane Library; EBSCO; Sport discuss; and SCOPUS.	none	N/A	A total of 176 articles were identified and 12 met the inclusion criteria and were included in the study. The prescribed exercises are focused on strengthening and stabilizing the core. They include stretching exercises prior to performance to reduce strain to the musculoskeletal system. Warmup exercises were included as part of the overall exercise intervention in four studies and only two studies reported on the specific warm-up exercises done.	scoping review	Instrument/ test: scoping review structured on the population, phenomena of interest, intervention and outcome (PICO) and had five steps (to identify the research questions and relevant studies; to select material for the study; to chart data; and to summarize and collate the results) Analysis: No mention of analysis or evaluation of the studies' results. Validity/ Reliability: No mention of validity or reliability	N/A	No evaluation of the data No mention of validity or reliability
Amason et al_2018	Practice or Teaching Habits	23 music students from the Iceland Academy of the Arts in the first and second years Volunteers	prevention course on body awareness	13 students taking the course were compared to a comparison group of 10 students	Pre-intervention, there was no significant difference on the use of warm-ups (stretches and dynamic movements) between the two groups. However, post-intervention, the prevention group increased the amount of warm-up prior to music performance and the comparison group lessened the amount of warm-up, showing a significant group difference after the course (69% vs. 20% p=0.036). Pre-intervention, the prevention group reported a current playing-related musculoskeletal disorder at 80% and the control at 60%. Post intervention, the numbers were 50% for the prevention group and 66% for the control group.	pre-test, intervention, post-test	Instrument/ test: questionnaire (used in previous research) on body awareness, importance of good health, PRMD history, engagement in regular physical activity, warm-up habits before playing, and the use of PRMD preventative strategies Intervention: The course was divided into 4 lectures and 16 practical sessions and taught once a week throughout the school year. The teacher was a musician and physical therapist. The course content included a basic introduction of the musculoskeletal system and its function, the most common risk factors for playing-related musculoskeletal disorders, the most common injuries affecting musicians, optimal body alignment through a variety of physical exercises, specific shoulder and thoracic strengthening and mobility exercises and warm-up routines. Analysis via SPSS: Chi-square, McNemar and ANOVA tests to evaluate significant differences between or within groups. Statistically significant differences were identified as p<0.05. Validity/ Reliability: Indicates possible effects of the selection bias (non-randomized) on the external validity.	II	

Reference	Category by grouping	Participants	Intervention	comparison	outcome	study design	method/ statistical tests	levels of evidence	comments
Barton and Feinberg_2008	Practice or Teaching Habits	26 freshmen music majors Convenience sample/ No randomization	8-week course on health promotion and prevention of injury	no separate control group, participants acted as own control group	There was no significant difference between the total mean scores (out of 5) for the warm-up item of the questionnaire when comparing the pre-course test (4.4) to post-test 1 (4.3) and post-test 2 (4.5). There were some score differences for stretching before playing: pre-course test (2.8), post-test 1 (3.5) and post-test 2 (3.3). The pre-course test revealed that 42% of participants noted that they never or infrequently performed stretching prior to playing and the number of participants with this answer decreased to 21% at post-test 1 and 30% at post-test 2.	pre-test, intervention, post-test 1, post-test 2	Instrument/Test: The types of questionnaires were demographic, baseline and acquired knowledge, and use of health promotion and prevention strategies. Intervention: 8-week course entitled "Health Promotion and Prevention of Injury for Musicians" taught by the researcher, a musician, educator and occupational therapist Analysis via SPSS: descriptive analysis, independent t-test, Mann-Whitney U-test, Friedman ANOVA and Wilcoxon matched-pairs ranked test Validity/ Reliability: Mentions the issue of the small sample size and lack of control group and their effect on the external validity.	IV	
Beckett et al_2015	Psychological and/or Physiological Correlation or Effect	1,379 (792 females, 587 males) members of 21 collegiate marching bands response rate of 28.2% Volunteers	none	N/A	Outcome on stretching as indicated by the authors on page 109: "participants in marching programs that only offered a structured and supervised stretching/strengthening program on an individual basis for less than 5 minutes reported a higher prevalence of musculoskeletal injury ($\chi^2=23.408$, $p<0.001$). This may be attributed to the program's lack of coordinated conditioning for participants in marching activities."	questionnaire	Instrument/ Test: Survey developed and delivered via the Qualtrics survey platform. The items included demographics, years of experience, training and performance, footwear worn, instrument played, equipment used, participation in stretching or strengthening programs, injury prevalence and type, treatment sought for injury and participation time lost due to injury. Analysis via SPSS: Frequency analysis, percentages, and descriptive statistics were used to summarize responses. Descriptive data was analyzed using chi-square test for independence and numerical data was analyzed using a one-way analysis of variance (ANOVA). The significance level for statistical testing was set at $p\leq 0.01$. Validity/ Reliability: A preliminary draft of the survey was distributed to a panel of faculty members of the University of Central Florida Doctor of Physical Therapy Program for review of content.	V	no mention of reliability or validity specifically

Reference	Category by grouping	Participants	Intervention	comparison	outcome	study design	method/ statistical tests	levels of evidence	comments
Bertsch and Maca_2001	Psychological and/or Physiological Correlation or Effect	16 trumpet players: 5 professional trumpet players (with an average 22 years of routine, standard deviation [SD] ± 8 years), 5 students (13 years routine, SD ± 4 years) and 6 beginners (4 years of routine, SD ± 2 years)	warm-up phases	compare playing patterns of professional players (n=5) with students (n=5) and beginners (n=6) All participants completed the intervention (no controls)	Based on the questionnaire, the amount of time on warm-ups varied from 0 to 90 minutes which was not correlated to the playing level. Participants were also asked to evaluate how they can accurately play a b2 before or after a warm-up; professionals indicated a 18% increase in the rate of accuracy after a warm-up and students a 30% increase on average. The physiological measures revealed that the pulse of professional dropped 3.6 bpm after the warm-up, indicating that they might be more relaxed after the warm-up. The rate of beginners and students raised by 2.4 bpm and 7.2 bpm respectively. The infrared thermography indicated that the embouchure region increased temperatures during brass playing and the blood supply seems to be redistributed from lateral to central parts, restricted to only a few muscle groups in this area (M. orbicularis oris, M. depressor angulioris, M. levator anguli oris). A professional musician shows a very symmetric and compact warm region in the embouchure area, a beginner has an asymmetric warm region and a student has a larger warm area than a professional. For all players, the inner corner of the eyes seems to be a hot spot before and after playing and the M. buccinator seems to be of minor importance since the area of the cheeks are not warming up.	pre-test, intervention, mid-intervention tests, post-test	Instruments/ Tests: Frontal and lateral thermography images were taken before the start of the warm-up and after each part of the warm-up. Participants completed a questionnaire which included questions on the importance and duration of warm-ups. The following measures were also taken auxiliary and finger temperatures, blood pressure and pulse rate. Intervention: 3 warm-up phases consisted of easy exercises for three minutes, than an exercise of medium difficulty and then 10 minutes of their individual warm-ups. Analysis: No written details on the analysis in the article. Validity/ Reliability: No mention of validity or reliability measures in the article. Other: Participants instructed to not eat or smoke four hours before the test and to acclimate for 30 minutes.	IV	No specification as to how the participants were selected, how the analysis was conducted or if the validity or reliability was taken into consideration. This article however refers to the original thesis, written in German which is out of the scope of this study: Bertsch Matthias, "Studien zur Tonerzeugung auf der Trompete". Dissertation, Universite de Vienne/ University of Vienna/ Universitat Wien, 1998.
Blackie et al_1999	Practice or Teaching Habits	16 piano university students (age: 18-24) Response rate: 64%	none	N/A	Results indicated that 4 students received prevention education on the importance of warm-up/cool-down. The results on frequency of use of warm-up/cool-down was: 4 responded never, 4 rarely, 1 occasionally, 4 frequently and 2 almost always. The frequency of use for stretching was 6 responded never, 5 rarely, 1 occasionally, 2 frequently and 1 almost always. A longer warm-up period was not an action taken by piano students to resolve pain or discomfort but incorporating more stretching into the practice was used by 4 students to resolve pain or discomfort.	questionnaire	Instrument/ Test: Questionnaire items were demographic, information about practice and technique, injury prevention education received and used, specific information concerning pain/discomfort and injury, and a self-assessment of the participants' ability, comfort level of playing, and stress reduction habits. Analysis: descriptive statistics, means and standard deviations calculated, frequencies and modes, correlation to examine relationship between onset of pain and the duration of practice sessions. Validity/ Reliability: Pilot survey reviewed by a piano faculty member.	V	no mention of reliability or validity specifically

Reference	Category by grouping	Participants	Intervention	comparison	outcome	study design	method/ statistical tests	levels of evidence	comments
Buckley and Manchester _2006	Practice or Teaching Habits	111 students who attended the Montana Fiddle Camp (age: 10-87) Response Rate: 68%	none	N/A	Results indicated that 30% of the participants regularly used warm-ups before practicing or playing. The injured group was not more likely to do warm-up exercises than did the non-injured group. Seventeen injured participants (28.3%) indicated warming up prior to playing and 17 non-injured participants (33.3%) also indicated warming up prior to playing. During the camp, 25% of the participants indicated doing warm-up activities. Seventeen participants indicated they warmed-up by stretching the neck, shoulders, arms, hands, and fingers, 13 indicated doing finger exercises such as scales, 4 by playing a familiar tune prior to playing.	baseline questionnaire and follow-up questionnaire	Instrument/ Test: Baseline questionnaire items were age, gender, occupation, repetitive hand motion, primary and secondary instruments played, years playing instrument, enrollment in private lessons, practice habits, and past injuries attributed to playing a musical instrument. Follow-up questionnaire items were playing time per day, practice habits, and onset of any new injury or recurrence of an old injury at the camp. Midway through the week, participants could enroll in a videotaping session midway through the week with the purpose of analyzing the posture and technique of the subjects to attempt to identify a correlation between specific technical deficits and certain types of musculoskeletal pain. Analysis: Video analyzed by a qualified instructor. Validity/ Reliability: Mentions that limitations of time and resources prevented access to multiple observers in order to establish inter-observer reliability.	V	no mention of validity
Cooper et al_2012	Psychological and/or Physiological Correlation or Effect	126 High School and Junior High School string orchestra students from four schools in the Northwestern United States ranging in age from 14 to 18. treatment group: n=57 control group: n=43 Groups selected by independent adjudicator	stretches and exercises designed to reduce fatigue and / or stress or discomfort at various intervals throughout the rehearsals	treatment group compared to control group who completed the rehearsals without the stretching/ exercise intervals	Overall, students in the treatment groups reported significantly lower levels of discomfort after treatment than before treatment and students in the control groups reported higher levels of discomfort after rehearsals than before rehearsals. Therefore, stretching exercises appeared to have lowered students' perception of discomfort.	pre-test, intervention, post-test	Instrument/ Test: Perception of Discomfort survey, demographic questionnaire and five-part question using a Likert-type scale to report any experienced discomfort in the hands, wrists, arms, shoulders, and neck. Discomfort or lack of discomfort was measured prior to and following 4 rehearsals over a 2 week period. Intervention: At various intervals throughout the rehearsal (approximately 10 minutes apart), the instructor directed students to complete stretches/exercises designed to reduce fatigue and/or stress or discomfort, taken from Stretching for Strings (Winberg & Salus, 1990). Analysis: Data analyzed with a two-way multivariate analysis of variance (MANOVA). Validity/ Reliability: No mention of validity or reliability	II	no mention of reliability or validity specifically

Reference	Category by grouping	Participants	Intervention	comparison	outcome	study design	method/ statistical tests	levels of evidence	comments
Davies and Mangion_2002	Psychological and/or Physiological Correlation or Effect	240 permanently employed and freelance musicians working in Sydney's classical and non-classical music industry Response rate:45% Volunteers	none	N/A	The results indicated that for players with severe pain and symptoms of high stress interacted with lack of warm-up. Also, playing-related stress was significant for pain/symptoms during the previous year and the playing lifetime. Players having had a serious injury, or suffering from frequent pain/symptoms, used significantly more of the prevention tools of warming up, cooling down, and taking breaks in their private practice. According to the authors, these higher levels of preventive behaviors are more likely to be an effect of pain/symptoms rather than a cause, it is indicated that and therefore used for symptom management rather than for prevention.	questionnaire	Instrument/ Test: The questionnaire items were levels of musculoskeletal pain and symptoms, musical background, health and lifestyle activities, beliefs and attitudes about pain/symptoms and their correlates, current professional activities, work environment, and work-related stress. Analysis: Statistical regression analysis used to determine the significant predictors and use of multivariate analysis. Validity/ Reliability: No mention of validity and reliability	V	No mention of validity and reliability
De Smet et al_1998	Psychological and/or Physiological Correlation or Effect	66 pianists (age: 18 to 32) and 66 volunteers for the control group (age: 18 to 32)	none	pianists compared to a control group	Twenty-eight pianists had an incidence of overuse syndrome. The incidence of overuse syndrome was significantly different from the controls ($p < 0.001$). Warming-up before playing and stretching afterwards did not influence the incidence of overuse syndromes in pianists as it was not significantly different between pianists with and without overuse syndromes ($p > 0.05$).	questionnaire and physiologic measurements	Instrument/ Test: Questionnaire items were playing habits and musculoskeletal problems. Physiological measures were hand size and hypermobility. Analysis: Chi square Validity/ Reliability: No mention of validity or reliability	V	No mention of validity or reliability
Drinkwater et al_2010	Performance Quality Correlation or Effect	10 wind players from the local community with a range of 3 to 38 years of playing experience Volunteers	10 min performance	no separate control group, participants acted as own control group	Results indicate a significant increase in markers of physical stress once the performance began. With each performance, there was a small to large increase (4.9 to 23.5%; $d = 0.28$ to 0.93) of heart rate, respiration, and rating of perceived exertion. There was also a significant small (21%, $d = 0.43$) decrease in errors after the first performance and a significant large increase (70.4%, $d = 1.14$) after the second performance. The authors indicate that the initial increase in physiological stress with a decrease in errors after the first performance likely indicates a warming up period and the continued increase in markers of physical stress with an increase of errors after the second performance likely indicates fatigue.	pre-test, intervention, mid-intervention tests, post-test	Instrument/ test: Prior to the performance and within short breaks between performances, physiological measures (heart rate, respiratory rate, blood pressure and blood lactate concentration) were collected as well as a rating of perceived exertion (RPE), and rating of anxiety. Intervention: 10 min of repertoire for their chosen wind instrument that they played three times consecutively. Analysis: All performances were audio recorded and later analyzed for performance errors. Errors were initially counted in each category and then combined into a single metric for analysis. Data was analyzed using SPSS and the following tests were completed: ANOVA, unprotected pairwise comparisons. The alpha for statistical significance was set at ≤ 0.05 and the beta for non-significance was set at ≥ 0.80 . Validity/ Reliability: A repeat analysis of a smaller sample of data (15 rather than 30 video performances) was completed in order to establish reliability when assessing the performance errors.	IV	No mention of validity

Reference	Category by grouping	Participants	Intervention	comparison	outcome	study design	method/ statistical tests	levels of evidence	comments
Grieco et al_1989	Psychological and/or Physiological Correlation or Effect	117 piano students for the questionnaires (54 males and 63 females) of whom 6 (3 males and 3 females) participated in the electromyographic study Response rate of questionnaire: 75%	none	N/A	The warm-up phase prior to the study of a score in the electromyographic data indicates the level of effort of some muscle groups such as the deltoid and bicipital muscles show a low level of effort and the effort of trapezius muscles was asymmetric. Some muscles were used to greater extent in the male participants, for example the epitrochlea. The female participants had a marked effort of the intrinsic muscle structure of the hand. In his conclusion, the author suggests relaxation and stretching exercises for the muscle groups most involved during practice and exercises to strengthen the supporting muscle groups as tools for injury prevention.	questionnaire and pilot study (6 participants only) for electromyographic analysis	Instrument/ test: The questionnaire items were organization of study and free time, occurrence, site and characteristics of musculoskeletal disorders and occurrence of psychic, respiratory or digestive complaints. Electromyographic data was collected during a set of standard piano exercises with varying difficulty by Hanon and a sight-reading piece by Scott Joplin. Each student also performed one or two passages from their repertoire. The processing method for the electromyographic data was derived from Jonsson (1982). Analysis: Electromyographic analysis of upper body while performing on the piano. Final graphic representation and statistical analysis was performed at the end of the experimental session. Validity/ Reliability: No mention of validity or reliability	V	Data does not indicate that warm-ups prevent injury. Data indicates which muscles are involved while playing a musical warm-up and how much effort is required from these muscles
Hagglund and Jaccobs_1996	Practice or Teaching Habits	questionnaire distributed to 300 music students at Boston University: 45 responded and of these 45, 19 participated in an interview Volunteers	none	N/A	33 of 44 respondents (75%) described stretching and performing warm up exercises prior to playing their instrument, but of these participants, 22 (68%) acquired injuries before, during, or after the habit of stretching began. 74% of respondents indicated receiving one or more of the following treatment methods: altering posture, habits or playing technique, exercise and stretching, rest, ice and massage. Based on the interview, respondents indicated that the following methods were other popular aids in injury rehabilitation: shorter practice sessions and frequent breaks, warming up, the use of strategic practicing, relaxation techniques, changes in posture, adaptive equipment and splinting.	questionnaire and interview	Instrument/ test: Questionnaire items were practice habits (mental and physical), past or present injuries, treatments and possible contributing factors. The interview was semi-structured as the investigators had scripted questions but could ask the participants to clarify. Participants were also encouraged to share personal experiences of information which they felt pertinent. Analysis: Descriptive statistics were used to identify the mean, standard deviation, and percentages Validity/ Reliability: Authors mention that the results are limited due to internal and external validity issues such as possible errors in interpretation of questions and small sample size.	V	No mention of improving reliability or validity

Reference	Category by grouping	Participants	Intervention	comparison	outcome	study design	method/ statistical tests	levels of evidence	comments
Kaufman et al_2011	Psychological and/or Physiological Correlation or Effect AND Practice or Teaching Habits	59 orchestral classical musicians recruited from 3 major Israeli classical orchestras	none	N/A	Results indicated an average of only 10 min a day of warm-up prior to playing and only half of the musicians dedicated time to warm-up exercises. The correlation analysis between playing-related musculoskeletal disorder and warm-up prior to playing was significant ($r=-0.55$, p smaller than 0.01).	questionnaire and observations by a specialist	Instrument/Test: The questionnaires were The Standardized Nordic Questionnaire on musculoskeletal pain with an addition that reviewed the presence of pain in the muscles of the arm, elbow, forearm, palm and each of the fingers, The Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire, The National Institute for Occupational Safety and Health (NIOSH) questionnaire and the Rapid Upper Limb Assessment (RULA). The Rula observations were undertaken by a hand therapist. Personal information of participants was also collected with a demographic questionnaire. Analysis: variance statistical analysis, univariate analysis Validity/ Reliability: The Standardized Nordic Questionnaire has been shown to be both reliable and valid. The additional questionnaire was also valid and reliable. Use of standardized questionnaires.	V	
Leon et al_2015	Practice or Teaching Habits AND Experts' opinion	55 members of youth Band of Zapopan and Guadalajara (ages 12 to 34)	none	N/A	The results indicated that 77.4% of participating musicians warm up, but only 42.3% of these respondents stretch. The participants' perceptions of musculoskeletal disorders regarding poor warmups indicated that: 20.7% believed it did not have an impact, 43.4% believed it had an intermediate impact and 35.8% believe it had an impact.	questionnaire	Instrument/ test: Questionnaire items were habits of practice, injury symptoms, use of ergonomics furniture, knowledge about musculoskeletal disorders risk factors, and awareness of any preventative education. Analysis via SPSS: Authors analyzed the frequencies related to age, played instruments, pain reports, preventive habits as warm-ups and stretching, objects or devices used, and perception of the main risk factors. The relation between medical conditions and the kind of instrument played was analyzed using the Chi square test. Validity/ Reliability: No mention of validity or reliability	V	No mention of validity or reliability

Reference	Category by grouping	Participants	Intervention	comparison	outcome	study design	method/ statistical tests	levels of evidence	comments
Logue et al_2005	Practice or Teaching Habits	14 cellists (ages 18-32) from Belmont University School of Music and the Vanderbilt University Blair School of Music orchestras students, professionals and amateurs Response rate: 17 cellists invited to participate and 3 declined	none	N/A	Based on history questionnaire, nine of the 14 participants reported that they performed warm-up exercises before playing the instrument. The exercises included: scales, finger stretches, playing slow long notes, neck side bending, and arm rotations. The results also indicated that the participants had normal upper extremity neural and musculoskeletal function.	questionnaire, interview and physical examination	Instrument/ test: demographic and history questionnaire, interview and physical examination (nerve conduction study, examination body movements such as cervical and shoulder, extremity sensory examination with pin prick, reflexes, Tinel's sign of median and ulnar nerves at the wrist, Tinel's sign of the ulnar nerve at the elbow and Phalen's test) Analysis: Descriptive statistics were computed for all nerve conduction latencies, amplitudes, and conduction velocities via Microsoft Excel. Validity/ Reliability: No mention of validity or reliability	V	No mention of validity or reliability
Lopez et al_2013	Practice or Teaching Habits	students at the High Conservatory of Music of Salamanca, Spain: control group of 56 and experimental group of 90 A total of 149 students were randomly chosen. Average years of experience: 13.5	1-year prevention course and 1-year program of warm-up exercises and postural hygiene	control group	Students in the experimental group improved their body awareness by 91% and the frequency of their injuries decreased by 78%. The control group did not improve by the end of the experiment. There was no significant change for the control group for types and frequencies of warm-ups. Thirty percent of the individuals warmed up daily but did not obtain the desired benefits because they were not doing the exercises correctly. The experimental group had a significant change. In the initial evaluation, 90% of the students did not warm-up before practicing their instrument, and most believed that the term warm-up was used exclusively to mean playing scales or technical exercises before practicing a piece of music. At the end of the experiment, 90% of the students did a correct warm-up before practicing. Stretching exercises were the exercises done most frequently by the experimental group, between 4 and 7 days/week (76.7%), with 90% effectiveness (quite or completely satisfied). The authors also found wide acceptance of other suggested warm-up exercises: frictions, mobilizations, tractions, and self-massage. These were practiced between 4 and 7 days/week with 59.9 to 69.9% effectiveness (quite or completely satisfied).	pre-test, intervention, mid-intervention test, post-test	Instrument/ test: The questionnaire items were years of study of instrument, hours of practice per week, primary and secondary instrument, warm-up habits and frequency of warm-ups. Intervention: 1 year program of warm-up exercises and postural hygiene and three-credit course on the prevention of musculoskeletal injuries, postural habits, and warm-up exercises for musicians Analysis via SPSS: The level of statistical significance was established at $p < 0.04$. Validity/ Reliability: No mention of validity or reliability	II	No mention of validity or reliability

Reference	Category by grouping	Participants	Intervention	comparison	outcome	study design	method/ statistical tests	levels of evidence	comments
McCrary et al_2016	Psychological and/or Physiological Correlation or Effect AND Performance Quality Correlation or Effect	55 undergraduates, postgraduates and professional violinists (n = 55; 15 male, 40 females; 17 professionals, 3 postgraduates, 35 undergraduates) Stratified randomization	one of three warm-up sessions	compared to control group	The three warm-up conditions did not have a significant effect on the muscle activity levels. Performance quality did not significantly increase. Perceived exertion significantly decreased for the three warm-up conditions and did not significantly decreased for the control condition.	pre-test, intervention, post-test	Instruments/ tests: performance of 5 excerpts while collecting EMG data and questionnaire with items such as warm-up habits, perception of effect of warm-ups and location, type and duration of physical symptoms Intervention of 15 minutes: 1 of 4 conditions, cardiovascular warm-up, core muscle warm-up, musical warm-up(technical violin exercises) and control condition where participants did not partake in a warm-up exercise. Analysis via Statistica 64 version 10: ANCOVA, Tukey HSD post hoc test, Wilcoxon matched pairs tests, ANOVA for performance scores Validity/ Reliability: Duplicate recordings were included to ensure reliability of adjudication. Authors mentions validity as their methodology did represent accurately the variable physical demands of violin performance.	I	
McPherson and McCormick_1999	Performance Quality Correlation or Effect	190 pianists (age: 9 to 18), students completing Trinity College examinations Response rate: 60%	none	N/A	The results indicated that the students with higher levels of practice in the month leading up to the examination were more likely to practice technical work, such as a warm-up routine, scales/arpeggios, studies and etudes, and sight-reading exercises and were also more inclined to feel anxious about their performance examination. The results also indicated that participants who spent more practice time on informal/creative activities (improvising), repertoire (new and familiar pieces) and technical work (such as warm-up routine, scales, arpeggios, etudes and sight-reading) tended to be more cognitively engaged while practicing and express more intrinsic interest in learning their instrument.	questionnaire and performance examination	Instrument/ test: The questionnaire was designed with 7-point Likert scale and 17 items on self-regulatory learning components (cognitive strategy use, self-regulation of practice) and motivational components (intrinsic value, anxiety/confidence) of instrumental learning. Analysis: factor analytic solutions, regression analyses Validity/ Reliability: No mention of validity or reliability	V	No mention of validity or reliability

Reference	Category by grouping	Participants	Intervention	comparison	outcome	study design	method/ statistical tests	levels of evidence	comments
Redmond and Tiernan_2001	Practice or Teaching Habits	42 piano instructors from the Washington State Music Teachers Association Response rate: 28%	none	N/A	The results indicated that the participants had received education in injury prevention, most frequently from their teachers or colleagues. The participants were most likely to teach their students about proper body mechanics and posture (83%), specific playing techniques (78.6%), importance of warm-up (73.8%), and choosing repertoire that was appropriate for the student's physical abilities (64.3%). Most participants indicated a desire for more information on playing-related injury prevention but were hesitant to provide students with information that was outside of their experience. As indicated in table 2 (p.34), the importance of warm-up (n=27) was received from the following sources of information: 9 one-on-one, 9 workshop, 3 class or course, 17 music teacher, 6 medical practitioner, 3 book and 1 other. As for stretching (n=24), the sources of information were: 4 one-on-one, 6 workshop, 3 class or course, 10 music teacher, 7 medical practitioner, 4 book and 5 other.	questionnaire	Instrument/ test: Questionnaire developed by researchers and the items were demographics, injury prevention education received by the respondent, injury prevention instruction provided to students, and whether the participant wanted more information on injury prevention. Analysis: Frequencies and means were calculated on the demographic data and the injury prevention data. Common themes were extracted from the comments section. Validity and Reliability: Survey was not tested for reliability and validity. The researcher's review committee reviewed the survey for content validity, appearance, and overall clarity and the survey was piloted by two piano teachers (not included in the final research sample).	V	Survey not tested for reliability or validity.
Rohwer_2008	Experts' opinion	83 adult musicians (age: 47 to 91) who were attending a national summer senior band camp: 52 woodwind players and 31 brass or percussion players	none	N/A	Participants indicated that accommodations for ailments centered around two general issues: things a musician could buy (e.g., ear plugs, instrument rests, cushions) or things they could do to avoid pain (e.g., education, stretching, regular practice, massage therapy, relaxation techniques, exercise, weight loss, going to a chiropractor).	questionnaire	Instrument/ test: Questionnaire items were physical ailments while playing their instrument, whether any pain experienced was greater when playing music than in everyday life, and accommodations they may have found. Analysis: Descriptive analysis were used for all research questions. Word-based questions were coded to see any trends in response behavior. Validity/ Reliability: The study had been validated by a content validity panel and pilot-tested with 15 adult musicians for item test retest reliability (reliability coefficients ranging from 0.92 to 0.99).	V	

Reference	Category by grouping	Participants	Intervention	comparison	outcome	study design	method/ statistical tests	levels of evidence	comments
Russell and Benedetto_2014	Psychological and/or Physiological Correlation or Effect AND Practice or Teaching Habits	elementary (n=101), middle (n=97) and high school (n=159) string students non-probability sampling	none	N/A	Participants experienced little musculoskeletal discomfort, and no relationship was found between discomfort and warm-up or physical activities. Most participants reported warming up only “sometimes” (33.4%) or “usually” (25%). Some indicated warming-up “almost each time” (17.4%) or “always” (18.3%). Only 21 participants (5.9%) indicated that they “never” warmed up before playing their instrument. The majority of participants (62.8%) reported usually warming up between 1 and 5 min. The rest of the participants reported the following: 19% reported warming up for less than 1 min, 12.6% indicated spending an average of 6 to 10 min warming up and 5.7% (n=20) warm up for more than 10 min. Participants most commonly warmed up by playing scales (82%). The other mentioned warm-up methods were playing a favorite tune or exploration (58%), finger patterns (49%), long tones (44%), employing string-crossing warm-ups (31%) and position exercises (24%). Participants were least likely to engage in physical warm-ups such as stretching (20%).	questionnaire	Instrument/ test: The Physical Discomfort Questionnaire II (used in previous studies) had items on musculoskeletal discomfort (extent and location), warm-up activities, physical activities and psychological issues thought to impact perceived discomfort. Analysis via SPSS: one-shot cross-sectional survey method, independent samples t-tests, factorial ANOVA Validity/ Reliability: In previous research, high reliability with Cronbach’s $\alpha = .96$. In this study, also high reliability with Cronbach’s $\alpha = .91$. The validity of the questionnaire was investigated by comparing collected data with previous studies and the authors examined the predictive validity of responses.	V	
Russell_2006	Psychological and/or Physiological Correlation or Effect AND Practice or Teaching Habits	6th, 7th and 8th grade string players (N=158) 7 middle schools with string programs were randomly selected from a total of 16 schools. Only 6 schools agreed to participate from the selected 7.	none	N/A	Participants generally did not experience discomfort while playing their instruments, however 6th graders reported higher discomfort than 7th or 8th graders. The frequency, type or duration of warm-ups did not impact perceived discomfort. Warm-up frequency ranged from never to always: never (0.006%), sometimes (13%), usually (22%), almost each time (28%) and always (37%). Most participants (88%) reported having been taught how to warm-up by either their school orchestra teacher or a private instructor. The remaining 12% indicated that they were never taught how to warm-up. The frequencies of warm-up duration were: less than 1 minute (8%), 1 to 5 minutes (63%), 6 to 10 minutes (22%), and 10 or more minutes (7%).	questionnaire	Instrument/ test: The Physical Discomfort Questionnaire with items on the perceived discomfort and the body region of this discomfort as well as questions on the frequency, type and duration of warm-up activities. Analysis via SPSS: Statistical analysis included descriptive statistics, analysis of variance, and a series of t-tests using the Bonferroni adjustment. Validity/ Reliability: high reliability with Cronbach’s $\alpha = .96$. Author indicates that the selection process is a threat to the internal validity of this research.	V	
Silvey_2013	Practice or Teaching Habits	161 Missouri high school band directors (teacher) Response Rate: 36.8%	none	N/A	The results indicated that the most frequently used warm-up book was Superior Performance: Warm-ups and Techniques for Band by Richard Williams and Jeff King. The most frequently addressed music skills during warm-ups were tone quality, intonation, and balance and blend. Participants indicated that they spent in average of rehearsal time: 63.01% on rehearsing music selections, 19.21% on ensemble warm-up activities and 10.41% on sight-reading new music. Most participants (92%) indicated that students were allowed to warm-up individually before the start of the rehearsal. Most participants (65%) indicated that they create their own warm-ups.	questionnaire	Instrument/ test: Questionnaire items were tuning procedures, warm-up materials and procedures, and use of rehearsal time Analysis: coding by theme Validity/ Reliability: interrater reliability of 87% for question 6, 90% for question 10 and 85% for question 16 Other: questionnaire first used in pilot study with 5 high school band directors of neighboring states	V	

Reference	Category by grouping	Participants	Intervention	comparison	outcome	study design	method/ statistical tests	levels of evidence	comments
Yoshimura et al_2006	Practice or Teaching Habits	35 piano university majors	none	N/A	The results indicated the following on practice habits and warm-ups: the mean for warming-up prior to practice was 4.37 with a standard deviation (SD) of 3.29, the mean for physical warm-up time spent (min) was 3.26 with a SD of 10.46, the mean for psychological warm-up time spent (min) was 2.03 with a SD of 10.23 and the mean for musical warm-up time spent (min) was 17.71 with a SD of 13.07.	questionnaire and physiologic measurements	Instrument/test: Physiologic measurements were bilateral anthropometric measurements of the upper arm and hand, and upper-extremity performance tests for range of motion, isometric strength, and rotation speed. Finger mobility was assessed using digital photography. Questionnaire items were demographics and musical background, practice habits, and medical problems. Each question was presented with a visual analogue scale (VAS). Analysis via SPSS: descriptive statistics, cross-correlations, inter-correlations, factor development for regression modeling Validity/ Reliability: Authors indicated that the VAS is a reliable and valid approach for measuring pain.	V	
Yoshimura et al_2008	Psychological and/or Physiological Correlation or Effect	47 piano teachers from the Music Teachers Association Volunteers	none	N/A	The results suggest that playing-related pain of piano teachers is positively correlated to stretching as part of a warm-up and is inversely related to the amount of playing.	questionnaire and physiologic measurements	Instrument/ test: The physiologic measurements were anthropometric measurement of upper arm and hand, and bilateral upper-extremity performance tests (range of motion, isometric strength, and rotation speed). The questionnaire items included demographics, music background, practice habits, playing-related pain and general health. Analysis: descriptive, regression, cross- and inter-correlations and factor identification Validity/ Reliability: No mention of validity or reliability	V	No mention of validity or reliability

Reference	Category by grouping	Participants	Intervention	comparison	outcome	study design	method/ statistical tests	levels of evidence	comments
Zaza et al_1997	Psychological and/or Physiological Correlation or Effect	281 classically trained professionals and university students in ON, Canada participants were excluded if they indicated non-playing related problems Response rate: 66.7%	none	subjects who identified themselves with prevalent PRMD cases (n=110) and controls without a current PRMD (n=171)	Warming up before practice sessions protected the subject from a first episode of playing-related musculoskeletal disorders (PRMD), however a musical warmup did not predict the risk of recurrent PRMD. Physical warmup was protective of a PRMD. It is important to note that there was no operational definition of PRMD, participants rather self-identified if they responded yes to the question: “Currently, do you have a playing related musculoskeletal problem (i.e., any pain, weakness, numbness, tingling, or other symptoms that interfere with your ability to play your instrument at the level you are accustomed to)?”	questionnaire and physiologic measurements	Instrument/ test: The Playing-Related Health Questionnaire included five categories of questions: 1) Physical and Demographic Variables, 2) Psychological Variables, 3) Practice Behaviors and Other Playing-Related Variables, 4) Non-Music Related Variables, and 5) Instrument Groups. Participants were also asked to completed other questionnaires such as the Multidimensional Perfectionism Scale, A-Trait scale of the State Trait Anxiety Inventory, Kagan and Squires' Compulsiveness Inventory and The Positive Affect Negative Affect Schedule. Physiological measurements were hand span and hypermobility. Hypermobility was measured based on a standard protocol which was developed by Carter and Wilkinson in 1964. Analysis: The data were divided into 2 analyses both using univariate analyses and multivariate analyses. The 1st analysis used the data from participants with a 1st episode of PRMD (n=44) compared to no history of PRMD (n=90). The 2nd analysis compared all cases to all controls. Validity/ Reliability: The traits of perfectionism, anxiety and compulsivity were measured with standardized validated scales.	V	

Discussion

This is the first known systematized review of warm-ups and instrumental musicians. Given the number (7) and diversity of databases searched (medicine and arts), it is likely that a large percentage of relevant papers have been sourced. This review has identified several methodological limitations in the literature focusing on warm-ups and musicians and has ranked the scientific evidence by using the AACPDm levels of evidence. The following paragraphs will discuss the methodology and results of the included studies in their respective categories and indicate the level of evidence for each of these categories. Some studies overlapped in more than one category but were only included in one portion of the discussion. This will be followed by comparing the results to studies on warm-ups in other fields of research. Limitations of this review and suggestions for future research projects on the topics of warm-ups and music will also be addressed.

Practice or teaching habits: V(n=12), IV(n=1), II(n=2)

Abreu-Ramos and colleagues (2007) studied the playing habits of professional musicians. The method consisted of distributing a questionnaire and asking participants to complete a neuromusculoskeletal physical examination of the upper body. Eighty-three musicians volunteered for this study and the response rate was 90.4%. The results indicated that 90.7% of participants had a warm-up routine and stretching and warm-up were reported as factors for alleviating musculoskeletal symptoms. However, this study had methodological limitations such as lack of randomization of participants or lack of control group. The study design is also limiting in studying the effect of warm-ups as it did not include an intervention, but rather relied on the perception of participants in order to determine if stretching or warm-ups alleviated musculoskeletal symptoms. For these reasons, this study's evidence was rated at level V.

Kaufman and colleagues (2011) also studied the practice habits of professional musicians. The methodology consisted of a demographic questionnaire and the following standardized questionnaires: The Standardized Nordic Questionnaire on musculoskeletal pain, The Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire, The National Institute for Occupational Safety and Health (NIOSH) questionnaire and the Rapid Upper Limb Assessment (RULA). A hand therapist also observed the participants. Fifty-nine musicians from 3 major Israeli classical orchestras agreed to participate to this study. Results indicated an average of only 10 minutes a day of warm-up prior to playing and half of the musicians dedicated time to warm-up exercises. This study also indicated a negative correlation between playing-related musculoskeletal disorders and warm-up, therefore an increase in warm-up activities lowered the amount of playing-related musculoskeletal disorders. However, this study had a lack of intervention, and pre or post measures in order to determine the effect of warm-up activities on musculoskeletal disorders. This study also did not include a control group or multiple observers. The level of evidence was therefore evaluated as level V.

Arnason and colleagues (2018) studied the effect of an injury prevention course on music students. The study design was pre-test, intervention, post-test. The test was questionnaire on health history, practice and health habits, use of preventative strategies and history of playing-related musculoskeletal disorders (PRMD). The intervention was a course taught once a week during the school year and the content of the course included the following topics: a basic introduction of the musculoskeletal system and its function, the most common risk factors for PRMD, the most common injuries affecting musicians, optimal body alignment through a variety of physical exercises, specific shoulder and thoracic strengthening and mobility exercises and warm-up routines. Twenty-three students from the Iceland Academy of the Arts volunteered for

this study. These participants were divided into two groups: prevention group (n=13) and control group who did not participate in the intervention (n=10). The results indicated that post-intervention the prevention group increased the amount of warm-up prior to music performance compared to the control group which lessened the amount of warm-ups. The prevention group had a decrease in PRMD post-course, and the control had a slight increase in PRMD. This study had a few methodological limitations such as lack of randomization and small sample of participants but did include an intervention and a control group. For these reasons, this study was evaluated at level II. It is also important to note that the participants self-assessed their PRMD symptoms and were not officially diagnosed.

Barton and Feinberg (2008) also studied the effect of an injury prevention course on music students. The study design was pre-test, intervention, post-tests (post-test 1 after the course and post-test 2 a few weeks after the intervention). The test consisted of questionnaires on demographic, baseline or acquired knowledge and use of health promotion and prevention strategies. The intervention was an 8-week course on health promotion and injury prevention for musicians. Twenty-six music majors volunteered for this study. The results indicated that there was no significant difference between the total mean scores for the warm-up item of the questionnaire when comparing the pre-course test to the post-tests, however there was a difference between scores for stretching. Prior to the course 42% of participants indicated never or infrequently stretching prior to playing and this number decreased at 21% at post-test 1 and 30% at post-test 2. However, as mentioned by the authors, this study was limited by the small sample size and the lack of control group. Due to the lack of control group, this study was ranked as level IV.

Lopez and colleagues (2013) studied the effect of an injury prevention course on music students from the High Conservatory of Music of Salamanca in Spain. The study design consisted of a pre-test, an intervention, mid-intervention tests and a post-test. The test was a questionnaire on study of instrument, hours of practice per week, primary and secondary instrument, warm-up habits and frequency of warm-ups. The intervention was a one-year program of warm-up exercises and postural hygiene and a three-credit course on the prevention of musculoskeletal injuries, postural habits, and warm-up exercises for musicians. One hundred and forty-nine students were randomly chosen to participate in this study. Subjects were divided into two groups: an experimental group (n=56) and a control group (n=90). The results indicated that students in the experimental group had a decrease in injuries and the control group did not improve by the end of the experiment. There was a significant change in frequency of warm-ups for the experimental group; prior to the course, 90% of students did not warm-up prior to playing their instrument, and after the course 90% of the students in the experimental group did a correct warm-up prior to practicing. There was no significant change for the control group. This study did not establish that warm-ups decrease injuries directly as the program and course also included other injury prevention strategies such as postural habits. This study also did not mention validity or reliability measures. However, as this study included an intervention, a control group and the participants were randomized, it was ranked as level II.

Blackie and colleagues (1999) studied the practice habits of music students and their injury prevention education. The study design consisted of distributing a questionnaire which was previously piloted by a piano faculty member. The participants were 16 piano university students and the response was 64%. The results indicated that 4 students received prevention education on the importance of warm-up/cool-down and 4 students indicated using stretches to

resolve pain or discomfort. The results on frequency of use of warm-up/cool-down was: 4 responded never, 4 rarely, 1 occasionally, 4 frequently and 2 almost always. The frequency of use for stretching was 6 responded never, 5 rarely, 1 occasionally, 2 frequently and 1 almost always. However, this study did not include an intervention in order to determine if stretching reduced pain or discomfort. The sample of participants was small and there was no control group. The survey was not piloted by music students and the study does not specify if the survey was tested for reliability or validity. The evidence was therefore ranked at level V.

Buckley and Manchester (2006) studied the practice habits of music students during a summer camp. The study design consisted of a baseline questionnaire and a follow-up questionnaire. Some of the items on the questionnaires were: demographics, instrument played, practice habits, onset or reoccurrence of injuries, and previous injuries. Participants could also enroll in a videotaping session for the purpose of analyzing the posture and playing techniques of the students. These videos were analyzed by an instructor. One hundred and eleven students (age 10-87) participated in this study and the response rate was 68%. Results indicated that 30% of the participants regularly used warm-ups before practicing or playing and that the injured group was not more likely to do warm-up exercises than did the non-injured group. According to the participants, the warm-ups exercises included stretching, finger exercises such as scales and playing a familiar tune prior to playing. The methodological limitations include lack of randomization, lack of control, lack of intervention and lack of multiple observers for the analysis of videos. This paper did not mention validity measures. Participants also had a wide range of ages (from 10 to 87 years old). The level of evidence was ranked at level V.

Hagglund and Jacobs (1996) studied the practice habits of music students at the Boston University. The study design consisted of distributing a questionnaire and asking some

participants to complete a semi-structured interview. Three hundred music students received the questionnaire and 45 returned a completed questionnaire. Of these 45 participants, 19 agreed to an interview. As per my calculations, the response rate was therefore 15%. The results indicated that 33 of 44 respondents (75%) described stretching and performing warm up exercises prior to playing their instrument, but of these participants, 22 (68%) acquired injuries before, during, or after the habit of stretching began. However, this study design did not include an intervention with pre and post measures and did not include a control group. The questionnaire was not tested for validity or reliability. Furthermore, as mentioned by the authors, there is a possibility for errors in interpretation of questions and the sample size was small. The level of evidence is therefore level V.

Leon and colleagues (2015) studied the practice habits of members of a youth band. The study design consisted of a questionnaire on the practice habits, injury symptoms, use of ergonomics furniture, knowledge about musculoskeletal disorders risk factors, and awareness of any preventative education. Fifty-five members of youth Band of Zapopan and Guadalajara (ages 12 to 34) participated in this study. The results indicated that 77.4% of participating musicians warm-up, but only 42.3% of these respondents stretch. A majority of participants believed that poor warm-ups had an intermediate impact (43.4%) or larger than intermediate impact (35.8%) on musculoskeletal disorders. This study did not have an intervention or a control group and omitted to mention validity and reliability. Therefore, the evidence is a level V. The measured impact of warm-ups on musculoskeletal disorders was based on the perception of the participants via a questionnaire rather than a study design with a higher rating for levels of evidence.

Logue and colleagues (2005) studied the practice habits of cello students, professionals and amateurs. The methodology for this study included a questionnaire, interview and physical

examination. The physical examination consisted of a nerve conduction study, an examination of body movements such as cervical and shoulder, an extremity sensory examination with pin prick, reflexes, the Tinel's sign of median and ulnar nerves at the wrist, the Tinel's sign of the ulnar nerve at the elbow and the Phalen's test. Fourteen cellists (ages 18 to 32) participated in this study. Seventeen cellists were invited to participate and 3 declined, which to my calculation indicates a response rate of 82.35%. The results demonstrated that 9 of the 14 participants performed warm-up exercises before playing their instrument. The exercises included: scales, finger stretches, playing slow long notes, neck side bending, and arm rotations. Participants had normal upper extremity neural and musculoskeletal function. The methodological limitations for this study, was lack of intervention, lack of control, omission of validity or reliability measures, and small sample size. The evidence was then rated at the level V.

Russell (2006) studied the practice habits of 6th, 7th and 8th grade string players. The study design consisted of distributing The Physical Discomfort Questionnaire. Seven middle schools with string programs were randomly selected from a total of 16 schools, however, only 6 school agreed to participate. The total number of participants was 158. The results indicated that warm-up frequency ranged from never to always: never (0.006%), sometimes (13%), usually (22%), almost each time (28%) and always (37%). Most participants (88%) reported having been taught how to warm-up by either their school orchestra teacher or a private instructor and the majority of students (63%) indicated that their warm-up duration was 1 to 5 minutes. The frequency, type or duration of warm-ups did not impact perceived discomfort. The questionnaire had a high reliability; however, the participants were not chosen randomly, and the study design was solely based on a questionnaire without an intervention or control group. Therefore, the level of evidence is V.

Russell and Benedetto (2014) studied the practice habits of elementary, middle and high school string students. The study design consisted of distributing The Physical Discomfort Questionnaire II which was used in previous studies to students who were selected via non-probability sampling. A total of 357 students participated in this study: 101 elementary students, 97 middle school students and 159 high school students. Most participants reported warming up only “sometimes” (33.4%) or “usually” (25%). Some indicated warming-up “almost each time” (17.4%) or “always” (18.3%). Only 21 participants (5.9%) indicated that they “never” warmed up before playing their instrument. The majority of participants (62.8%) reported usually warming up between 1 and 5 min. Furthermore, participants experienced little musculoskeletal discomfort, and no relationship was found between discomfort and warm-up or physical activities. The questionnaire had high reliability and was tested for validity by comparing the collected data of previous studies. However, the study design solely relied on a questionnaire without an intervention or a control group, therefore the evidence was ranked at level V.

Yoshimura and colleagues (2006) studied the practice habits of university piano students. The study design consisted of a questionnaire and physiologic measurements. The questionnaire items were demographics, musical background, practice habits, and medical problems, and each question was presented with a visual analogue scale (VAS) which is considered a reliable and valid approach for measuring pain. The physiologic measurements were bilateral anthropometric measurements of the upper arm and hand, and upper-extremity performance tests for range of motion, isometric strength, and rotation speed. Thirty-five piano students agreed to participate to this research project. The results indicated that the mean for warming-up prior to practice was 4.37 with a standard deviation (SD) of 3.29, the mean for physical warm-up time spent (min) was 3.26 with a SD of 10.46, the mean for psychological warm-up time spent (min) was 2.03

with a SD of 10.23 and the mean for musical warm-up time spent (min) was 17.71 with a SD of 13.07. This study did not indicate if warm-ups had an effect on injury prevention and the study design relied on a questionnaire and physiologic measurements without an intervention.

Therefore, the study's evidence was ranked at level V.

Redmond and Tiernan (2001) studied the teaching habits of piano instructors from the Washington State Music Teachers Association. The methodology consisted of distributing a questionnaire demographics, injury prevention education received by the respondent, injury prevention instruction provided to students, and whether the participant wanted more information on injury prevention. Forty-two piano teachers participated in this study and the response rate was 28%. The results indicated that participants received education in injury prevention, most frequently from their teachers or colleagues. Participants were more likely to teach the importance of warm-up (73.8%) to their students among other strategies such as playing techniques (78.6%), and body mechanics and posture (83%). This study indicated that piano instructors teach injury prevention strategies based on information they received from their teachers or colleagues but did not provide data to support the statement that warm-ups prevent injuries for musicians. Therefore, the importance of warm-ups for injury prevention was taught based on experts in the field of music. This study also had the following methodological limitations: volunteers, lack of randomization, lack of intervention, lack of control, low response rate. Furthermore as indicated by the authors, the survey was not tested for reliability or validity, it was, however, reviewed by a committee for content validity, appearance and overall clarity, and was piloted by two piano teachers that were not included in the final research sample. The level of evidence for this study is V.

Silvey (2013) studied the teaching habits of Missouri high school band directors. The study design was to distribute a questionnaire on tuning procedures, warm-up materials and use of rehearsal time. The questionnaire was previously piloted with 5 high school band directors in neighbouring states. The number of participants was 161 teachers; however, the response rate was low at 36.8%. The results indicated that participants spent in average of rehearsal time: 63.01% on rehearsing music selections, 19.21% on ensemble warm-up activities and 10.41% on sight-reading new music. Most participants (65%) indicated that they create their own warm-ups and the addressed skills during group warm-ups were tone quality, intonation, and balance and blend. Most participants (92%) also indicated that students were allowed to warm-up individually before the start of the rehearsal. The questionnaire was tested for interrater reliability; however, the study design was solely based on a questionnaire, the response rate was low and the participants were volunteers and not randomized. Therefore, the level of evidence is V.

As a practice habit across all included studies, the percentage of participants who warmed up prior to practicing or playing varied between 10% (one study indicated that students did not warm-up at 90% prior to taking an injury prevention course) and 90.7%. Also, some studies indicated that music teachers tended to teach their students about warm-ups or that students learned to warm-up from their teachers. However, most of these studies were ranked at level V as the study design was only based on a questionnaire, participants were volunteers, and there was no randomization and control group. No study ranked at level 1 for this category. The study by Lopez and colleagues (2013) ranked at level II which indicated that students practice a warm-up routine more frequently after an injury prevention course. It is important to note that this study did not provide a result that indicates if warm-ups can prevent injury. The study by

Arnason and colleagues ranked at level II and indicated that the prevention group (who followed a prevention course) increased the amount of warm-up prior to music performance and the comparison group lessened the amount of warm-up. This study also indicated that the prevention group reported a lower rate of current playing-related musculoskeletal disorder after the course and the control group had a slightly higher rate of musculoskeletal disorder; however, no direct correlation was established between the use of warm-up and the lower rate of musculoskeletal disorder.

Experts' opinion: V (n=2)

Ajidahun and Philipps (2013) studied the opinion of experts in performing arts on the use of warm-ups for musicians. The study design was a delphi study with 3 phases in order to obtain an informed consensus from a group of experts via a questionnaire. The consensus was set at 65%. The participants were 7 experts in performing arts who volunteered for this study: 3 medical doctors, 2 physical therapists, 1 occupational therapist and 1 freelance musician. All participants agreed that a warm-up program should be taught as an injury prevention strategy and should be completed prior to playing a music instrument. Participants also agreed that the content of the program includes musical warm-up and stretching but excludes aerobic exercises as a consensus was not reached. Consensus was not reached on the duration of the warm-up program, but the result suggests that the duration could be within 5 to 15 minutes. The methodological limitations are the following: small sample size, no mention of reliability, no intervention and no randomization of participants. This study did not provide strong evidence as the results are based on experts' opinion rather than using a study design that could lead to stronger conclusions. This study suggests that experts recommend warm-ups for injury

prevention but does not provide empirical data to support this statement. Therefore, the level of evidence is ranked at V.

Rowher (2008) studied the opinion of adult musicians on the use of warm-ups. The study design was a questionnaire. The questionnaire validated by a content validity panel and piloted by 15 adult musicians for item re-test reliability. Eighty-three musicians (ages: 47 to 91) who attended a summer senior band camp participated to the study. The participants indicated that stretching is an exercise that can be done in order pain among other strategies such as regular practice, education and relation techniques. The methodological limitations are the following: omission of response rate, no intervention and no control group. The result was based on opinion rather than objective measures. The study was therefore ranked as level V.

These two studies indicated that experts believe in warm-ups and or stretching as injury prevention strategies and they also believe that these strategies have an impact on playing-related injuries and discomfort. However, both studies' evidence was ranked at level V as it did not provide strong evidence to support the claim that warm-ups prevent injury.

Performance quality correlation or effect: V (n=1), IV (n=1)

Some of the included studies in this review were categorized by the first author of this review as performance quality correlation or effect. Drinkwater and colleagues (2010) studied the effect of multiple performances on wind players. The study design was pre-test, intervention mid-intervention tests and post-test. The tests consisted of collecting physiological measures such as heart rate, respiratory rate, blood pressure and blood lactate concentration, and collecting psychological measures such as perceived exertion and anxiety rating. The intervention was 3 consecutive performances of 10 minutes of repertoire for the chosen wind instrument. These performances were audio recorded and later analysed for performance errors and a repeat

analysis of a smaller sample of data was completed in order to establish reliability. Ten wind players with a range of 3 to 38 years of playing experience participated in this study. Participants acted as their own control group. The results indicated that there was a warm-up period which showed an initial increase in physiological stress of the participants with fewer errors. However, this study had some methodological limitations such as no separate control group, no mention of validity measures, no randomization, and small sample size with a large difference in years of experience. For these reasons, the level of evidence was ranked at level IV.

McPherson and McCormick (1999) studied piano students who were completing the Trinity College examinations. The study design was a questionnaire on self-regulatory learning components and motivational components of instrumental learning. The results of the performance examinations were also included as part of the analysis. The number of participants was 190 piano students (age:9 to 18) for a response rate of 60%. The results indicated that participants with higher levels of practice were more likely to have a warm-up routine. This study also indicated that if participants were spending more time on creative activities, repertoire and technical work (including a warm-up routine), they tended to be more cognitively engaged during practice and to have more intrinsic learning interest for their instrument. The methodological limitations were no mention of validity or reliability, no intervention, no control group, and no randomization. As this study did not include an intervention, the evidence was ranked at level V.

Therefore, these two studies (Drinkwater et al., 2010; McPherson and McCormick, 1999) did not provide strong evidence in order to support the statement that warm-ups have an effect on musicians. The study by Drinkwater and colleagues (2010) was ranked at level IV which may

suggest a causation between warm-ups and performance quality, however, more research is required in order to establish the correlation or effect.

Psychological and/ or physiological correlation or effect: V (n=6), IV (n=1), II (n=1), I (n=1)

A few papers studied the psychological or physiological correlation or effect of warm-ups on musicians. Beckett and colleagues (2015) investigated the prevalence of musculoskeletal injury and associated factors of collegiate marching band members. The study design consisted of distributing a questionnaire to 21 collegiate marching bands. The questionnaire items were demographics, years of experience, training and performance, footwear worn, instrument played, equipment used, participation in stretching or strengthening programs, injury prevalence and type, treatment sought for injury and participation time lost due to injury. The response rate was 28.2% and 1379 musicians volunteered for this study. The results indicated that some marching bands offering a structured and supervised stretching/strengthening program on an individual basis for less than 5 minutes. The participants in these programs reported a higher prevalence of musculoskeletal injury. The methodological limitations were lack of intervention, lack of control, lack of randomization, low response rate. Furthermore, the content of the survey was reviewed by a panel, but the authors did not indicate if the survey was tested for validity or reliability. The evidence was therefore evaluated at level V.

Bertsch and Maca (2001) studied the effect of warm-ups on trumpet players. The study design was pre-test, intervention, mid-intervention tests and post-test. The tests consisted of frontal and lateral thermography images, a questionnaire on the importance and duration of warm-ups and physiological measures such as auxiliary and finger temperatures, blood pressure and pulse rate. The intervention was 3 warm-up phases: easy exercises for three minutes, an

exercise of medium difficulty and 10 minutes of individual warm-ups. The number of participants was 16 trumpet players: 5 professionals, 5 students and 6 beginners. Participants indicated that their daily amount of time on warm-ups varied from 0 to 90 minutes and that was not correlated to the playing level. Participants also indicated an increase in the rate of accuracy when playing a b2 after a warm-up. The pulse of professional dropped 3.6 bpm after the warm-up, but it augmented for students and beginners after the warm-up. The infrared thermography indicated that the embouchure region increased temperatures during brass playing and the blood supply seems to be redistributed from lateral to central parts, restricted to only a few muscle groups in this area (M. orbicularis oris, M. depressor angulioris, M. levator anguli oris). The methodological limitations were lack of control group and small sample size. Furthermore, this study did not specify how the participants were selected, how the analysis was conducted or if the validity or reliability was taken into consideration. This article, however, refers to the original thesis, written in German which is out of the scope of this study. Due to the lack of control group, small sample size and no mention of randomization of participants, the evidence was ranked at level IV.

Cooper and colleagues (2012) studied the effect of a stretching program on high school string students. The study design was pre-test, intervention and post-test. The tests were Perception of Discomfort survey, demographic questionnaire and five-part question using a Likert-type scale to report any experienced discomfort in the hands, wrists, arms, shoulders, and neck. The intervention was stretching exercises from *Stretching for Strings* by Winberg and Salus (as cited in Copper et al., 2012) that were completed at various intervals throughout rehearsals. One hundred and twenty-six students from 4 schools participated to this study and were divided into two groups: treatment group (n=57) and control group (n=43). The results

indicated that students in the treatment group reported lower discomfort levels after treatment than before the treatment and the control group reported higher levels of discomfort after rehearsal than before rehearsal. The methodological limitations were lack of randomization, more participants in the treatment group than in the control group and no mention of validity or reliability. The study's evidence was ranked at level II.

Davies and Mangion (2002) studied the investigating predictors of pain and symptoms of professional musicians. The study design was a questionnaire on musculoskeletal pain and symptoms, musical background, health and lifestyle activities, beliefs and attitudes about pain/symptoms and their correlates, current professional activities, work environment, and work-related stress. Two hundred and forty musicians working in Sydney's classical and non-classical music industry volunteered for this study. The response rate was 45%. The results indicated that players with severe pain and symptoms of high stress interacted with lack of warm-up. Players with previous injuries used more frequent prevention strategies such as warming-up, cooling down, and taking breaks during their practice. According to the authors these higher levels of preventative behaviors are more likely to be an effect of pain/symptom rather than a cause. The methodological limitations were lack of intervention, lack of control group, lack of randomization, use of volunteers and no mention of validity or reliability. Therefore, the evidence was ranked at level V.

De Smet and colleagues (1998) studied the incidence of upper limb problems among pianists and their playing habits. The study design was a questionnaire on playing habits and musculoskeletal problems, and physiological measurements such as hand size and hypermobility. Sixty-six pianists (age: 18 to 32) and 66 volunteers for the control group (age: 18 to 32) participated in this study. The results indicated that warming-up before playing and stretching

afterwards did not influence the incidence of overuse syndromes in pianists as it was not significantly different between pianists with (n=28) and without (n=38) overuse syndromes. The methodological limitations were lack of intervention, lack of randomization, use of volunteers and no mention of validity or reliability. The level of evidence was ranked at V.

Grieco and colleagues (1989) studied music practice and musculoskeletal disorders among piano students. The study design consisted of first distributing a questionnaire to piano students. The questionnaire items were organization of study and free time, occurrence, site and characteristics of musculoskeletal disorders and occurrence of psychic, respiratory or digestive complaints. Respondents of the questionnaire were also asked if they were interested to participate for the electromyographic collection of data which was collected during a set of standard piano exercises with varying difficulty by Hanon, a sight-reading piece by Scott Joplin and two passages from the student's repertoire. One hundred and seventeen piano students completed the questionnaire of whom six participated (3 male and 3 female participants) in the electromyographic study. The questionnaire response rate was 75%. The results of the electromyographic data indicated that during the warm-up phase which occurred prior to the study of a score, the deltoid and bicipital muscles showed a low level of effort and the effort of trapezius muscles was asymmetric. Some muscles were used to greater extent in the male participants, for example the epitrochlea. The female participants had a marked effort of the intrinsic muscle structure of the hand. The authors concluded that musicians should perform relaxation and stretching exercises for the muscle groups most involved during practice and exercises to strengthen the supporting muscle groups as tools for injury prevention. The methodological limitations were small sample size for the electromyographic data collection, no

mention of validity or reliability, lack of intervention, no control group, no randomization of participants and volunteered based. The level of evidence was ranked at level V.

McCrary and colleagues (2016) studied the effect of warm-ups on professional violinists. The study design was pre-test, intervention, post-test. The tests consisted of a performance of 5 excerpts while collecting EMG data and a questionnaire with the following items: warm-up habits, perception of effect of warm-ups and location, and type and duration of physical symptoms. The 15-minute intervention consisted of one of four conditions: cardiovascular warm-up, core muscle warm-up, musical warm-up (technical violin exercises) and control condition where participants did not partake in a warm-up exercise. Performances were recorded and evaluated. Duplicate recordings were included in order to ensure reliability of adjudication. Fifty-five undergraduate, postgraduate and professional violinists participated in this study. A stratified randomization was completed in order to assign participants to a condition and to ensure that a similar number of participants with playing-related issues were assigned to each condition. The results indicated that the three warm-up conditions did not have a significant effect on the muscle activity levels. Performance quality did not significantly increase. Perceived exertion significantly decreased for the three warm-up conditions and did not significantly decrease for the control condition. This study had an intervention, control group and participants were randomized, therefore the evidence was ranked at level I.

Yoshimura and colleagues (2008) studied the playing-related pain of piano teachers and possible related factors. The study design was a questionnaire on music background, practice habits, playing-related pain and general health. The study design also included the following physiologic measurements: anthropometric measurement of upper arm and hand, and bilateral upper-extremity performance tests (range of motion, isometric strength, and rotation speed).

Forty-seven piano teachers from the Music Teachers Association volunteered for this study. The results indicated that playing-related pain of piano teachers is positively correlated to stretching as part of a warm-up and is inversely related to the amount of playing. The methodological limitations were no mention of reliability or validity, lack of intervention, lack of controls, lack of randomization and volunteer based. The evidence was ranked at level V.

Zaza and colleagues (1997) studied the risk factors of playing-related musculoskeletal disorders of musicians. The study design consisted of questionnaires and physiologic measurements. The questionnaires were the Playing-Related Health Questionnaire, Multidimensional Perfectionism Scale, A-Trait scale of the State Trait Anxiety Inventory, Kagan and Squires' Compulsiveness Inventory and The Positive Affect Negative Affect Schedule. The authors mentioned that some of these questionnaires (Multidimensional Perfectionism Scale, A-Trait scale of the State Trait Anxiety Inventory, Kagan and Squires' Compulsiveness Inventory) were standardized and validated. The physiologic measurements were hand span and hypermobility. Two hundred eighty-one classically trained professionals and university students participated in this study. The response rate for this study was 66.7%. Subjects who identified themselves with prevalent playing-related musculoskeletal disorders (n=110) were compared to controls who did not have a current playing-related musculoskeletal disorders (n=171). The results indicated that warming-up before practice sessions protected the subject from a first episode of playing-related musculoskeletal disorders (PRMD), however a musical warmup did not predict the risk of recurrent PRMD. Physical warm-up was protective of a PRMD. The methodological limitations were lack of intervention, lack of randomization, and self-identification of participants for PRMD. This study's evidence was ranked at level V.

Most of these studies with a result regarding psychological or physiological correlations or effects of warm-ups on musicians were ranked at an evidence level of V. One study (Bertsch and Maca, 2001) ranked at level IV which merely indicate a causation more research is required in order to establish the correlation or effect. One study ranked at level II (Cooper et al., 2012) which indicates a tentative conclusion that stretching throughout the rehearsal may help to alleviate some discomfort in music students. However, only one study (McCrary et al., 2016) was ranked at level I and indicated that the 3 warm-up conditions did not have a significant effect on the muscle activity levels and performance quality did not significantly increase. The only significant change between the 3 warm-up conditions and the control condition is that perceived exertion significantly decreased for the warm-up conditions and did not significantly decrease for the control condition. As indicated by Butler and Darrah (2001), it is important for clinicians to rely on the best evidence to inform their treatment recommendations. These researchers indicate that the level I studies of the AACPDM's levels of evidence produce the most credible evidence and, therefore, provide the most definitive results. Therefore, the only study that was ranked at level I, did not find a significant effect of three warm-up conditions on the muscle activity levels of musicians.

Other scoping review: Level of evidence non-applicable due to the study design

The scoping review by Ajidahun and colleagues (2019) studied the evidence of exercise-based programmes in the management of musculoskeletal problems of musicians. The methodology consisted of searching the following databases: Searched Databases: Physiotherapy Evidence Database (PEDro); MEDLINE via PubMed; Cumulative Index to Nursing and Allied Health Literature (CINAHL); Cochrane Controlled Trials Register in the Cochrane Library; EBSCO; Sport discuss; and SCOPUS. This review was structured on the population, phenomena

of interest, intervention and outcome (PICO) and had the following five steps: to identify the research questions and relevant studies; to select material for the study; to chart data; and to summarise and collate the results. A total of 176 articles were identified and 12 met the inclusion criteria and were included in the study. The results indicated that the prescribed exercises include stretching exercises prior to performance to reduce strain to the musculoskeletal system. Warm-up exercises were included as part of the overall exercise intervention in four studies and only two studies reported on the specific warm-up exercises done. One of the methodological limitations of this review was no mention of validity or reliability. Furthermore, as indicated by the authors, this study did not evaluate the quality of the reviewed articles. Therefore, the authors indicated that: “the result of effectiveness should be interpreted with caution.” (Ajidahun et al., 2019, p. 24)

Conclusion

Of the 29 studies which were included in this systematized review, the evidence was mostly ranked at level V and therefore cannot lead to an empirically supported conclusion. Most of these studies were based on anecdotal evidence obtained via questionnaires rather than measuring the effect of an intervention. A few studies were ranked at level IV which only suggest causation. Three studies (Arnason et al., 2018) were ranked at level II which indicates a tentative conclusion. Only one study was ranked at the evidence level of I (McCrary et al., 2016) which indicated that three warm-ups conditions did not have a significant effect on the muscle activity level of musicians. Therefore, there is currently no empirical evidence that supports the statement that warm-ups prevent playing-related injuries. More studies with fewer methodological limitations are required and there is a need for standardization as there was no consistency for the methodology, effect measured, and type of warm-up measured.

It is interesting to compare these results to the literature in sports medicine as warm-ups are also frequently discussed in this field of research. In a literature review, Bishop (2003b) indicated that warm-ups are based on trial and error rather than scientific study in the athletic community. He also mentions: “while warm up is considered to be essential for optimum performance, there is little scientific evidence supporting its effectiveness in many situations,” and that the studies were not controlled, had few participants and often omitted statistical analyses (p. 483). However, in another literature review, Woods and colleagues (2007) indicated: “there are conflicting opinions regarding methods of reducing muscular injury through warm-up and stretching techniques” but that it is due to contradicting definitions of the term. Woods and colleagues’ review was able to convey that certain techniques of warm-ups or stretches had a positive outcome on deterring injuries of athletes.

McCrary and colleagues (2015) completed a systematic review on the effects of upper body warm-up on performance and injury in athletes. The following databases were searched: Web of Science, Medline, SPORTDiscus, PsycINFO and Cochrane databases. The search string was: “warm up” OR “warm-up” OR “warmup” AND “upper extremity” OR “upper limb” OR “back” OR “trunk” OR “neck” OR “spine” OR “shoulder” OR “elbow” OR “arm” OR “wrist” OR “hand” OR “forearm.” Inclusion criteria were English, randomised controlled trials, peer-reviewed and had to study upper body warm-up on performance and injury prevention outcomes. Included studies were assessed for methodological quality using the PEDro scale. Thirty-one studies were included in this review. The results indicated that outcomes were grouped into eight categories and that the included studies did not indicate an effect of warm-ups on injury prevention. As for performance enhancement, static stretching and passive heating or cooling were ineffective methods. In McCrary and colleagues’ review, few studies indicated a potential

effect of warm-ups on the upper body of athletes, but most included studies (21 of 31) had a good methodological quality. These results are comparable to our systematized review as it was not able to demonstrate that warm-ups or stretches had a positive outcome on deterring injuries for musicians.

Limitations

In order to limit the scope of the study due to reduced resources and time, student dissertations (master or doctorate theses) were not included. Only English published articles were considered for this study. This study was also limited as the data collection and analysis were completed by one reviewer which affects the reliability and validity of this study. However, the evaluation of the data was completed by a second graduate student in order to validate the first reviewer's ranking of evidence and the collection of data was completed twice during a one-month period by the first reviewer in order to limit potential mistakes.

Another limitation was the use of a single search string for each type of database, there is a possibility that more studies could have been included if the search string had terms related to injury prevention. However, this would have widened the scope of the current study. Furthermore, due to COVID-19, some potential articles (n=4) sourced from reference lists were not available as they could not be sourced online, and the inter-library loan program was not available.

Implications for further research

Our systematized review indicated that there was no consistency in methodology, effect measured, or type of warm-up measured. No studies assessed the optimal duration of a warm-up and the interval of time between warm-up and performance. Also as indicated by Woods and colleagues' review in sports medicine (2007), the various definitions of the term may lead to

contradicting results. Therefore, further studies on the definitions of warm-ups for musicians are necessary.

Chapter 5 – Study 2

Terminology review and taxonomy: Definitions of musicians' warm-ups

Abstract

Warm-ups are often recommended to musicians as an injury prevention strategy; however, the definition of warm-ups and associated terms differ between authors. In order to facilitate more effective communication in the field, this study will consist of a terminology review and taxonomy on warm-ups for musicians. The corpus contained 29 empirical studies that were previously identified for a systematized review. The terms were selected based on their contextual surroundings and the chosen method of extraction was manual highlighting. The terminology review indicated that stretching may not always be part of a warm-up, therefore it was determined that a second definition should be created for stretching specifically. The resulting definition of warm-up is: “A routine, habit or exercise(s) that is/ are completed prior to playing repertoire or learning new material on a music instrument in order to prepare physically and mentally the musician. The following can be included as part of a musician’s warm-up: physical warm-up (completed without the instrument, for example stretches), musical warm-up (completed with the instrument, for example: scales, familiar tune/ favorite tune, long tones), and psychological warm-up.” The resulting definition for stretching is: “Slow, controlled and progressive movements that are maintained for at least 20-30 seconds. These are done at various intervals throughout the day such as prior, during (breaks), and after the practice of a music instrument. They are referred to as physical exercises (away from the instrument). The following are some examples of stretching exercises: wrist rotations, forward neck roll, oppositional finger-wrist press, hand-finger extensions, fist clench and unclench, arms-bicep curls, handshakes, arms-triceps extension, and fingers clenched and unclenched.” The taxonomy indicated three warm-up categories: physical, musical and psychological. The physical and musical warm-ups

were subcategorized but it was not possible to subcategorize psychological warm-ups due to a lack of definition and examples in the literature.

Keywords: music, musicians, warm-up, stretching, injury prevention, terminology review, taxonomy

Introduction

Many researchers have studied playing-related pain and injuries of musicians (Ackermann, et al., 2002; Chan et al., 2014; Dawson, 2008; Fishbein et al., 1988; Guptill et al., 2000; Hagglund, 1996; Lederman, 1989; Ranelli et al., 2008; Shoup, 1995; Silva et al., 2015; Yeung et al., 1999; Zaza, 1992; Zaza and Farewell, 1997). These studies indicate a high rate of pain and injury among professionals and students, and the proposed solutions are to educate musicians on injury prevention strategies or to provide injury prevention programs for this population. Zaza (1993) provided a rationale for the prevention of playing-related health problems and indicated that there are extrinsic risk factors for musicians' injuries that are behavioral and changeable such as stress, technique, or practice habits, therefore a prevention program for musicians is realizable. This researcher also states that a program for musicians is in demand due to concerns for playing-related health problems. Music students in particular are not necessarily aware of the possible health conditions related to being a musician or of how to prevent them.

One of the strategies frequently recommended is to warm-up prior to practicing or performing (Chesky et al., 2006; Guptill and Zaza, 2010; Spaulding, 1988; Parry, 2003; Paull and Harrison, 1997; Horvath, 2009; Watson, 2009; Tatz and Mayoroff, 2010; Tubiana and Amadio, 2000). According to Horvath (2009), warming up is considered one of her five essential practice rules in order to reduce the risk for injury. Guptill and Zaza (2010) also indicated that

warm-ups are an important component of injury prevention for musicians. Furthermore, many injury prevention programs such as the one by Brandfonbrener (1997) or the one by Zander and colleagues (2010) include warm-up exercises.

While warm-ups are frequently recommended as an injury prevention strategy, one of the issues with the current literature is the lack of well-defined terminology. The definition of warm-ups differs between authors and the concept is rarely clearly defined. Some authors indicate that warm-ups should include musical (e.g. scales or easy pieces), and physical (e.g. stretches) components (Guptill and Zaza, 2010; Parry, 2003; Paull and Harrison, 1997; Horvath, 2009; Watson, 2009); however the list of warm-ups activities can be completely different between articles. For example, Parry (2003) indicated that a proper warm-up should include physical exercises such as stretching and full body flexibility exercises. On the other hand, Guptill and Zaza (2010) indicated that deep breathing exercises for wind players should be part of a physical warm-up and recommended slow comfortable playing for a musical warm-up which could include scale, arpeggios or easy repertoire. Spaulding (1988) mentioned that a daily warm-up should also include music composition, which was not included in the warm-up programmes of the previously mentioned authors. In textbooks on musicians' wellness, Paull and Harrison (1997) recommend a pre-practice routine which includes a body warm-up with an aerobic activity such as cycling and dancing, followed by pre-practice stretches and another warm-up on the instrument which can include technical exercises and repertoire as long as it is moderately demanding and varied. Horvath (2009)'s routine includes a brisk walk, stretches and warm-up on the instrument. Watson (2009) indicates two phases in the warm-up routine: one without the instrument and one with the instrument where the musician is instructed to play some easy pieces or exercises. These authors (Guptill and Zaza, 2010; Parry, 2003; Paull and Harrison, 1997;

Horvath, 2009; Spaulding, 1988; Watson, 2009) mentioned various terms when discussing warm-ups such as “stretching,” “aerobic activity” and “brisk walk,” “without the instrument,” “with the instrument,” “technical exercises,” “scales,” “repertoire” and “pieces.”

The use of multiple terms leads to terminology issues. Firstly, not every term is defined. For example, Watson (2009) does not explain what he means by “warming-up the muscles,” or “exercises concentrating on accuracy.” Secondly, some terms are defined differently. For example, Horvath (2009) mentions that stretching should be part of a daily warm-up: “Stretching before you begin to play is essential to begin warming you up for the challenge of playing” (p. 86). However, she also quotes Peter DeLuca, M.D. which contradicts her own definition: “One of the misconceptions is that stretching is a warm up, and it’s not...” (p. 196). Finally, some terms are used in various contexts depending of the author such as the term “finger exercise” which is used by Tatz in Mayoroff (2010) to describe both physical and musical warm-ups: “finger exercise 1 warms up the muscles responsible for finger action in the hand and arm. Count to three in your head. “1, 2” –clench your fist- “3”- unclench your fist, letting your fingers half-bent” (p. 162) and “finger exercise 10 shake your hands around. Stay relaxed as you do these examples [...] example VI play this chromatic scale up and down” (p. 165).” Furthermore, Tatz and Mayoroff (2010) use terms interchangeably “morning warm-up” and “gymnastic exercises”, however the use of these terms may be interpreted differently from one individual to another as there is no clear definition of both terms. The use of multiple terms can therefore create confusion due to the lack of definition and the unclear term relationships. In order to facilitate more effective communication in the field, this study will consist of a terminology review and taxonomy.

Methodology

For this terminology review, the chosen field is music performance. The first step consisted of obtaining a corpus. The corpus contained empirical studies that were previously selected for a systematized review in a previous paper (Fleet and Comeau, In preparation). The resulting 29 studies were considered for this terminology review. However, one study (Ajidahun et al., 2019) was deemed non-applicable for this review due to the study design. Ajidahun and colleagues (2019) completed a scoping review and were therefore paraphrasing other authors. For the accuracy of the terminology review, it is important to obtain material from the original source. Therefore, the total number of studies that were included to obtain the terminology data was 28.

The second step, term extraction, began by finding sentences and paragraphs that included the words “warm” or “stretch” by using the search function in Adobe Reader when available. These words were chosen as the starting point of reference in order to identify terms that were associated to warm-ups or stretches via proximity. The words “warm” or “stretch” were also chosen as they would identify various versions of the word “warm-up” such as “warming up,” “warmup,” “warm up” or the word “stretch” such as “stretches” and “stretching.” Relevant terms were then identified based on the context of the sentence and were categorized as terms used to define warm-ups or stretches, or terms used to describe other injury prevention techniques. The chosen method of extraction was manual highlighting by using the highlighter function in Adobe Reader which consisted of manually marking the beginning and the end of each term’s context such as one or multiple sentences if necessary. This data (terms and their context) was subsequently transcribed in a Microsoft Excel table. The extraction phase was

repeated a second time in order to reduce the possibility for errors and to ensure that all terms were collected.

The third step consisted of consolidating the terms and grouping them into larger categories in order to create a terminology entry with a definition of warm-up. The consolidation of terms was completed by counting the number of articles that used each term and keeping track of this data in Microsoft Word tables. Terms were retained for the definition of warm-up if they were present in more than 2 articles. This condition did not apply for terms that indicated a category such as musical warm-up or physical warm-up. The terminology entry for this study was then created with Microsoft Word. It includes the following information: key terms, definition of warm-up, context of the definition and terms, and observations. The terminology entry was based on the Government of Canada's terminological record, which is known as Termium Plus. This record was chosen as the reference for this study because "it is one of the largest terminology and linguistic data banks in the world" (Termium Plus, 2020, para. 1).

The fourth step consisted of creating a taxonomy in order to illustrate the warm-up categories and their related terms. This was created by following Bloom's guiding principles for developing a taxonomy as his major purpose for constructing a taxonomy of educational objectives was to facilitate communication (Bloom, 1956). Bloom's first principle is that the taxonomy is based on existing studies and reflects the distinctions that were made by the researchers. The second principle is that the taxonomy needs to be logically developed and internally consistent throughout. The third principle is that the taxonomy is consistent with present understanding of the phenomena. The fourth principle is that the taxonomy should be purely descriptive and represented in a neutral fashion. According to Bloom, the steps to create a taxonomy are the following: gather a large list of terms from the literature, attempt to find

divisions or groups to place the terms, divide groups into subdivisions and attempt to find ways of defining these subdivisions. Therefore, we attempted to subdivide terms into categories and to find ways of defining these subdivisions based on the distinctions that were made by the researchers of the included articles. The taxonomy on warm-ups was represented with a tree diagram that was created in Microsoft Word. This study was funded by the Canada Graduate Scholarship (NSERC-CIHR). No additional source of funding was used to complete this research.

Results

Terminology review

The following terms were frequently located in the same sentence as warm-ups when describing them or when describing other preventative techniques: exercise (n=11), scales (n=10), physical warm-up (n=6), musical warm-up (n=6) and breaks (n=5). A more comprehensive list of terms for each study is included in table 8. The count of reference for each term (number of articles with this term) is included in tables 9 to 14. The count of reference for variations on the term warm-up (warmup, warm up, warming up and warming-up) indicated that the most frequently used version is warm-up at 57% (n=16). Twelve studies indicated that warm-ups should be completed prior to playing the instrument and one indicated that warm-ups should be done during breaks and after the practice. Based on the larger number of studies, it was determined that warm-ups should be completed prior to playing in the terminology entry (see figure 3). Based on the most frequently used terms with the exception of categories such as ‘individually,’ ‘in an ensemble,’ and ‘psychological warm-up,’ the resulting definition of warm-up is: “A routine, habit or exercise(s) that is/ are completed prior to playing repertoire or learning new material on a music instrument in order to prepare physically and mentally the musician.

The following can be included as part of a musician's warm-up: physical warm-up (completed without the instrument, for example stretches), musical warm-up (completed with the instrument, for example: scales, familiar tune/favorite tune, long tones), and psychological warm-up.”

Among the warm-up exercises, one was particularly confusing. The terms stretch(es) and stretching were used to define warm-up(s) in 5 and 6 articles respectively. An additional 8 articles mentioned the term stretching but it could not be linked to a definition of warm-up as most of them did not have sufficient information and a couple articles indicated the term stretching as a separate injury prevention strategy from a warm-up. It was determined, therefore, that a clear definition for stretching should be elaborated. This definition was created with the terms that were used to define stretching specifically. The rule of more than 2 articles mentioning the term was revoked for the definition of stretching due to the low number of studies that defined stretching. The resulting definition is: “Slow, controlled and progressive movements that are maintained for at least 20-30 seconds. These are done at various intervals throughout the day such as prior, during (breaks), and after the practice of a music instrument. They are referred to as physical exercises (away from the instrument). The following are some examples of stretching exercises: wrist rotations, forward neck roll, oppositional finger-wrist press, hand-finger extensions, fist clench and unclench, arms-bicep curls, handshakes, arms-triceps extension, and fingers clenched and unclenched.” Stretching can be done throughout the day and can be a component of a warm-up only when it is completed prior to playing the instrument.

Taxonomy

Only one taxonomy for warm-ups was created as there was insufficient information to divide stretching into subcategories. Stretching was included as one of the warm-up subcategories as it sometimes meets the criteria of being completed prior to playing a musical

instrument. As illustrated in the taxonomy (see figure 4), warm-up was divided into three categories: physical, musical and psychological. These were further divided into subcategories and examples from the literature were provided when available. Physical warm-ups, which are done without the instrument, were divided into the following subcategories: stretching exercises, cardiovascular exercises, manual therapy and applying heat. The categorization was based on terms used in the literature, except for “manual therapy.” This category was added by the first author of this terminology and taxonomy study in order to regroup the terms “self-massage,” “traction,” “mobilization,” and “friction” which were present in the literature. Furthermore, the term “movement” was excluded from the taxonomy as it could have been categorized under various subcategories of physical and musical warm-ups.

Musical warm-ups, which are done with the instrument, were divided into the following subcategories: technical exercises, familiar/favorite tunes and exploration/ improvisation. These categories were obtained from the literature except for the term “improvisation.” Based on the years of teaching experience of the first author of this terminology and taxonomy study, it was determined that the term “exploration” is not as frequently used in music pedagogy as the term “improvisation” and it was therefore decided to include the term “improvisation” for reasons of clarity within the community of music teachers. The category technical exercises include postural awareness and proper posture as examples to reflect the literature’s contextual surrounding. Posture is discussed in relation to the instrument and is part of proper technique. Other examples of this category include scales, arpeggios, études and specific technical exercises such as tremolo or string crossing exercises. The category on familiar/favorite tunes was based on the most frequently used terms in the empirical literature rather than using the term “easy pieces” which was mentioned in the literature on musicians’ wellness. Only one empirical study

mentioned “easy exercises,” however no additional information was provided in order to link this type of exercise to musical warm-ups. The category of psychological warm-up was not subdivided as the literature did not provide a definition or examples for this type of warm-up.

Table 8

Summary of terminology data per paper

Reference	Definition of warm-up	Context	Terms	Quotes	Mentions Musical and Physical Warm-ups (Y/N)	comments
Abreu-Ramos et al_2007	Completed prior to playing , *no further details .	Terms used in a questionnaire in order to collect participants' playing habits.	-Warm-up routine -Stretching (may or may not be part of warm-ups) -cool-down (opposite of warm-up)	"Although 90.7% had a warm-up routine prior to playing, almost none (20%) practiced a cool-down process after they had finished playing." p. 99 "Rest (77.1%), posture change (39.3%), and stretching (37.7%) were the most commonly reported alleviating factors after development of musculoskeletal symptoms"	N/A	
Ajidahun and Philipps_2013	Stretching exercises and musical warm-up prior to playing but excludes aerobic exercises. Postural awareness may be part of a warm-up program. The duration can be between 5 to 20 minutes. *no specific definition of musical warm-up or stretching exercises	Delphi study and expert consensus	-stretching exercises -physical warm up -musical warm up -warm up programme -postural awareness	"Stretching is usually considered as a physical warm-up" p. 2069 "The content of the warm up program using the Delphi study includes stretching exercises and musical warm up prior to playing while strengthening and conditioning should be done thrice a week." p.2069 "On the content of the warm up programme, the inclusion of conditioning, stretching and strengthening as part of an injury prevention programme was agreed on by the participants; aerobic exercise was excluded from the content of the warm up programme. However, postural awareness was suggested by one member of the panel as part of the warm up programme. Physical conditioning and core strengthening were suggested by two members of the panel to be included as an injury prevention program to be done on a more regular basis outside the warm up programme." p. 2072 "Consensus was not reached on the duration of the warm up programme prior to practice or playing, as 42.9 % of experts agreed on 5 - 10 minutes and 10 - 15 minutes while 14.3 % agreed on the duration of the warm up to be 20 minutes." p. 2072	Yes	
Ajidahun et al_2019	N/A	Scoping review which summarized the results and data of other studies	N/A	N/A	N/A	Non-applicable as paraphrasing other authors. For the accuracy of this terminology review, it is important to source the material from the original source.
Arnason et al_2018	Warm-up exercises stretches and/or dynamic movements before playing	Injury prevention course	-warm-up routine -stretch -dynamic movements -warm-up strategies -posture (related) -prevention strategies	"Pre-intervention, the use of warm-ups (stretches and/or dynamic movements) before playing did not differ significantly between groups. However, at postintervention, a significant difference was found between the groups, as more participants from the PG reported doing warm-up before playing compared to the CG (69% vs. 20%, respectively, p=0.036)" p. 133 where PG=prevention group and CG=control group "The course emphasized education about common medical problems encountered by musicians, as well as advice regarding posture, warm-up strategies, and effective prevention strategies." p. 131 "Specific shoulder and thoracic strengthening and mobility exercises and warm-up routines were also taught." p. 132	No, only physical	
Barton and Feinberg_2008	Prior to playing an instrument.	Injury prevention course	-stretch -warm up -stretching	"I stretch my body before I play or sing." p. 51 "I warm up before I play/sing with simple instrumental/vocal exercises." p. 51	N/A	

Reference	Definition of warm-up	Context	Terms	Quotes	Mentions Musical and Physical Warm-ups (Y/N)	comments
	*No further details. Do not know if stretching is part of warm-ups or not.		-injury prevention strategy	"Stretching before playing one's instrument is highly recommended as an injury prevention strategy for musicians, along with improving overall physical conditioning." p. 52		
Beckett et al_2015	No definition of stretching/strengthening program. No mention if part of warm-ups.	Information collected from participants via a questionnaire.	Stretching/strengthening program	"Information collected included demographics; years of experience; training and performance characteristics; footwear worn; instrument played/equipment used; participation in stretching/strengthening programs; injury prevalence and type; treatment sought for injury; and participation time lost due to injury." p. 106	N/A	
Bertsch and Maca_2001	Playing easy exercises, exercises of medium difficulty and individualized warm-ups. Warm-ups are longer than 10 minutes.	Study to compare professional, students and beginners and the physiologic effects of warm-ups.	-routine -easy exercises -warming up -warm up -routine	"The purpose of this study is to observe the individual reactions of different facial muscle groups during warm up and to compare playing patterns of professional players (n=5) with students (n=5) and beginners (n=6)." p. 27 "Then, all trumpet players were instructed to play easy exercises for three minutes (given music tasks "wu1 ") then an exercise of medium difficulty (given music tasks "wu2 ") and, finally, about 10 minutes of playing whatever they play usually for warming up (individual music "wu3"). pp. 27-28 "For that reason this warming up is the first part of a brass player's daily routine to enhance muscle coordination of the complex setup of the embouchure" p. 26	No, only musical	
Blackie et al_1999	Warm-ups may include musical warm-up (scales, études, exercises), stretches and applying heat before practice	Study via questionnaire on the practice habits and injury prevention education of musicians.	-stretch -musical warm-up -scales -études -exercises -heat -cool-down (opposite)	Question 5 from the questionnaire: "Do you warm-up before practice? Check all that apply and indicate specifically what do you do and for how long in the space provided after each choice: stretch before practice, stretch after practice, musical warm-up (i.e., scales, études, exercises), apply heat before practice, other" p. 147 "Importance of warm-up/cool-down" p. 143	Yes	Indicates applying heat before practice as a warm-up
Buckley and Manchester_2006	Warm-up activities included stretches (of the neck, shoulders, arms, hands, and fingers), doing finger exercises such as scales and playing a familiar tune prior to learning new material. Warm-ups are done before playing.	Study via questionnaire to research practice habits of participants. These definitions are based on the participants' perceptions.	-stretching -finger exercises -scales -familiar tune -practice habits -breaks (related)	"Specific warm-up activities included stretching the neck, shoulders, arms, hands, and fingers (17 students), doing finger exercises such as scales (13 students), or playing a familiar tune prior to learning new material (4 students)." p. 82 "The baseline survey asked about certain practice habits prior to the camp—e.g., whether or not study participants took private lessons, did warm-ups before playing, and took breaks while playing." p. 81	Yes	

Reference	Definition of warm-up	Context	Terms	Quotes	Mentions Musical and Physical Warm-ups (Y/N)	comments
Cooper et al_2012	Stretching was defined as a set list of exercises and movements for this study: wrist rotations, shoulder-deltoid exercise, forward neck roll, oppositional finger-wrist press, hand-finger extensions, fist clench and unclench, hand wringing, arms-bicep curls, shoulder-deltoid variation (ear to shoulder), handshakes, arms-triceps extension, and fingers clenched and unclenched. These exercises were done throughout the rehearsals.	Exercises were taken from Stretching for Strings (Winberg and Salus, 1990).	-stretches -exercises -physical intervention -preventative techniques -warm-up	"The following four sets of stretches/exercises could be administered in any order, as long as all were used within each rehearsal. Set 1: Wrist rotations, shoulder-deltoid exercise, and forward neck roll/ Set 2: Oppositional finger-wrist press, hand-finger extensions, and fist clench and unclench/ Set 3: Hand wringing, arms-bicep curls, and shoulder-deltoid variation (ear to shoulder)/ Set 4: Handshakes, arms-triceps extension, and fingers clenched and unclenched" p. 73 "When considering performance-related injuries, preventative techniques—such as warm-ups and stretching exercises—would seem an obvious place to start." p. 72 "The focus of this study was to determine whether physical intervention—easily performed stretches for the hands, arms, and shoulders of a brief duration— administered during rehearsals at approximately 10-minute intervals would affect orchestra students' perceptions of physical discomfort." p. 73 "the instructor directed students to complete stretches/exercises designed to reduce fatigue and/or stress or discomfort. Exercises were taken from Stretching for Strings (Winberg & Salus, 1990)." p. 73	No, only physical	Study on a physical intervention for prevention, not on warm-ups per say.
Davies and Mangion_2002	Warming up away from the instrument (e.g.: stretch, movement), warming up on the instrument (e.g.: slow scales, long tones, finger exercises)	Survey question	-warming up away from the instrument -stretch -movement -warming up on the instrument -slow scales -long tones -finger exercises -cooling down (opposite) -breaks (related)	"Our measure came from four questions about the frequency of the following behaviors during private practice sessions: warming up away from the instrument (e.g.: stretch, movement), warming up on the instrument (e.g.: slow scales, long tones, finger exercises), cooling down after playing (e.g.: stretch, movement), and taking breaks." p.160	Yes	Mentions warming up away from the instrument and warming up on the instrument
De Smet et al_1998	Warm-up before playing and stretching afterwards. *No further details	Questionnaire on playing habits	-warming-up -stretching	"Conditioning, sports activity, playing a second or third instrument, warming-up before playing and stretching afterwards did not influence the incidence of overuse syndromes." p. 309	N/A	
Drinkwater et al_2010	No operational definition however, the results indicate a warm-up effect after a performance of music repertoire of 10 minutes . It should be done before playing .	Study on the physical demands of a musical performance and the data indicated the effect of a warm-up phase	-warming up -warm up	"The initial increase in physiological stress with corresponding decrease in errors after the first performance likely indicates "warming up," while the continued increase in markers of physical stress with dramatic decrement in performance quality likely indicates fatigue." p. 66 "first, the data presented here support the widely held belief that musicians should warm up prior to a performance; secondly, playing a wind instrument is sufficiently physically demanding to elicit deleterious effects on the quality of performance if sustained for a sufficient time period." p. 70	No, only musical	

Reference	Definition of warm-up	Context	Terms	Quotes	Mentions Musical and Physical Warm-ups (Y/N)	comments
Grieco et al_1989	The warm-up phase of the study included the following exercises as indicated in table 7 (p. 705): scales and arpeggios, notes repeated and trill, octaves, alternate octave scale and tremolo, terzina staccato. Stretching should be completed throughout the day and also before starting to play for 10 min.	The author recommends a stretching program for injury prevention before, during and after the practice session. Also the data were obtained via a study on muscular effort.	-stretching -exercise -scales -arpeggios -notes repeated -trill -octaves -alternate octave -tremolo, terzina staccato -warm-up -slowly and progressively (stretching)	"Stretching the muscular and ligament structures is useful because: (1) it tends to relax the tension accumulated during hours of practice in fixed positions, (2) it prepares the muscles for intense activity, (3) it helps to relax muscular tension due to fatigue by improving blood circulation in the muscles involved" p. 713 "With these concepts in mind, a typical program could be organized as follows: (phase 1) in the morning as soon as you get up (5-10 min), (phase 2) before starting to play (10 min), (phase 3) exercises during practice (several minutes), (phase 4) at the end of practice day (15-20 min.). These exercises should be done slowly and progressively, and the final position should be maintained for at least 20-30 seconds." p. 713 "Warm-up exercises: For the sake of brevity, only the results of groups of exercises grouped according to their similarity in muscular effort of the upper limbs are reported and discussed." p. 704 Table 7 exercise columns: "scales and arpeggios/ notes repeated and trill/ octaves/ alternate octave scale and tremolo/ terzina staccato" p. 705	Yes	
Hagglund and Jaccobs_1996	Warm-up and stretching exercises prior to playing the instrument. *No further details	Data collected from participants via interview and questionnaire	-warming up -warm up -exercise -breaks (related) -injury rehabilitation (related) -preventative factors -posture (related) -adaptive equipment (related) -splinting (related)	"According to the interviews and additional comments by the respondents, other popular aids in injury rehabilitation included having shorter practice sessions and frequent breaks, warming up, the use of strategic practising, relaxation techniques, changes in posture, adaptive equipment and splinting. All of these methods correspond to those preventative factors mentioned at the beginning of this paper." p. 17 "44 respondents described stretching and performing warm up exercises prior to playing their instrument." p. 18	N/A	
Kaufman et al_2011	They are completed for 10 min. prior to playing. *No further details.	Data collected from participants via questionnaire	-warm-up -warm-up exercises	"According to this survey, an average of 5 h/day (SD 2.45, range 2–18) was devoted to playing the instrument, with an average of only 10 min 'warm-up' prior to playing (SD 3.63, range 3–15). Only half of the musicians dedicated time to warm-up exercises." p. 92	N/A	
Leon et al_2015	No specific definition indicates that it is a preventative habit. *No further details	Data collected from participants via questionnaire	-warm up -practice habits -preventative habits -stretching	"Regarding practice habits almost 77.4% of musicians warm up." p. 6124 "At first, we analyzed frequencies related to age, played instruments, pain reports, preventive habits as warm-ups and stretching, objects or devices used, and perception of the main risk factors." p. 6126	N/A	
Logue et al_2005	warm-up exercises included scales, finger stretches, playing slow long notes, neck side bending, and arm rotations before playing the instrument	Data collected from participants via questionnaire	-exercises -routines -scales -finger stretches -playing slow long notes -neck side bending -arm rotation -warm-up	"Nine subjects stated that they performed warm-up exercises before playing the instrument. These routines included scales, finger stretches, playing slow long notes, neck side bending and arm rotations." p.72	Yes	

Reference	Definition of warm-up	Context	Terms	Quotes	Mentions Musical and Physical Warm-ups (Y/N)	comments
Lopez et al_2013	Warm-up exercises include stretching, friction, mobilizations, traction, and self-massage. Authors mention warming-up with the instrument (scales and technical exercises).	Injury prevention course and input from participants via questionnaire	-warm-up exercises -friction -mobilization -traction -self-massage -warming up with the instrument -breaks (related) -scales -technical exercises -stretch -postural habits (related)	"Consistently doing warm-up exercises is of vital importance in the prevention of musculoskeletal injuries in instrumental musicians. These warm-up exercises should consist of friction, mobilizations, traction, and self-massage. They should be done after warming up with the instrument, during breaks, and always at the end of each day of practicing." p. 106 "In the initial evaluation, 90% of the students did not do warm-up exercises before practicing their instrument, and in the majority of the cases, the term warm-up was used exclusively to mean playing scales or technical exercises before practicing a piece of music." p. 102 "It was concluded that this was due to the fact that stretching was a type of exercise made familiar to the students through their practice of sports. However, we also found wide acceptance of other suggested warm-up exercises: frictions, mobilizations, tractions, and self-massage." p. 102 "In designing the course, an emphasis was placed on the effectiveness of incorporating correct postural habits and doing warm-up exercises (mobilization, friction, self-massage, traction, and stretches) as a means of preventing or recuperating from musculoskeletal injuries that superior-grade music students suffer or could suffer." p.100	Yes	mentions warm-up with the instrument
McCrory et al_2016	This study had three warm-up conditions of 15 minutes: cardiovascular with a brisk walk, musical such as scales, arpeggios, study excerpts, vibrato exercises and shifting exercises, and core muscle exercises performed in a slow controlled fashion.	Study which had three warm-ups conditions as an intervention.	-warm-up -cardiovascular -musical (scales, arpeggios, etc.) -core muscle -exercises -slow and controlled fashion (core muscle/stretching)	"Warm-up protocols were as follows: 1) Cardiovascular—brisk walk in the areas surrounding the test sites. 2) Musical—standard violin warm-up using specific exercises recommended by a violin professor (see Document, Supplemental Digital Content 8, full description of musical warm-up, http://links.lww.com/MSS/A570). 3) Core muscle—eight exercises designed to activate gluteal, abdominal, and shoulder muscles in all three planes of movement. All movements were performed in a slow, controlled fashion to ensure that core muscles were contracted for the duration of the movement. Exercises could be modified to suit individual fitness levels and were performed in the following sequence (see Table, Supplemental Digital Content 9, full description of core muscle warm-up, http://links.lww.com/MSS/A571): dual loading gluteal bridges, single loading gluteal bridge leg marches, leg crossovers, opposite arm/leg extension, dynamic side plank, shoulder "A," shoulder "T," shoulder "W," 4) Control—participants sat quietly in a chair" p. 310	Yes	
McPherson and McCormick_1999	The warm-up routine was part of technical work in this study. *No further details	Practicing habits while preparing for a music exam	-technical work -warm-up routine	"Regression analyses also revealed a consistent pattern across three components of musical practice with a finding that subjects who reported greater amounts of practice on Informal/Creative Activities (i.e., playing by ear and improvising), Repertoire (new unlearned pieces, older familiar pieces) and Technical Work (i.e., using a warm-up routine, practicing scales/arpeggios, studies, etudes and sight-reading) tended to be more cognitively engaged while practicing and express more intrinsic interest in learning their instrument." p.98	No, only musical	
Redmond et al_2001	No clear definition of warm-up or stretching.	Data collected from participants via questionnaire	-warm-up -stretching -flexibility exercises (related) -massage technique	"The principles that the participants were most likely to teach their students included proper body mechanics and posture, specific playing techniques, importance of warm-up, and choosing repertoire that was appropriate for the student's physical abilities." p. 32 "The participants with more experience were more likely to teach specific stretching or flexibility exercises ($z = 0.996$, $p < 0.01$." p. 35 Table 5: "Stretching/massage techniques" p. 36	N/A	

Reference	Definition of warm-up	Context	Terms	Quotes	Mentions Musical and Physical Warm-ups (Y/N)	comments
Rohwer_2008	Stretching can be done to avoid pain. *No further details	Data collected from participants via questionnaire	-stretching -stretch breaks	"Accommodations for ailments centered around two general issues: things a musician could buy (e.g., ear plugs, instrument rests, cushions) or things they could do to avoid pain (e.g., education, stretching)." p. 54 "While some preventive measures are under the control of the musicians, other preventive measures are under the direct control of the conductor, such as allowing the musicians to sit where they can hear or see the best, letting the musicians have regular stretch breaks, or conducting cleanly instead of flamboyantly." p. 57	N/A	
Russell and Benedetto_2014	Type of warm-up activities practiced by students: playing scales, playing a favorite tune or exploration, finger patterns, long tones, string-crossing warm-ups, position exercises and stretching.	Data collected from participants via questionnaire	-warm-up -scales -favorite tune -exploration -finger patterns -long tones -string crossing -position exercises -physical warm-ups -without their instrument -stretching -warm-up habits	"Participants most commonly warm-up by playing scales (82%) and playing a favorite tune or exploration (58%). Roughly half of the participants warm up using finger patterns (49%) or long tones (44%). Fewer reported employing string-crossing warm-ups (31%) or position exercises (24%). Participants were least likely to engage in physical warm-ups without their instrument, such as stretching (20%)." pp. 265-266 "Participants also responded to a series of items that addressed warm-up habits (frequency of warming up prior to playing their instrument, length of typical warm-up period, and type of warm-up activities) and additional items that focus on music background and demographics." p. 263	Yes	Mentions warming up away from the instrument
Russell_2006	Physical warm-ups without their instrument, such as stretching or body posture, and instrument-based warm-ups such as long tone warm-ups, scale exercises, position exercises, string crossing exercises, finger pattern exercises, playing favorite tunes, or exploration. Prior to playing the instrument.	Data collected from participants via questionnaire	-warm-ups -physical warm-ups -without the instrument -stretching -instrument-based warm-up -long tone warm-ups -scale exercises -position exercises -string crossing exercises -finger pattern exercises -playing favorite tunes -exploration -proper posture -warm-up habits	"Proper posture should be a part of every student's warm-ups and daily practice." p. 102 "Neither physical warm-ups without the instrument (such as stretching), nor instrument-based warm-ups (long tone warm-ups, scale exercises, position exercises, string crossing exercises, finger pattern exercises, playing favorite tunes, or exploration) impacted reported discomfort." p. 102 "students responded to three additional questionnaire items that addressed warm-up habits (frequency of warming-up prior to playing their instrument, length of typical warm-up period, and type of warm-up activities) and seven additional items that focused on musical background and demographics." p. 96	Yes	Mentions warming up away from the instrument and warming up on the instrument
Silvey_2013	No specific definition	Data collected from participants via questionnaire	-ensemble warm-up activities -warm-up individually	"Average percentages reported of time spent for rehearsal activities were rehearsing music selections (63.01%), ensemble warm-up activities (19.21%), and sightreading new music (10.41%)." p. 20 "In response to Question 7, nearly all band directors indicated that they allowed their students to warm-up individually prior to the start of each rehearsal" p. 26	N/A	

Reference	Definition of warm-up	Context	Terms	Quotes	Mentions Musical and Physical Warm-ups (Y/N)	comments
Yoshimura et al_2006	No specific definition , but indicates three categories of warm-ups: physical, psychological and musical.	Questions on a survey	-physical warm-up -psychological warm-up -musical warm-up	Table 2:"Do you warm-up before practice? / Physical warm-up time spent (min)/ Psychological warm-up time spent (min)/ Musical warm-up time spent" p.120	Yes	Mentions psychological warm-up
Yoshimura et al_2008	Physical warm-up was described as stretching. Mentions psychological warm-up and musical warm-up but does not provide a definition.	Questions on a survey	-physical warm-up -stretching -psychological warm-up -musical warm-up	"The variable "physical warm-up" was described as "stretching" by nearly all subjects (95%) who answered that they do physical warm-ups." p. 110 "Although it is not clear what type of stretching was employed by the subjects in this study, pianists (especially with small hands) are known to passively pull fingers with the opposite hand to perform stretches of the wrist flexor muscles statically". p. 110 "Physical warm-up time spent (min)/ Psychological warm-up time spent (min)/ Musical warm-up time spent (min)" p. 109 Table 2	Yes	Mentions psychological warm-up
Zaza et al_1997	Musical warmup such as playing slow scales physical warmup such as stretching exercises	Questions on a survey	-musical warmup -slow scales -physical warmup -stretching exercises -breaks (related)	"Playing-related factors included musical warmup (e.g., playing slow scales), physical warmup (e.g., stretching exercises), breaks, practice time, recent changes, and other factors." p. 294	Yes	

Table 9*Count of reference for variations on the term warm-up*

Variations	Number of articles with this term
Warm-up	16
Warm up	6
Warming up	4
Warming-up	1
Warmup	1

Table 10*Count of reference for terms related to definition of warm-ups*

Terms	Number of articles with this term
Routine	6
Programme	1
Exercise	11
Habits	4
Stretch	5
Stretching	6
Core muscle exercises (e.g.: dual loading gluteal bridges, single loading gluteal bridge leg marches, leg crossovers, opposite arm/leg extension, dynamic side plank)	1
Finger stretches	1
Movement	1
Friction	1
Mobilization	1
Traction	1
Self-massage	1
Cardiovascular (e.g.: brisk walk)	1
Physical warm-up	6
Musical warm-up	6
Psychological warm-up	2
Scales (slow scales, n=2)	10
Arpeggios	2
Notes repeated	1
Octave/ alternate octave	1
Tremolo	1
Terzina staccato	1
Finger exercises	2
Long tones/ slow long notes	4
Easy exercise	1
Familiar tune/ favorite tune	3
Études	1
Exploration	2
Finger patterns	2
String crossing	2

Terms	Number of articles with this term
Position exercises	2
Technical exercises/ Technical work	2
Postural awareness/ proper posture	2
Dynamic movement	1
Neck side bending	1
Arm Rotation	1
Injury prevention strategy	1
Heat	1
Warming up on the instrument (e.g.: slow scales, long tones, finger exercises, etc.)/ with the instrument	2
Warming up away from the instrument (e.g.: stretch, movement)/ without the instrument	3
Ensemble warm-up	1
Warm-up individually	1

Table 11

Count of reference on when to perform warm-ups

Moment	Number of articles
Before playing (repertoire)/ learning new material	12
During breaks and after	1

Table 12

Count of reference for terms related to definition of stretching

Terms	Number of articles with this term
Exercises (e.g.: Wrist rotations, shoulder-deltoid exercise, and forward neck roll, oppositional finger-wrist press, hand-finger extensions, and fist clench and unclench, hand wringing, arms-bicep curls, and shoulder-deltoid variation (ear to shoulder), handshakes, arms-triceps extension, and fingers clenched and unclenched)	1
Physical Intervention	1
Preventative technique/ preventative measure	2
Stretch Break	1
Slow/ slowly	2
progressively	1
Controlled fashion	1
muscles were contracted for the duration of the movement	1
should be maintained for at least 20-30 seconds	1

Table 13*Count of reference on when to stretch*

Moment	Number of articles
Throughout the rehearsal/ day	2
Stretching afterwards	1
Prior to playing (without mention of warm-up)	1

Table 14*Count of reference for terms related to other injury prevention technique*

Terms	Number of articles with this term
Cool-down	3
posture	3
Prevention strategies/ preventative factor	2
Breaks	5
Adaptative equipment	1
Splinting	1
Flexibility exercises	1
Massage technique	1
Strengthening	1

Figure 3*Terminology entry for warm-up*

Key term(s) • warmup • warm-up • warm up • warmup • routine • programme • warming up/ warming-up • warming up away from the instrument/ warm-up without the instrument • movement • exercise • habit • physical warm-up • musical warm-up (scales, études, familiar/ favorite tune, long tones, arpeggios, notes repeated, trill, octave, tremolo, terzina staccato, technical exercise, string crossing, study excerpts, vibrato exercises, shifting exercises, position exercises) • psychological warm-up • Stretch (finger stretch, neck side bending, arm rotation) • stretching • dynamic movement • postural awareness/ posture • heat
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- finger exercises/ finger pattern
- exploration
- friction
- mobilization
- traction
- self-massage/ massage technique
- warming up with the instrument
- cardiovascular warm-up
- core muscle exercise
- easy exercise
- ensemble warm-up activities
- warm-up individually
- injury prevention strategy

Subject field(s)

- Music (General)
- Injury Prevention Education
- Practice and Performance Routine or Habits
- Injury rehabilitation
- **Warm-up**

DEF

A routine, habit or exercise(s) that is/ are completed prior to playing repertoire or learning new material on a music instrument in order to prepare physically and mentally the musician. The following can be included as part of a musician's warm-up: physical warm-up (completed without the instrument, for example stretches), musical warm-up (completed with the instrument, for example: scales, familiar tune/ favorite tune, long tones), and psychological warm-up.

CONT

Empirical studies on warm-ups and musicians

OBS

Warm-up is often described along with the following concepts: breaks, and cool-down.

OBS

Warm-up may or may not include stretching or postural awareness exercises.

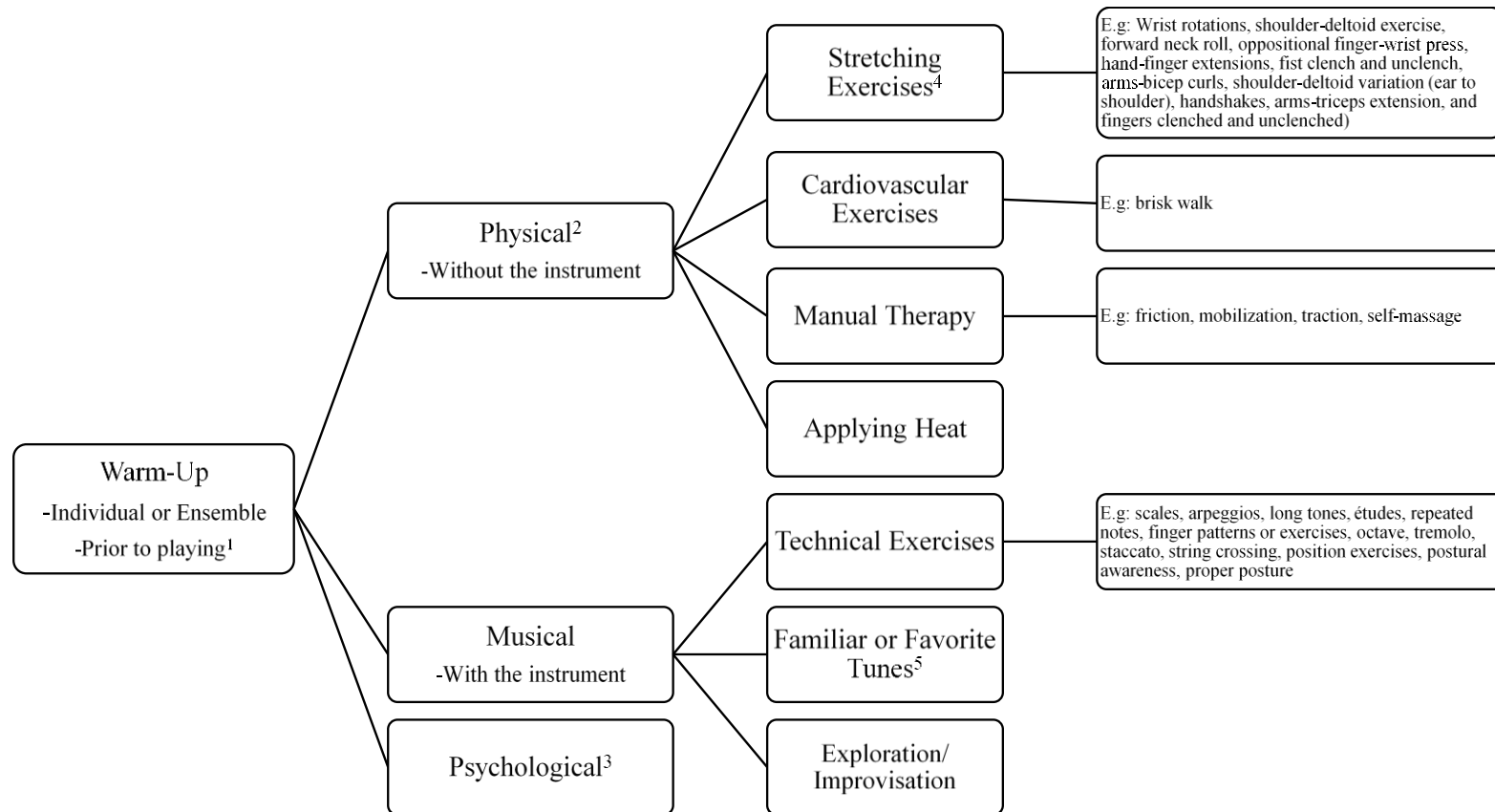
OBS

Warm-up is sometimes spelled as warm up and warmup. It may also be referred as warming up.

* **DEF** (definition), **CONT** (context), **OBS** (observation)

Figure 4

Taxonomy based on existing literature addressing warm-ups for musicians



1. Prior to playing repertoire or learning new material.

2. While stretching exercises were the most mentioned physical warm-up in the literature, the terms “cardiovascular”, “brisk walk”, “friction”, “mobilization”, “traction”, “self-massage” and “applying heat” were also present in the literature.

3. No definition or example were provided in the literature for psychological warm-up.

4. Stretching is a component of a warm-up only when it is completed prior to playing the instrument.

5. In the empirical literature, the terms “familiar tune” and “favorite tune” were more frequently used compared to “easy pieces” in the non-empirical literature. Only one article in the empirical literature had the term “easy exercise”, however no additional detail was provided.

Discussion

This is the first known terminology review and taxonomy of warm-ups and instrumental musicians. This study has identified several terminological limitations in the literature focusing on warm-ups and musicians such as the use of multiple terms and the lack of definition of some of these terms. This study therefore attempted to facilitate communication in the field by providing definitions for warm-up and stretching, and by categorizing the information in the form of a taxonomy. The following paragraphs will discuss the results of this terminology and taxonomy study, limitations of this study, and suggestions for future research projects.

By completing this terminology review, the first author was able to provide a general definition of warm-ups and stretching. These definitions are broad, but they provide a structure that is needed in the field by synthesizing and organising the information. These definitions also provide clarity for why stretching is sometimes perceived as a warm-up and other times perceived as its own injury strategy prevention. The difference being the moment in which it is completed. Warm-ups are to be completed prior to playing repertoire or learning new material on a musical instrument and stretching can be completed any time throughout the day.

The taxonomy provided a clear hierarchical structure of the terms frequently used to define warm-ups in music. This allows other researchers in the field to understand the different types of warm-ups at first glance. It is interesting to consider comparing these results to categories of warm-ups in sports as doing so could lead to a more comprehensive taxonomy and could bridge the concepts between the two fields. According to Bishop (2003a, p. 439): “warm-up techniques can be broadly classified into two major categories: passive warm up or active warm up. Passive warm up involves raising muscle or core temperature by some external means, while active warm up utilises exercise.” In the case of the music taxonomy, only the application

of heat, which was mentioned once in the literature, would be considered a passive warm-up and all the other types of warm-up would be considered active. According to Ahmadi's Master's thesis (2011), a subcategory of active warm-up is a specific warm-up "consists of repetition/related movements and visualization." (Ahmadi, 2011, p. 46) As indicated in her thesis, this specific warm-up consists of mimicking the movements that will be performed during the athletic activity but at a lower level of intensity. The specific warm-up can then be compared to musical warm-up of the taxonomy as the musician recreates the physical movements, while playing technical exercises, favorite or familiar tunes and improvisation/ exploration, that will occur during a performance. The visualization aspect of a specific warm-up could be included in the category of psychological warm-up.

The taxonomy also illustrated gaps in the literature as one of its categories (psychological warm-ups) could not be subcategorized. Psychological warm-ups were mentioned in two articles (Yoshimura et al., 2006; Yoshimura et al., 2008); however, the studies did not include an example or detailed definition of this category. For the time being, it is therefore necessary to look at other fields of research in order to understand what a psychological warm-up could include. A possible psychological warm-up could be to use a mental practice strategy which was defined by Mielke (2016, p.159) in her glossary on mental practice in music as "method, involving repeated cognitive performance of an activity, used in order to achieve a long term music learning and/or performance goal." Another possibility could be to use mindfulness techniques prior to playing repertoire or learning new material. According to Stanson (2019) one of the mindfulness techniques is meditation which is defined by Tang and colleagues (2015, p. 213) as: "a form of mental training that aims to improve individual's core psychological

capacities, such as attention, and emotional self-regulation.” However, more research is required on the “warming up” aspect of these strategies and techniques.

Limitations

This study was limited by a small corpus that only included empirical studies. A future study could include music pedagogical resources in order to understand what are the warm-ups that are being recommended by music teachers. This was not possible for this study due to limitation of time and resources. Furthermore, this review was only completed by one graduate student which limits the validity and reliability of this study.

Implications for further research

More in-depth research is required in order to understand the warm-ups that are recommended to musicians. The terminology review and taxonomy were a first attempt at defining warm-ups and stretching for musicians, indicating the terms that are used to describe the warm-ups and stretches for musicians and categorizing these terms in order to organize and synthesize the information. However, this study only included a small corpus of empirical articles and it would be interesting to see what is recommended in pedagogical resources. Furthermore, the resulting definition of this terminology review did not include the duration of a warm-up/stretch or how a warm-up/stretch should be completed.

Chapter 6

Conclusion

The review of literature of this thesis demonstrated that warm-ups are frequently recommended for musicians, however this recommendation was not supported with empirical data. It also demonstrated that multiple terms are used to describe warm-ups and that these terms are not standardized. The lack of empirical data and lack of standardization on the terms used to describe warm-ups lead to confusion on the effect and definition of this injury prevention strategy. Therefore, this thesis attempted to reduce the confusion with two studies.

The first study was a systematized review of published articles, written in English, with a methodological outline. The purpose was to summarize, present and evaluate the scientific data on musicians' warm-ups in order to answer the following research question: what is the evidence to support the statement that warm-ups prevent injuries? The results of this study indicated that there was no empirical evidence to support the statement that warm-ups can prevent musicians' injury. Of the 29 included articles, only one had a level of evidence of I which as indicated by Butler and Darrah (2001) is the level that produces the most credible evidence and, therefore, provides the most definitive results. The results of this study (McCrary et al., 2016) indicated that all three warm-up conditions tested in their experimentation did not have an effect on muscle activity and performance quality. Most studies (n=21) were ranked as level V which cannot lead to a conclusion on the efficacy of warm-ups for injury prevention. Some studies (n=3) were ranked as level IV. Three studies were ranked as level II, zero study was ranked as level III and one study was non-applicable due to the study design of scoping review. All studies which were ranked at levels II to V, had methodological issues. Some methodological limitations identified in a majority of papers were presence of sampling and measurement biases such as lack of

randomization, lack of control group, small sample size, and volunteer based. Due to the very high number of studies with a lower level of evidence and the low number of studies with a higher level of evidence, it is not possible to empirically support the statement that warm-ups help to prevent injuries of musicians. Furthermore, there was no standardized approach in the methodology, groups of participants and types of warm-ups. The lack of standardization of the types of studied warm-ups leads to the second study of this thesis in order to understand how warm-ups are defined for the music performance community.

The second study of this thesis was a terminology review and taxonomy of musicians' warm-ups in order to identify terms, understand the context of these terms, synthesize and organize the information into terminology entries and a taxonomy. This study used the same published English articles as for the systematized review. Terms were manually extracted from the corpus and the most frequently used terms formed the basis for the definition of warm-ups and stretching. The definition for warm-ups was: "A routine, habit or exercise(s) that is/ are completed prior to playing repertoire or learning new material on a music instrument in order to prepare physically and mentally the musician. The following can be included as part of a musician's warm-up: physical warm-up (completed without the instrument, for example stretches), musical warm-up (completed with the instrument, for example: scales, familiar tune/favorite tune, long tones), and psychological warm-up." The definition for stretching was: "Slow, controlled and progressive movements that are maintained for at least 20-30 seconds. These are done at various intervals throughout the day such as prior, during (breaks), and after the practice of a music instrument. They are referred to as physical exercises (away from the instrument). The following are some examples of stretching exercises: wrist rotations, forward neck roll, oppositional finger-wrist press, hand-finger extensions, fist clench and unclench, arms-

bicep curls, handshakes, arms-triceps extension, and fingers clenched and unclenched.” These definitions synthesised the information in the literature and indicated the larger categories of warm-ups. These definitions also clarify the possible difference between warm-ups and stretching as stretching is not always done prior to playing a musical instrument. The taxonomy had three larger categories such as physical, musical and psychological and the physical and musical categories were subdivided into subcategories. It was not possible to subcategorize psychological warm-ups as the literature did not define nor provide examples for this category. The taxonomy therefore facilitates the communication in the field by indicating the different types of warm-ups at a first glance. It also indicated the gaps in the literature as not all categories could be subdivided or supported with examples. This terminology and taxonomy study was one step towards standardization as it provided a definition of the concept of warming up, a list of frequently used terms and a diagram that categorized these terms. However, standardization is more than just a definition which opens the need for future research in order to develop standardized methodologies and protocols.

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Appendix A
PRISMA checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	29
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	29
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	29-31
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	31
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	N/A
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	34
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	31-35
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	31-35
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	31-35
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	31-35
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	31-35
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be	35

		used in any data synthesis.	
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	N/A
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I ²) for each meta-analysis.	35

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Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	31-35
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	N/A
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	37
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	40-56
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	40-56
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	40-56
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	N/A
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	40-56
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	38-40
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	55-75
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	77
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	75-78
FUNDING			

Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	35
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Note. From Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Journal of Clinical Epidemiology*, 62, 1006-1012. DOI: 10.1016/j.jclinepi.2009.06.005

Appendix B

Termium entry for warm-up

Source: Termium Plus. (2019). The Government of Canada's terminology and linguistic data bank. Retrieved from http://www.btb.termiumplus.gc.ca/tpv2alpha/alpha-eng.html?lang=eng&i=1&srchtxt=WARM-UP&index=alt&codom2nd_wet=1#resultrecs

Key term(s)

- preliminary warmup
- pre-race warmup
- warmup
- **warm-up**

Subject field(s)

- Sports (General)
- Physical Education, Coaching and Sport Psychology
- **warm-up**

correct, noun

- warm up

correct, noun, see observation

- warming-up

DEF

A series of exercises executed before strenuous physical activity or athletic competition, designed to loosen muscles and prevent injury.

CONT

The active warm-up involves movement that is at a low intensity and general in nature.

CONT

If you can isolate an area of vulnerability, preferably by scouting beforehand or by being observant in the warm-up and first few games, you are a step ahead.

OBS

warm-up: Nominal form; warm up: Verbal form often used as a noun [in the field].

*****The textual supports **DEF** (definition), **CONT** (context), **OBS** (observation) and **PHR** (phraseologism) provide the definition of the term, an example of the term in a text fragment, terminology, linguistic or technical information, or common combination of a term with a noun, adjective or verb, respectively.