

Assessment of the Effects of Global Postural Re-Education on Musicians with
Nonspecific Musculoskeletal Pain as assessed by Questionnaires and Infrared
Thermography

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ABSTRACT

Background: The Global Postural Re-education (GPR) method seems to be an effective method for the treatment of musculoskeletal disorders. However, no study has examined its effects on a group of musicians with musculoskeletal pain. Additionally, infrared thermography (IRT) has been widely used in the field of medicine as a monitoring a diagnostic tool, which can provide empirical data about the effectiveness of the GPR method.

Objective: To examine the effects of GPR using scales and questionnaires and IRT.

Methods: This thesis enclosed two articles. In the first, musicians with (N=6) and without (N=6) musculoskeletal pain underwent a thermographic evaluation to examine the skin temperature asymmetry (STA) between both groups as a representation of musculoskeletal pain. The second article was a randomized control trial and examined the effects of the GPR on a group of 13 participants with musculoskeletal pain (7 experimental, 6 controls) after receiving 8 sessions of GPR. Pain, disability and quality of life data was collected using the VAS, MPIIQM, SF-36. A thermographic assessment was also conducted to examine the correlation between pain severity and degree of STA, and changes in contralateral skin asymmetries before and after the intervention.

Results: The first article revealed no significant differences in STA between groups. Results from the second article showed statistical significant improvements in pain, disability and quality of life on the group who received the GPR intervention. Results from the IRT analysis were not significant.

Conclusion: Results from the self-report questionnaires suggest that GPR is effective in treating musculoskeletal pain in the targeted group of musicians. Pain changes did not correlate with thermal outcomes. Further studies are need it to confirm the results obtained with IRT.

Keywords: Global Postural Re-education, musicians, infrared thermography, physiotherapy

DEDICATION

To all the Venezuelan families and families all over the world that had to separate due to unjust causes. One day, we will all be reunited and will share our love in freedom.

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TABLE OF CONTENTS

Abstract	ii
Dedication	iii
Acknowledgments	iv
List of tables	ix
List of figures	x
List of Appendixes	xii
CHAPTER 1: INTRODUCTION	1
CHAPTER 2: LITERATURE REVIEW	
2.1 The Global Postural Re-education Method	3
2.1.1 Overview of the method	3
2.1.2 Treatment Postures	5
2.1.3 Effectiveness of the method	6
2.1.3.1 Randomized control trials	6
2.1.3.2 Non-randomized control trials	15
2.1.3.3 Case-studies	16
2.1.4 Summary of GPR	17
2.2 Human Body Temperature	18
2.2.1 Normal body temperature	18
2.2.2 Human body and its thermal responses to pain	19
2.3 Infrared Thermography (IRT)	21
2.3.1 Infrared thermography and the human body	22
2.3.2 Diagnosis in medical thermography	23
2.3.2.1 Temperature changes as an indicator of an injury or disease	23
2.3.2.2 Temperature changes as an indicator of pain	27
2.3.3 Normal asymmetry values	30
2.3.4 IRT for the assessment of treatment approaches	31
2.3.5 Summary of Thermal Imaging	34
2.4 Musician's health problems	35
2.4.1 Prevalence of neuro-musculoskeletal disorders and pain among musicians	37

2.4.2 Musicians' treatment preferences and needs	41
2.4.3 Summary of musician's health problems	43
CHAPTER 3: RESEARCH QUESTIONS	44
CHAPTER 4: STUDY 1- Can we detect the presence of musculoskeletal pain on musicians by measuring their skin temperature asymmetries using infrared technology?	45
4.1 Introduction	45
4.2 Research questions	46
4.3 Methods	47
4.3.1 Participants	47
4.3.2 Scales and questionnaires	48
4.3.3 Infrared thermography	48
4.3.3.1 Camera	48
4.3.3.2 Room	49
4.3.3.3 Participants	49
4.3.3.4 Image station	49
4.3.4 Experimental Protocol	50
4.3.5 Image analysis	51
4.3.6 Statistical Analysis	53
4.4 Results	55
4.5 Discussion	59
4.6 Limitations	64
4.7 Conclusion	65
REFERENCES	66
CHAPTER 5: STUDY 2- Assessment of the effects of Global Postural Re-education Method in Musicians with Nonspecific Musculoskeletal Pain: A randomized controlled trial	73
5.1 Introduction	73
5.2 Research questions	75
5.2 Methods	76
5.3.1 Participants	77
5.3.2 Scales and questionnaires	77

5.3.3 Infrared thermography	78
5.3.4 Physical evaluation	78
5.3.5 Intervention	79
5.3.6 Image analysis	82
5.3.7 Statistical analysis	82
5.4 Results	83
5.5 Discussion	89
5.6 Limitations	93
5.7 Conclusion	93
REFERENCES	95
CHAPTER 6: GENERAL DISCUSSION AND CONCLUSION	101
6.1 Discussion	101
6.1.1 Infrared thermography challenges	101
6.1.2 Differences in left-right skin temperature asymmetry	103
6.1.3 Measuring the effects of GPR	104
6.2 Limitations	108
6.3 Conclusion	109
REFERENCES	111

LIST OF TABLES

Table 1	Demographic data for participants in the healthy and non-healthy group	55
Table 2	Average asymmetry differences between healthy and non-healthy	56
Table 3	Impact of different cut-off values on the presence left-right temperature asymmetries	58
Table 4	Demographic data for participants in the control and experimental group	84
Table 5	Results from the MPIIQM. GPR group (pre-compared to post)	84
Table 6	Results from the MPIIQM. GPR group (post compared to follow-up)	85
Table 7	Pain relief results obtained from VAS (Pre-compared to follow-up)	86
Table 8	Pain intensity results obtained from VAS (GPR group)	86
Table 9	Thermal asymmetries changes between pre and post evaluations within the control group	87
Table 10	Thermal asymmetries changes between pre, post evaluations within the GPR group	87
Table 11	Thermal asymmetry changes between the post and follow-up evaluations within the GPR group	88

LIST OF FIGURES

Figure 1	Image station set-up	50
Figure 2	All temperatures less than the threshold temperature have been indicated with a dark blue colour	51
Figure 3	Allocation of the middle line. Final 16 ROIs with the respective temperature and asymmetry values.	52
Figure 4	Examples used as a reference for the Likert scale going from 1	54
Figure 5	Comparison of asymmetry levels between healthy and non-healthy participants (all regions)	56
Figure 6	Comparison of asymmetry levels between healthy and non-healthy participants (regions with pain)	57
Figure 7	Scatterplot correlation between VAS and average asymmetry values at T2	59
Figure 8	Scatter plots from correlations between pain intensity scores obtained with the VAS (Pre-VAS, relief-VAS and Follow-up-VAS) and the asymmetry values obtained with the MATLAB analysis	89

LIST OF APPENDICES

Appendix A: Treatment Postures Used in the Global Postural Re-Education Method	121
Appendix B: Consent Forms	122
Appendix C: Demographic Questionnaire	132
Appendix D: Participants' Preparation before the collection of thermograms	136
Appendix E: Participants' Playing Requirements	137
Appendix F: Visual Analog Scale (VAS)	138
Appendix G: The Musculoskeletal Pain Intensity and Interference Questionnaire for Musicians (MPIIQM)	139
Appendix H: Medical Outcomes Study Questionnaire Short Form 36 Health Survey	140

CHAPTER 1: INTRODUCTION

Over the years there has been an increasing interest in musicians' health problems as a consequence of their occupation (Elbaum, 2006; Fishbein, Middlestadt, Ottaitraus, Strauss & Ellis, 1989; Kreutz & Ginsborg, 2008; Lederman, 2003; Zaza, 1997; Lonsdale & Boon, 2016). Factors such as strenuous practice, instruments played, technique, stress and posture, seem to be the triggers of musicians' health problems ranging from anxiety and depression (Furuya, Hidehiro, Hidehiro & Hiroshi, 2005; Lonsdale et al., 2016), to neuro-musculoskeletal disorders, the latter described in the literature as the most common health problems affecting the community (Allsop & Ackland, 2010; Ageitos-Alonso, 2016; Bejjani, Kaye, Benham, 1996, Fotiadis, Fotiadou, Kokaridas & Mylonas, 2013; Larsson, Baum, Mudholkar, Kollia, 1993; Lederman, 1989; Shileds, 1999; Steinmetz, Zeh, Delank, Peroz, 2015) with disability and pain as the most reported symptoms (Fishbein et al., 1988; Kreutz et al., 2008; Pak, Chesky, 2001; Zaza, 1992). As in any other group, musicians have special needs based on their activity that call for individualised care and treatment and a method called Global Postural Re-education (GPR) can possibly answer those needs. GPR has proven to be an effective tool for the treatment of postural impairments and symptoms with a mechanical origin; this is, symptoms that worsen with movement and improve with rest (Bonetti et al., 2010; De Amorim, Gracitelli, Marques & Dos Santos, 2014; Dimitroval & Rohleva 2014; Lawand, Lombardi, Jones, Sardim, Ribeiro & Natour, 2015; Oliveri et al., 2012)

The aim of the GPR method is to stretch antigravity muscles using the property of viscoelastic tissue and by enhancing contraction of the antagonist muscles (Oliveri et al., 2012) while taken into consideration the neuromuscular chain to which they belong. As a

method, GPR has its own way to evaluate and diagnose the disorders that affect the neuro-musculoskeletal system, and with the use of its specific "treatment postures", along with a physiotherapist's manual adjustment, it provides a tailored treatment and modifies the situation (morphological and/or functional) identified as responsible for the problem.

In many cases pain is a physiological response to the presence of a pathological event or a potentially harmful stimulus. It is also a highly subjective and personal symptom, which makes it difficult to evaluate (Herry, 2002). Due to its complexity and heterogeneity, nonspecific musculoskeletal pain represents a challenge to health professionals when trying to find a cause or measure its intensity. Infrared thermography (IRT) can possibly be a solution to this problemat. IRT does not provide a picture of the patients' pain but according to the literature, it can offer a more objective demonstration of the sympathetic skin thermal changes that suggest the existence of pain or injury (Bardhan, Bhowmik, Nath & Bhattacharjee, 2015; Michaels, 2005; Nahm, 2013). Additionally, this approach has been used as a reliable diagnostic and monitoring tool in the field of medicine for more than 60 years and several authors have used this tool to assess the effects of a treatment technique and evaluate the success of a treatment procedure.

In summary, since many studies have shown the effectiveness of the GPR for the treatment of musculoskeletal pain and due the features and applications of IRT in the health field, this study aimed to evaluate the effects of the GPR in musicians suffering from nonspecific musculoskeletal pain by means of self-reported questionnaires and scales, and infrared thermography.

CHAPTER 2: LITERATURE REVIEW

2.1 The Global Postural Re-education Method

2.1.1 Overview of the method

Global Postural Re-education is a method created by the physiotherapist Philippe Souchart in 1980 to treat postural disorders as a result of changes in the biomechanical system from morphological, behavioural and/or psychological factors (Olivieri et al., 2012). This manual therapy is based on strong biomechanical and physiological concepts, and it considers three primary principles when dealing with neuro-musculoskeletal disorders: the first one is individualism, understanding that people are essentially different from one another and that each person is organized, functions and is clinically altered in a very personal and unique way. The second is causality, which states that to obtain a permanent and real solution to a problem, the real cause of the problem should be found and treated and not only the generated consequences such as acute pain; and lastly globalism, which dismisses the idea of isolated muscle functions and suggest that the human body should be analyzed and treated as a whole (Souchart, 2012).

Physiologically, the GPR relies on these three main concepts. Firstly, on the function and physiology of the striated muscles, whose type of fibres determine their behaviour and allows for their division into phasic and tonic muscles (Bosco, 1997; Guyton, 2010; Goldspink, 1978). The phasic muscles have a reduced tone, they are little fibrous and of fast contraction. These do not intervene in the erect position; however, they guarantee the displacement, movement of the extremities and the fulfillment of basic functions such as eating. That is why they are also known as dynamic. Unlike the tonics, the phasic muscles' injury is towards weakness and elongation.

The tonic muscles represent two thirds of the total of our musculature, they are quite fibrous, of slow contraction and have a high tone. These characteristics reinforce their resistance and make it possible for part of their fibers to remain in permanent contraction and in constant interaction with gravity. Its characteristics guarantee us the possibility of being erect and achieving stability, hence the reason why they are commonly known as postural muscles. This group tends to stiffen and shorten, and its injury is commonly the result of overuse or misuse. Some examples could be the trapezius muscle, hamstrings and spinal muscles (long dorsal, transverse spiny, etc.). Additionally, due to their arrangement in the joints, when they become more hypertonic and shorten, they add a compression and shearing component to joints that could evolve in a morphological change and therefore an unbalance of tensions and possibly pain. Due to large differences between the two groups, in the presence of an injury or disorder, the treatment cannot be the same for both. The treatment with GPR considers the physiology of each muscle group and focuses on the elongation of the tonic muscles conditioned at the same time by an eccentric contraction of the dynamic muscles while achieving a decompression and correct alignment of the joint segments.

Secondly, is the fact that each muscle has different lines of action and that they are helicoidally arranged around the joints, this means that they do not work on a single axis (e.g. a flexor muscle also has a rotating component). This organization promotes the narrowing of the joint space and a deviation of segments when the muscle is in a hypertonic or retraction state (Kapandji, 2008, Souchart, 2012). Therefore, to ensure their stretching in GPR, the action is done in the opposite direction of all its lines of action and avoiding the possible compensations while performing a decompression action (Souchart, 2012). And thirdly, GPR relies on the muscles' property of viscoelasticity, which enables them to obtain a

permanent elongation (creep) after certain time and force-rate parameters are fulfilled according to Hooke's and Newton's model (Goldspink, 1978; Taylor, Dalton, James & Seaber, 1990; Trnkoczy, 1974). According to Hooke's model, an elastic material deformation is directly proportional to the applied forces, and its initial form is recovered after the force is ceased (Buchthal & Rosenflak, 1957). Conversely, Newton's model states that a viscous material deformation is influenced by the time and force rates applied and can hold permanent changes after these actions are ceased

2.1.2. Treatment postures

One of the cornerstones of the GPR method is that muscles are organized in motor coordination chains and that they do not work as isolated structures, therefore the alteration (shortness or elongation) of one or more keys of the chain (muscles) creates a compensatory response in nearby or distant muscles (Bonetti et al., 2010; Castagnoli, Cecchi, Del Canto, Paperini, Boni, Pasquini, Vannetti & Macchi, 2015). According to the method parameters; in order to treat a muscle(s), the entire chain to which it belongs has to be stretched from end to end to avoid possible compensations. To accomplish this, GPR uses specific "treatment postures" (Appendix A) and depending on the muscle chain they act on, the method describes four families of postures (8 in total) based on the opening and closure of the hip angle (coxo-femoral joint) with adduction or abduction of the upper limbs and under or out of gravity loads. Its selection depends on the result of the participant's physical evaluation. Once in the treatment posture, the stretch gradually begins from an initial position with minimum tension, to a progressive stretching and increase of tension towards the end of the stretch. For this reason, this approach was originally known as "method of the closed field" (Souchart, 1994, p.69) because its objective is to close the circle and avoid that corrections are masked by

compensations¹. Nevertheless, the tension reached in the desired muscle chain(s) is only one component of the treatment since the action (physiotherapist manual manipulation and patient active participation) is based on the result of a detailed understanding of the problem that is presented and directed to the specific structures identified as the responsible (Korell, 1998).

2.1.3 Effectiveness of the Global Postural Re-education method

Since its creation almost 40 years ago and because of its individualistic patient assessment, biomechanical and physiological analysis of the involved structures the GPR method has been used in a variety of neuro-musculoskeletal system disorders in heterogeneous groups. This method is commonly known for treating postural disorders (Dimitroval et al., 2014; Souchart, 2012) such as scoliosis, cervical rectifications, lumbar hyperlordosis, etc.; with a correction purpose (no pain involved) but also for the treatment of symptoms with a biomechanical origin (Di Ciaccio, Polastri, Bianchini & Gasbarrini, 2012; Lomas-Vega, Garrido-Jaut, Rus & Del-Pino-Casado, 2016). This section will overview studies that evaluated the effectiveness of the method.

2.1.3.1 Randomised control trials

GPR compared with no treatment. The studies grouped under this category randomly assigned their participants to a GPR group (experimental) and a control group in order to make comparisons and assess the effectiveness of the method. For example, Oliveri and colleagues (Oliveri et al., 2012) investigated the presence of neurophysiological changes of motor cortical areas aimed at specific muscles of the inferior limbs after applying the global

¹ A compensation action could be defined as an adaptation that the body does to avoid discomfort or pain. For example when asking people to try to touch their toes with their hand (as an intention to stretch the hamstring muscles) this usually causes them to do a retroversion of the pelvis and flexion of the knees

postural re-education method in a group of healthy subjects. A total of 30 participants were recruited for this study and equally divided into three groups: two experimental (G1 and G2) and one control (G3). Group 1 and 2 were treated with 2 different treatment postures and the manual manoeuvres were performed by a physiotherapist specialised in the method. Postures were held for two minutes and repeated over three times with an interval of 2 minutes between each posture. The remaining group (control group) performed 3 minutes of pedalling exercise and repeated them three times with an interval of 2 minutes between each cycle to demonstrate that the effects observed in group 1 and 2 (if any) corresponded to the GPR treatment. Data were collected using transcranial magnetic stimulation (TMS) of the motor cortex and recording the motor evoked potentials (MEPs) from right biceps femoris, soleus and anterior tibialis muscles before (baseline session) and immediately after the three interventions. Results in group 1 showed an increased inhibition in cortical areas controlling the flexor muscles (biceps femoris $p < 0.05$) while increasing the excitation of cortical areas controlling extensor muscles (anterior tibialis $p < 0.05$), in group 2 increased inhibition in cortical areas controlling flexor muscles (Biceps Femoris and Soleus) did not correspond with the excitation of the extensors ($p = 0.005$) and group 3 showed a decrease, rather than an increase in intracortical inhibition in both anterior tibialis and soleus muscles. Overall, results confirmed that the neurophysiological effects of a GPR treatment are present not only at a spinal level but also at a motor cortical level.

Recently, another study carried out by Agosti and colleagues (Agosti, Vitale, Avella, Rucco, Santangelo, Varriale & Sorrentino, 2016) focused on evaluating the effectiveness of a GPR treatment in improving gait patterns of patients diagnosed with Parkinson's disease (PD). For this, they recruited 10 volunteers diagnosed with PD according to the United Kingdom Parkinson's Disease Society Brain Bank criteria, with a Mini-Mental State

Examination (MMSE) score of C23.8, a stable dosage of dopaminergic medication and no other medical condition affecting the gait pattern. Subjects were randomised into an experimental group and a control group. The experimental group received three GPR sessions with the assistance of a physiotherapist experienced with the method and the control group received no treatment at all. Clinical data from both groups were collected with the assessment of a neurologist using the motor section of the Unified Parkinson's Disease Rating Scale (UPDRS-III) to measure motor symptoms and by the Hoehn and Yahr scale (HY) to measure staging of the disease. Motion data were collected using an eight-infrared camera to measure the range of motion (ROM) of the ankles, knees and thighs at entry level (T0), after the treatment (T1), and then after the 8th (T2) and 12th (T3) weeks as follow-up evaluations; and were analysed using the Visual3D C-Motion software. Changes in the clinical and kinematic gait parameters were assessed in terms of time and group factors and results from the experimental group showed that time factor imply a decrease in the UPDRS-III ($p=0.001$) scores and an increase in the ROM of the knee ($p=0.001$) and thigh ($p=0.001$) among T0 and T1, T2 and T3; no statistically significant differences were found in the control group. Group factor also had a significant effect on the UPDRS-III score ($p=0.001$) and kinematic assessment (Knee, $p=0.001$; Thigh, $p=0.001$) in the study group, which performed better across T1, T2, and T3 as compared with the control group. Conclusively, the GPR group showed statistically significant improvements in both clinical and kinematic assessments as compared with controls.

GPR compared with pharmacological treatment. The effectiveness of a global postural re-education treatment has also been compared to pharmacological treatments. In this concern, a recent study performed by Lawand and colleagues (Lawand et al., 2015) aimed to evaluate the effectiveness of GPR when compared to pharmacological treatment.

The sample was constituted of 61 patients who had been suffering from chronic low back pain with a mechanical origin for more than three months and had a score of 3 to 8 on a visual analogue scale for pain (VAS). At first, all participants were instructed to take 3.0g of acetaminophen per day as the first choice or up to 150mg of diclofenac as the secondary choice, if needed, and to keep a record of the intake. They were randomly allocated to a GPR group (N=31) and a control group (N=30). The experimental group was treated with GPR performed by an experienced physiotherapist, while the control group remained only under drug treatment. Data were collected at baseline (T0), right after the treatment (T1) and six months after the initial evaluation (T2) using a visual analog scale of pain (VAS), the Roland-Morris Questionnaire (RMQ), the Medical Outcomes Study Short-Form 36-Item Health Survey (SF-36) and the Beck Depression Inventory (BDI) to assess pain, function capacity, quality of life and depressive symptoms, respectively. The results revealed favourable changes in pain (VAS), with a decrease of more than 1.5 cm on the scale for 87% of the GPR group compared to 23% in the control group at T1 ($P < 0.05$), and 58% versus 17% in the control group at T2 ($P < 0.05$). The RMQ revealed an improvement of more than 5 points in 61% of the experimental group versus a 10% in the controls at T1 ($P = 0.031$), and 48% compared to 10% at T2 ($P < 0.05$). No statistically significant differences were found between groups in functional capacity, general health or social aspects subscales of the SF-36, whereas statistically significant changes were found regarding the limitations due to physical aspects, vitality and mental health subscales in the GPR group ($P < 0.05$; $P < 0.01$ and $P < 0.05$, respectively). As revealed in the results, the GPR group demonstrated statistically significant improvements in the evaluated parameters in comparison with the ones obtained by the control group.

Likewise, Refice and colleagues (Refice, Loriga, Pompa, Gambale, Altavilla, Paolucci, Altamura, Souchart & Vernieri, 2015) investigated the effects of GPR on migraine attacks when compared with exclusive pharmacological treatment. Sixteen participants affected by a common migraine were recruited and equally divided in an experimental and a control group. The experimental group received pharmacological treatment and 10 sessions of GPR, and the controls only received pharmacological treatment. Details of the treatments were not provided in the article. Both groups were evaluated before the intervention (T0) and after the 3rd (T1) and 7th week (T2). Data were collected using the numerical 11-point box pain scale (BS-11), the Palliative Prognostic Index (PPI) and the Short-form McGill Pain Questionnaire (SF-MPQ) to assess intensity and quality of pain, while disability was assessed by the headache impact test (HIT); additionally, each patient filled out a migraine diary to report their symptoms and amount of painkillers taken daily. Results showed an improvement of all rating scales values for the GPR group; more specifically T1 results showed a decrease in all the evaluated variables (pain intensity and quality, attacks duration, frequency and disability) compared to T0 ($p < 0.05$); similar results were obtained at T2, except for two subjects ($p < 0.05$). Additionally, 80% of patients in the GPR group replaced the anti-migraine medication, while the remaining 20% reduced the number of intakes. On the other hand, in the control group, after an initial partial improvement at T1 compared to T0, most of the values remained unchanged through the following re-evaluations.

GPR compared with conventional physiotherapy. Despite the fact that GPR is almost entirely used in physiotherapy establishments, this method is mostly recognised as a manual therapy method and distinguishes itself from “conventional physiotherapy”, which is usually characterised by an analytic treatment of an injury, prescribing modest exercises, analgesic electrotherapy and using physical agents such as moist heat and cold. On the other hand,

manual therapy practices tends to aim for the origin of the problem and the understanding of how the body got to that point in order to solve it through a set of specific manual techniques (i.e. soft tissue manipulations, manual traction, joints manipulation) that have been developed and refined by many practitioners throughout the years (Farrell & Jensen, 1992).

In this regard, a study performed by Castagnoli and colleagues (Castagnoli et al., 2015) compared the short and long-term (1-year follow-up) effectiveness between global postural re-education and a standard physiotherapy treatment on patients suffering from nonspecific low back pain. Sixty (60) participants were recruited and equally divided between a GPR and a conventional physiotherapy (CP) group. Both groups received 15 sessions of either a GPR or a CP adapted treatment by an experienced physiotherapist. Data were collected at baseline (T0), 15 days after the treatment (T1) and 1 year later (T2) using the Roland and Morris Disability Questionnaire (RMDQ) to examine low back pain disability and the Numeric Rating Scale (NRS) to assess pain severity. At short term (T1), both variables showed statistically and clinically relevant results in both groups ($P = < 0,001$), with no greater differentiation among them. The 1-year follow-up evaluation (T2) revealed an improvement in both NRS and RMDQ scores compared to T0 in both groups, but according to the literature, these results were not clinically significant. However, patients in the GPR group still reported statistically significant changes in intensity and frequency of pain at T2 compared to baseline, which suggested a longer-lasting effect of the method on pain parameters.

Another group of researchers (Pillastrini, De Lima, Resende, Banchelli, Burioli, Ciaccio, Guccione, Villafañe & Vanti, 2016) compared the effectiveness of GPR and a different manual therapy (MT) treatment on patients with chronic nonspecific neck pain

(NP). For this, they recruited 94 patients and randomly organised them to receive either a GPR (experimental) or an MT (control) treatment. Both interventions lasted 9 sessions in which three GPR experienced physiotherapists assessed the experimental group, and 5 experts in neck pain treatment were in charge of the MT program. In addition to the provided treatments, all participants were assigned to home exercises according to the group they belonged. Measurements for this studies were collected at baseline (T0), at the end of treatment (T1) and after 6 six months (T2) and gathered information on pain using a VAS scale; disability using the Neck Disability Index (NDI-I); kinesophobia (fear of movement) using the Tampa Scale of Kinesiophobia (TSK); the perceived effect of the intervention through the Global Perceived Effect Questionnaire (GPE); self-reported improvement or deterioration with a 5-point Likert-type scale; patient satisfaction using the Physical Therapy Patient Satisfaction Questionnaire (PTPSQ) and, finally, cervical ROM was assessed using an inclinometer which allows for 3D measurements (flexion/extension, lateral flexion, rotation). Between-group analysis were statistically significant for VAS scores at T1; for NDI and TSK at T2 and for ROM during the flexion- extension and lateral flexion at T1 and T2. The GPR group showed statistically significant improvements in pain at T1 ($P=.0043$) and in disability 6 months after the intervention (T2) ($P=.0113$) when compared to the control group. Time and group interaction was significant for VAS scores at T1 ($p=0.00$); for NDI ($p=0.01$), TSK ($p=0.04$) and ROM during flexion-extension ($p=0.01$) at T2.

GPR compared with segmental stretching. As mentioned before, the GPR method parameters state in order to stretch a muscle, the entire chain to which they belong has to be stretched from end to end to avoid possible compensations. In addition to this, the stretching action performed in GPR is significantly longer in time (20 minutes approximately) compared to segmental stretching, which tends to last around 1 to 2 minutes and mainly

focuses on stretching one specific muscle at a time (Neiger, 1998). Therefore, the efficacy between these two types of stretching has also been studied.

For example, Cunha and colleagues (Cunha, Nogueira, Renovato & Pasqual, 2008) compared the effects of GPR and conventional static stretching (CS) on patients with chronic neck pain. The sample was composed of 31 participants previously diagnosed with mechanical neck pain, which were randomly assigned into a GPR group (n=15) and a conventional stretching group (n=16). Both programs consisted of two 1-hour individual sessions per week for six weeks, both received manual therapy manoeuvres during the first 30 minutes of each session and both groups were assessed and treated by an experienced physiotherapist. Data were collected before (T0), immediately after (T1), and at six weeks after treatment (T2) on pain intensity using a visual analog scale (VAS), cervical spine range of motion using an universal goniometer of flexion, extension, lateral flexion, and rotation movements and health-related quality of life was assessed by the Study Short-Form 36 Health Survey questionnaire (SF-36). Results showed no significant differences between groups, although statistically significant relief of pain was found in both groups at T1 (GPR, $P=0.001$; CS $P=0.001$) with a slight reduction at follow-up time for the GPR group ($p=0.003$). Quality of life scores (SF-36) also raised after treatment, except for the GPR group in the general health domain at T1 ($P=0.152$); both groups showed scores reductions on the rest of the domains at T2. The range of motion results revealed statistically significant improvements especially in the flexion range at T1 for both groups (GPR, $P=0.001$; CS $P=0.001$) and was maintain at T2. In the other movements, ROM results were not as dramatically but still statistically significant at T1 with a slight decrease at T2.

Comparisons between global postural re-education and conventional segmental self-stretching (SS) were also made by Silva and colleagues (Silva, Andrade & Vilar 2012), in this compare it effects on ankylosing spondylitis (AS). The sample comprised 38 volunteers diagnosed with AS that were allocated into a GPR group (N=22) and a self-stretching (SS) group (N=16). Both interventions consisted of 16 one-hour session over 16 weeks and were supervised by a physiotherapist with experience in rheumatic diseases. Measurements were taken before and after the interventions using the Health Assessment Questionnaire–Spondyloarthropathies (HAQ- S) to assess pain intensity, morning stiffness, spine mobility, chest expansion and functional capacity; the Short Form 36 Healthy Survey (SF-36) to assess quality of life and the Bath Ankylosing Spondylitis Disease Activity Index (BASDAI) to examine disease activity. Results showed statistically significant improvements in all evaluated parameters for both groups, with slight intra-group differences in the after-treatment evaluation, pain intensity improvements; specifically, in the dorsal segment, were better in the SS group (GPR, $p=0.07$; SS, $p=0.03$). Cervical pain (GPR, $p=.000$; SS, $p=0.01$) and lumbar mobility were better in the GPR group (GPR, $p=.000$; SS, $p=0.41$). Additionally, inter-group comparison revealed better results for the GPR group in the morning stiffness variable ($p=0.01$) and in quality of life (physical and emotional aspects) ($p=0.000$).

On the other hand, De Amorim and group (De Amorim et al., 2014) compared the effects of GPR treatment and segmental stretching exercises on scapular dyskinesia associated with neck pain. To do this, they recruited 30 participants and randomly assigned them to a GPR or a stretching group (SG). Interventions were performed once a week for 10 weeks, with a duration of 60 minutes total. Data collection was conducted before (T1) and after the treatment (T2) to measure disability of the upper limb using the Disabilities of the

Arm, Shoulder, and Hand questionnaire (DASH); neck function by the Neck Disability Index (NDI); pain severity by the visual analogical scale (VAS); and health-related quality of life was assessed using the Short Form-12 surveys (SF-12). Within group results showed statistically significant improvements for the GPR group in the NDI, VAS and SF-12 scores ($p < 0.05$); and for the SE group in the DASH, NDI and VAS scores ($p < 0.05$). Between-group comparisons showed that the GPR patients' scores were greater in function; both in the NDI and DASH ($p = 0.001$), pain ($p = 0.001$) and physical domains of the quality of life survey ($p = 0.010$).

2.1.3.2 Non-randomized control trials

For a better understanding of the following article it is important to know that stabilization exercises (SE) are a growing approach in the field of physiotherapy and are commonly used to enhance motor control, strength and endurance of the pelvic floor muscles, diaphragm, transversus abdominis, internal oblique and multifidus which are believed to provide an important stabilization system of the lumbopelvic spine (Steinmetz, 2010).

In this regard, Bonetti and co-workers (Bonetti et al., 2010) evaluated the effectiveness of a global postural re-education treatment when compared to an SE program in persistent low back pain (LBP) at short- and mid-term follow-up. The final sample was composed of 78 participants suffering from chronic low back pain without specific cause who were assigned into a GPR or a SE group. All patients underwent 10 stretching sessions of 1 hour each, twice a week and were instructed to do home exercises for 15 minutes according to the group they belonged to; both interventions were provided by experienced physiotherapists. Measurements were taken at baseline (T0) and at three (T1) and 6 months (T2) from baseline to assess the following variables: disability using the Roland & Morris Disability

Questionnaire (RMDQ) and the Oswestry Disability Index (ODI); lumbar physical discomfort using a VAS and mobility of the whole spine and pelvis was assessed with the Fingertip-to-floor test (FFT). Between-group analysis showed a decrease in all evaluated parameters for the GPR group at short- and mid-term follow-up compared to the SE group. Group and time interaction showed statistically significant changes for the RMDQ, ODI, FFT and VAS scores ($p < 0.001$). An ordered logistic analysis showed an increased likelihood of definitive improvement for the GPR group compared to the SE group (OR 3.9, 95% CI 2.7 to 5.7). A multiple regression models analysis showed statistically significant improvement between T0 and T2 in the GPR group compared to the SE group for each variable evaluated, apart from the FFT values (RMDQ $b = -3.6$, from -4.8 to -2.4 ; ODI $b = -8.8$, from -11.4 to -6.3 ; FFT $b = -5.2$, from -11.8 to 1.3 ; and VAS $b = -22.2$ from -28.4 to -16.1).

2.1.3.3 Case studies

A case study carried out by Monteiro and colleagues (Monteiro, De-Oliveira, Dos-Santos, Collange, Neto, Oliveira, 2013) evaluated the effectiveness of GPR on a 23-year female patient suffering from a temporomandibular disorder on the right temporomandibular joint. The intervention consisted of 24 sessions of GPR three times per week. Electromyographic (EMG) data were bilaterally collected at rest (baseline) and during maximal occlusion from the masseter muscles and based on the reported discomfort. EMG results at baseline showed significantly higher amplitude of the signal on the affected side, which considerably decreased after the treatment leading to no significant differences between sides following the intervention. Results for the maximal occlusion of the right side were significantly higher prior to the intervention in comparison to the left side, however,

no differences were found between sides after the GPR program and there was an increase in the EMG signal on both sides.

2.1.4 Summary of GPR

As seen in the literature, GPR is widely used for the treatment of pain related to neuromusculoskeletal disorders (Bonetti et al, 2010; Castagnoli et al., 2015; Cunha et al., 2008; De Amorim et al., 2015; Lawand et al., 2015; Monteiro, Da Gama, Dos Santos, Grecco, Neto & Oliveira, 2013; Pillastrini et al., 2016; Refice et al., 2015), as well as for the treatment of movement patterns disorders as a result of neurological diseases (Agosti et al., 2016; Silva et al., 2012). According to the reviewed literature, this manual therapy method can provide statistically significant improvements in pain, disability and quality of life variables, among others (Bonetti et al., 2015; Cunha et al., 2008; De Amorim et al., 2015). Additionally, GPR seems to have a long-lasting effect on pain, range of motion and quality of life parameters (Castagnoli et al., 2015; Lawand et al., 2015; Refice et al, 2015). The selected studies exposed a consistency in the quantitative instruments used to evaluate the desire variables, the most common were the Visual Analogue Scale (VAS) to assess pain; the Neck and disability index (NDI) and the Ronald Morris Disability Questionnaire (RMDQ) to assess disability; the Short-Form 36-Item Health Survey (SF-36) to assess quality of life and the Fingertip-to-floor test (FFT) to evaluate mobility of the spine (other specific surveys and questionnaires were also used according to the variables evaluated), although some studies also provided empirical evidence with the use of 3D motion tracking analysis, EMG and transcranial magnetic stimulation (Agosti et al., 2016; Monteiro et al., 2013; Oliveri et al, 2012). As a summary, based on the fact that most musculoskeletal related pain are associated with mechanical disorders of the system (Blanco-Piñeiro, Pino Díaz-Pereira, & Martínez, 2016;;

Chaitow, 2001; Nyman, Wiktorin, Mulder & Johansson, 2007; Petty & Moore, 2001; Sahrmann, 2013) and that the treatment of its components can often provide an improvements of the aching (Souchart, 2012), it is reasonable to consider that the GPR method could be an effective tool for the treatment of nonspecific musculoskeletal pain.

2.2 Human Body Temperature

Temperature measurement is one of the oldest and widely used techniques in the medical field to indicate the presence or absence of health. Even before the invention of the thermometer in 1500, as far back as 400 BC Hippocrates applied mud pads to the body to observe which areas of the skin dried faster (hot areas = health problem). This section will reveal general, yet important information on human body temperature concepts and physiology.

2.2.1 Normal body temperature

Maintaining a normal core body temperature or thermoregulation, is a function of the autonomous nervous system (sympathetic), specifically of the hypothalamus glandule, which is in charge of preserving the body in a normal temperature (basal) to ensure that basic and survival functions are carried out. The hypothalamus receives temperature stimulus (afferences) from the skin thermoreceptors, deep tissues, spinal cord and other parts of the encephalon, which then process to provide a coherent response (efferences) (Barret, Barman, Boitano, Brooks, 2010). In the case of exposure to cold the body generates heat mainly through muscular activity and metabolism, and in the presence of heat, loses temperature by convection, conduction, sweat evaporation and radiation. Therefore, thermoregulation is the physiological process of balancing heat loss and heat production in order to maintain a constant core body temperature. The most accepted value for body normal core temperature

measured orally is 37°C (Wunderlich & Reeve, 1869) with a circadian fluctuation of 0.5 to 0.7°C and in healthy subjects can be affected by age, gender (Charkoudian, 2003), BMI (Lu, Shu-Hua, Dai, Yu-Tzu, 2009), physical activity and emotions (Barret et al., 2010; Herborn et al., 2015) among other factors. On the other hand, skin temperature is a function of blood flow, and contrary to the core body temperature, is less constant since it depends on the heat exchange between the environment, the body core and on the conditions of the skin and the structures lying beneath it (Barret et al., 2010; Bierman, 1936; Herry, 2002; Jones, 1998). The skin temperature may also vary significantly from one area of skin to another (Herry, 2002; Uematsu, 1988); however and according to the literature, in healthy individuals, skin temperature affects both sides of the body uniformly and simultaneously producing a symmetric thermal pattern (Haddad, Brioschi & Arita, 2012; Uematsu, 1986).

2.2.2 Human body and its thermal responses to pain

Pain is defined by the International Association for the Study of Pain (1986) as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage". Although in many cases the pain is derived from a real stimulus that can be potentially harmful, the sensation of pain is merely subjective and personal, which in many cases makes it difficult to evaluate and quantify. Because of its complexity, pain can be classified in different ways depending on the affected structures, location, etiology, duration or physiology. However, a clear separation of them is not always possible. Due to the purpose of this study, pain will be classified based on its physiological causes and responses as neuropathic and nociceptive.

Neuropathic pain is caused by damage or dysfunction of the nervous central system (peripheral or central) and symptoms are generally felt toward the damaged nerve(s) direction

or dermatome. It is usually accompanied by hyperalgia (exaggerated response to a stimulus) and allodynia (sensation of pain in response to an innocuous stimulus). Patients struggle to localize it and tend to describe it as flashing sensation, burning or numbness. Pharmacological treatment is partially effective and tends to be treated with Anti-epileptic (AEDs) and antidepressants. In many neuropathic pains, there is an increase of sympathetic excitation as a reflection of nerve root irritation. This overactivity leads to an active vasoconstriction and decreased heat emission along the course of the affected nerve root resulting in a decreased skin temperature or hypothermia (Michaels, 2004; Uematsu et al., 1988).

Nociceptive pain is caused by the activation of peripheral nociceptors due to tissue damage or potential tissue damage, the sensation is generally proportional to the level of damage and it usually responds to conventional analgesics (such as Nonsteroidal Anti-inflammatory Drugs). This type of pain can also be further classified as somatic or visceral pain. The somatic kind typically arises from bones, joints, muscles, skin or connective tissue. Symptoms are mostly local, and easy to pinpoint and describe (sharp, aching, tenderness or pressure-like). Visceral pain originates in viscera and it can be diffuse and referred to other areas, it is usually described as cramping, colic-like or aching depending on its cause (Herry, 2002). In response to tissue injury (when the stimulus is not innocuous), a release and synthesis of chemical mediators (potassium, bradykinin and prostaglandins) takes place in the damaged area and leads to the increased sensitivity of nociceptors; causing for example hyperalgesia (exaggerated response to a stimulus) and allodynia (sensation of pain in response to an innocuous stimulus); which in turn release the substance P (tachykinin, precursor 1). This substance is a powerful vasodilator associated with an increase of vascular

permeability and an increase in the production of other mediators (bradykinin, histamines and serotonin) resulting in an inflammation response, sometimes erythema (redness) and augmented radiant emission in the affected area or hyperthermia (Barret et al, 2010).

Musculoskeletal pain generally falls into this category and it is usually a consequence of an increase in the muscle tone, which is followed by rigidity, retraction and shortening of its morphology. According to Barret and group “If a muscle contracts rhythmically in the presence of an adequate blood supply, pain does not usually result. However, if the blood supply to a muscle is occluded, contraction soon causes pain. The pain persists after the contraction until blood flow is re-established.” (Barret et al., 2010, p.170). In addition to this the presence of a trigger point, frequently existing and responsible for musculoskeletal pain, can generate a constant sarcomeric contraction of the muscle fibre, and would be likely to compromise circulation producing local ischemia (reduced blood flow), thus reducing local muscle oxygenation and temperature (Haddad et al., 2012; Simons, 2004; Uematsu, 1988).

In summary, most typically, a dysfunction of the nervous central system (peripheral or central) results in a drop of skin temperature, and in the presence of visceral and/or connective injury an increase of temperature is often the response. However, due to the individuality of patients and pathologies, a consistent temperature response (hyperthermia or hypothermia) is not always the present for all cases, nevertheless a pathological stimulus does implicate a change in skin temperature asymmetry.

2.3 Infrared Thermography (IRT)

Infrared radiation was first discovered by the German astronomer Sir William Herschel in the year 1800 while conducting an experiment using a prism in sunlight. Herschel was

interested to solve an astronomical problem for he was looking a filtering technique that would give him adequate light for seeing without undesirable heating (Barr, 1961). When holding the prism against the sun it spread the light into a spectrum of colours going from violet to red, he then used a thermometer to record the temperature emanating from each colour and surprisingly the temperature kept rising after moving the thermometer beyond the red colour, implying the existence of energy beyond the red wavelength and visible spectrum discovering infrared radiation (Barr, 1961; Schlessinger, 1995). All objects at temperatures above absolute zero emit infrared radiation and the conversion of this electromagnetic radiation into a signal that can be seen by the human eye and thus can be interpreted in known as thermal imaging (Volmer & Möllmann, 2010). IRT has a large number of features and applications, and since 1987 was recognized as a feasible diagnostic and analytical tool in the field of medicine. The application of this approach in the assessment of skin temperature in medicine has been acknowledged and promoted by different authors (Priego, Cibrián, Pérez-Soriano & Salvador, 2017).

2.3.1 Infrared thermography and the human body

For more than 60 years (Lawson, 1956; Ring, 2010), infrared thermography has also been used in medicine as diagnostic tool, and unlike the thermometer (local), IRT records the distribution of body temperature by assessing the infrared radiation released by the human skin (Jones, 1998) which according to Skeetee (1973), has a relatively high emissivity (0.98 ± 0.01) for wavelengths of 2 and 14 μm in healthy subjects. Since its early use in medicine, infrared thermography has grown substantially and currently allows for precise observations and analysis of sympathetic temperature changes in the human body that lead to the identification of pathophysiological events or diseases (Bardhan, Bhowmik, Nath, &

Bhattacharjee, 2015; Schwartz, Goldberg, Govindan, Conwell & Hoekstra, 2006). Due to its characteristics as a non-contact, non-invasive, painless and fast testing time IRT has been used as a diagnostic and monitoring tool in a variety of medical scenarios, such as cancer detection, diabetic neuropathies, rheumatic diseases, blood pressure monitoring, physiological responses to emotions, dental diagnosis and pain disorders by targeting and quantifying the temperature changes distribution of the skin surface (Nahm, 2013; Lahiri, 2012).

2.3.2 Diagnosis in medical thermography

According to the literature (Herry & Frize 2004; Vaviov, Vaviova & Popov, 2001) decisions and diagnosis in medical thermography are commonly done by either taking the absolute temperature of a region of interest (Borojevic, Kolarić, Grazio, Grubišić, Antonini, Nola & Herceg, 2011), examining the presence of an abnormal temperature zone (hot/cold spots) (Lee, Lee, Song, Lee, Lee & Yoon, 2008), or by quantifying the degree of asymmetry between right and left sides of a region (Vardasca Ring, Plassmann & Jone, 2016; Zaproudina, Ming & Hänninen 2006; Uematsu, 1988). Our study examined the reliability of the last criteria. One of the major foundations of IRT is that healthy, asymptomatic individuals show a symmetrical skin temperature between left and right sides of the body, while a difference can indicate the presence of pain or pathology (Nahm, 2013; Uematsu, 1986; Vaviov et al., 2001). Additionally; based on the review studies, IRT is mostly used to find correlations either between temperature changes and the presence of injuries and diseases or between temperature changes and the presence of pain. Although both approaches will be examined in this section, our study was based on using IRT for the assessment of (musculoskeletal) pain.

2.3.2.1 Temperature changes as an indicator of an injury or disease. In this regard, Uematsu (1986) examined the temperature changes related to nerve injury of a total of 56

subjects (32 healthy, 8 with nerve trauma and 16 with lumbar disc herniation). Repeated temperature measurements were taken during a 12-months period. Results were based on 3 analyses: 1) in obtaining the degree of left-right temperature differences (asymmetries) of healthy controls; 2) in computing the absolute temperature differences of nerve damaged segments and compared with their counterparts and 3) in comparing the previously obtained values between groups. Temperature asymmetries side-to-side of the healthy group were small and stable, with an overall average temperature difference of 0.24°C . The asymptomatic group was divided into two groups based on whether they had a loss (A) or overactivity (B) of the sympathetic nerve function. Group A showed a higher skin temperature average on the damage side compared to the other side, and in group B the symptomatic side was colder than its counterpart. Both results were significant when compared with controls.

Nerve injury was also of the interest of Gratt and colleagues (Gratt, Shetty, Dent, Saiar & Sickles, 1995) who studied the effectiveness of IRT in assessing the signs of neurosensory deficits of the inferior alveolar nerve (IAN). The studied population consisted of 9 participants clinically diagnosed with IAN deficit and 22 healthy participants. Of these 22, 12 received a unilateral inferior alveolar nerve block injection with 1 ml of 2% lidocaine. Absolute temperature measurements and mean zone temperature differences were taken from selected regions of the chin and face. Thermograms of healthy subjects showed symmetrical heat patterns with absolute temperatures nearly the same. The 12 subjects who received the lidocaine injection showed an increase in temperature whereas the unaltered side remained virtually the same. For the 9 clinically diagnosed participants, the affected side was warmer

than its counterpart. Of all normal subjects, 79% had asymmetry values between 0.0 °C and 0.25°C. Asymmetry values above 0.35 °C were found on 76 % of the experimental group.

Zaproudina, Ming, and Hanninen (2006) evaluated the relationship between pain intensity and temperature asymmetries. The sample consisted of 65 patients with unilateral chronic low back pain (LBP) with (N=41) and without (N=24) referred non-radicular leg pain and 20 healthy controls. Collected data consisted of pain intensity obtained with a Visual Analog Scale (VAS), three questionnaires to assess mood, depression, and disability, a series of spinal mobility tests, and thermographic images of the low back area and legs. The average temperature difference between sides was calculated, and a difference of 0.3 °C was considered abnormal although the criteria for the selection of this number was not fully supported in the article. Average of the absolute temperature of the thigh proximal third and leg distal third was also collected. Their results showed that in 51% of the subjects the affected side was colder and in 48% was warmer compared with the lathy side. The affected side was colder in severe pain patients. In 90.77% of LBP patients, at least one region showed a temperature difference higher than 0.38°C with the maximal being 2.84°C. Statistically significant temperature asymmetries of the plantar surface were found between patients with referred leg pain in the heel areas and controls. In most of the sample, thermal abnormalities and location of painful areas did not correlate entirely.

Neuropathies were studied by Živčák and colleagues (Živčák, Madarász & Hudák, 2011) who used IRT for the diagnosis of carpal tunnel syndrome (CTS). The sample was constituted by 268 thermal images of the dorsal side of 120 healthy and 14 pathological hands with clinically diagnosed CTS from 8 patients. Temperature data was measured on 5 pre-identified points in the lines of median nerve on the dorsal and palmar side of hands which were then averaged. Correlations were made between absolute temperature healthy and

pathological hands. Results showed that injured hands exhibit the highest temperature in the distal phalanges contrary to what was found in the healthy group; these results were statistically significant.

Lee and colleagues (Lee, Paeng, Farhadi, Lee, Kim, Lee, 2015) used IRT to examine the changes in pain before and after a conservative treatment of a whiplash injury in 42 patients. Thermal data included the skin temperature of participants' anterior and posterior neck and left and right shoulders before and after the treatment. Additionally, a VAS assessed pain intensity before and after the treatment. Interpretation of data was based on the comparison of absolute temperature and temperature asymmetries between anterior and posterior neck, and right and left shoulders before and after the intervention. Normal temperature values (absolute and asymmetric) were considered from another study. Results showed 1–2°C of hyperthermia in the neck and shoulders before treatment compared to normal values, however; temperature was close to normal after the treatment. Asymmetries results across all measurements (neck and shoulders) either before or after the treatment did not exceed the normal criteria ($<0.5^{\circ}\text{C}$) for pathologic conditions used in the study. On the other hand, VAS results before and after the treatment were statistically significant for the neck and shoulder areas.

Finally, musicians were of the interest of Clemente and others (Clemente, Coimbra & Silva, 2011) however their results lacked statistical significance. The title and initial explanation of the article allege they are interested in assessing the effectiveness of IRT in distinguishing temperature asymmetries of the craniocervical-mandibular complex (CCMC) in musicians diagnosed with myofascial pain, however, diagnosis of myofascial pain it is not possible as it is a symptom and not a pathology per se. Later, in the methods section, they

stated that the data will be collected to understand the influence of the different instruments in the muscular activity of the CCMC. They also assessed the presence of trigger points which then they correlated with temperature values; we believe that was one of the objectives of the study. Although it was reported that musicians had trigger points in different muscles of the CCMC, temperature results were only provided for the trapezius muscle. The sample was too small and heterogeneous (N=5) and thermal data was collected while the musicians were playing their instruments. According to their results, all 5 musicians showed higher temperatures on the affected side with side-to-side asymmetries up to 1.6 °C which was also their dominant side. And of the 5 examined musicians, 3 played asymmetric instruments (violin, transverse flute, and bagpipe) which could easily explain the increase in temperature as no baseline or post-playing data was collected.

2.3.2.2 Temperature changes as an indicator of pain. Filho and colleagues (Filho, Packer, Costa, Berni-Schwarzenbeck, Dos Santos & Rodrigues-Bigaton, 2012) analyzed the temperature asymmetry of the upper trapezius muscles between a group of 36 women with (N=18) and without (N=18) mild neck pain. Thermographic data consisted of the skin surface temperature of the upper bilateral trapezius muscle. The absolute temperature of the targeted muscles and temperature asymmetries between right and left trapezius were analyzed. Correlation between the pain levels and temperature of the upper trapezius were also made. In this study, no significant differences were found between groups in none of the analyses.

Myofascial pain was studied by Haddad, Brioschi and Arita (2012) who investigated the correlation between myofascial trigger points (MTP) and changes in temperature in 26 female volunteers with a presence of trigger points in the masticatory muscles. Examination of trigger points was initially confirmed by palpation of an expert and an algometer was used

to measure the minimal force that induced pain (pain threshold). Thermal analysis consisted of comparing the averages of the absolute temperature of the targeted muscles and thermal asymmetries between opposite sides. Correlations were made between the pressure pain threshold and temperature values. Thermograms were taken from the masseter and the anterior temporal muscles on each side and subjects also indicated the intensity of their pain on a VAS. After obtaining the data, the examined points were divided into three groups: no MTP, MTP with local pain and MTP with referred pain. Results showed no thermal differences between the left and right sides. The correlations between the PPT and temperature were positive and moderate, where the higher PPT values (the greater the pain sensitivity of the point, the lower the PPT value) showed higher local temperature. Points of local pain showed a higher temperature than the point of referred pain and the most heated areas of the face were correlated with regions without MTP.

Another study (Rodrigues-Bigaton, Filho, Vieira, Costa, Packer & De Castro, 2013) examined the accuracy of infrared thermography in the recognition of arthralgia (joint pain) in 30 women with (N=15) and without (N=15) temporomandibular joint (TMJ) disorders. Both groups underwent a thermography session to assess the skin surface temperature and asymmetries of the TMJ for later comparison of absolute temperature and asymmetries between groups. The arthralgia group showed higher temperatures for both left ($P = .004$) and right ($P = .012$) TMJ compare to control, however, no statistically significant differences between groups were found regarding thermal asymmetry.

More recently a group of researchers (Rossignoli, Fernández-Cuevas, Benito & Herrero, 2016) used IRT to examine the presence of shoulder pain (SP) in wheelchair users. Specifically, the study considered the changes in shoulder skin temperature during a

wheelchair propulsion test (pre, post-1minute and post-10 minutes), relationship between shoulder pain and skin temperature asymmetry and a third analysis to relate the SP with the kinematic variables of the test. Thermal analysis was based on detection of inter-side thermal asymmetries between anterior and posterior arm, shoulder, forearm, trapezius, dorsal, infraspinatus, supraspinatus, pectoral and central trapezius. An asymmetry higher than 0.5°C was considered abnormal. There were significant inverse relationships between shoulder pain and skin asymmetries before and after exercise; this is, that the higher the SP the lower the thermal asymmetry and vice versa. Significant differences were observed between the post-10 and pre-test in 12 of the assessed regions, however, there was a lack of significant differences between the pre-test and post-test. Asymmetries had a tendency decrease immediately after the test and then significantly increase after 10 minutes of completing the activity.

A study on musicians with overuse pain related to playing the piano was performed by Mohamed, Frize and Comeau (2011) examined thermal differences in hand and arms between 9 pianists with (N=6) and without pain (N=3) associated with their musical practice. Participants were instructed to play 3 series of piano exercises which progressively increased in difficulty. Thermal images of hands and arms (anterior and posterior) were collected at rest (T0) after the acclimatization period, after 15 minutes of playing (T1), right after finishing playing the exercises (T2) and the last one 30 minutes after playing the last piano exercise (T3). The analysis focused on the mean absolute temperature. Results did not show significant differences between groups in the lower and upper arm segments; however, statistically significant differences were found in the mean hand temperature of pianists with pain compared to those without pain across all four measurements

2.3.3 Normal asymmetry values

One of the major functions of the hypothalamus glandule is temperature regulation to maintain the chemical constancy and homeostasis of the body internal environment (Barrett et al., 2010). It is well known that in normal conditions, the blood flow spreads through the skin uniformly producing a symmetric thermal pattern. However, universal values for normal skin asymmetries across the body measured with IRT varies among studies and it is commonly selected based on the analyzed data and pathological processes. For example, Gratt and colleagues (Gratt, et al., 1995) considered a thermal pattern "abnormal" when asymmetries were greater than or equal to $\pm 0.36^{\circ}\text{C}$; Michaels (2005) used 1.0°C as the abnormality criteria which agreed with Hoosmand's study (1997). Zaproudina and colleagues (Zaproudina et al., 2006) considered a temperature difference of more than 0.38°C as abnormal. Results from Vardasca and Rodrigues (2016) showed that the highest temperature symmetry difference on healthy subjects was 0.4°C . Uematsu (1986) found that 0.24°C was the overall difference across healthy subjects. Other studies considered differences 0.5°C as an abnormal (Lee et al, 2008; Lee et al., 2015). Additionally, since until now, there are no established parameters on the selection of regions of interest and further analysis of the data, it seems incorrect to use previous studies for a reference for normal values. In this study, as in many others, normal asymmetry values will be based on the data obtained from the healthy participants.

2.3.4 IRT for the assessment of treatment approaches.

The studies described below used this technology to assess the effects of different treatments on disease, pain or other physiological processes and examined effects on thermal asymmetries, among other variables. For example, Seixas and group (Seixas et al., 2016) examined the effects of a treatment for trigger points by monitoring the skin temperature changes of 5 volunteers after an intervention with dry needling. The gathered data consisted of mean absolute temperature of the regions of interest, the degree of asymmetry between treated and non-treated sides and the pressure pain threshold of trigger points. No relevant differences were found in any of the assessed variables between the pre and post evaluations showing an agreement between all measurements.

In another study performed by Hakgüder and group (Hakgüder, Birtane, Gürcan, Kokino & Tura, 2003) thermography was used to study the effects of low-level laser therapy (LLT) and stretching exercises in myofascial pain. A total of 62 patients with active trigger points in the neck and upper back constituted the sample and were divided into 2 groups: A LLT group and a stretching group. Participants were analyzed in terms of their pain intensity using a Visual Analog Scale (VAS), algometry values (pressure pain threshold) for the trigger points and skin thermal asymmetry values between the symptomatic and asymptomatic sides before and after the interventions. With some differences in the groups, infrared thermography measures were related to the values found in the pain and algometric assessment, as pain decreased and the algometry value increased (positive effect) after the treatments. The presence of thermal asymmetries (a difference of at least 0.5°C was considered abnormal) decreased from twenty cases in group 1, to three cases after the intervention, and from seventeenth to twelve cases in group 2.

With the purpose of unmasking the subjectivity of pain and transforming this symptom into objective visible images, many authors examined the correlations between pain and the degree of thermal asymmetries between corresponding parts of the body (symptomatic versus asymptomatic, treated versus non-treated, etc). In this regard, Wu and group (Wu et al., 2009) examined the local physiological responses in 53 patients with coccygodynia, before and after two conservative treatments. Pain and skin temperature data were collected after 8 weeks of treatment with manual techniques and short-wave diathermy. Analysis consisted of a comparison of before and after pain scores and examining the relationship between pain and surface skin temperature. Results showed a decrease in both pain intensity and temperature and a statistically significant correlation between pain scores and temperature values.

Lee and colleagues (Lee, Paeng, Farhadi, Lee, Kim, Lee, 2015) used IRT to examine the changes in pain before and after a conservative treatment of a whiplash injury in 42 patients. Thermal data included the skin temperature of participants' anterior and posterior neck and left and right shoulders before and after the treatment. Additionally, a VAS assessed pain intensity before and after the treatment. Interpretation of data was based on the comparison of absolute temperature and temperature asymmetries between the 4 regions, changes in the VAS scores, and correlations between the VAS scores and temperature outcomes before and after the intervention. Results showed 1–2°C of hyperthermia in the neck and shoulders before treatment compared to normal values, however; temperature was close to normal after the treatment. Thermal differences of the anterior and posterior neck and left and right shoulders either before or after the treatment did not exceed the normal criteria for pathologic conditions used in the study ($<0.5^{\circ}\text{C}$). However, the asymmetry values

between counterparts were statistically significant before and after the intervention. VAS results decreased after the treatment and showed a significant correlation with the asymmetry values of the neck and shoulders before and after the treatment.

Correlations between pain severity and temperature using IRT were also studied by Kim and Cho (1995) in 147 patients presenting a lumbar disc herniation. Patients in the sample had unilateral leg pain complaint as a consequence of the lumbar disc herniation and were divided into an acute (N=78) or chronic (N=69) group. Thermal differences between the symptomatic and asymptomatic legs were collected using a Dorex DITI system, the intensity of pain by means of a VAS and a Graphic Rating Scale (GRS) and clinical signs with the Straight Leg Raising Test. Thermal outcomes and pain severity scores were correlated. No relevant results were found for the chronic group in any of the examined parameters. However, statistically significant results were found in the acute group where the severity of pain correlated with the degree of temperature asymmetries. Additionally, thermal differences were also correlated with clinical signs, showing that the more the nerve compromise was, the greater the asymmetry.

Similar correlations between pain and inter-side temperature asymmetries were also investigated by Zaproudina and colleagues (Zaproudina, Ming & Hanninen, 2006) to evaluate the skin temperature differences between subjects with and without chronic unilateral low back pain (LBP) and its correlation with pain severity. A total of 85 subjects were recruited for this study, of which 65 suffered from chronic LBP (with non-radicular leg pain= 41; without non-radicular leg pain= 24) and the remaining 20 were healthy. Pain intensity was assessed using a VAS and a body diagram to locate their pain, and thermograms from plantar surfaces of feet were taken with an infrared video camera. Other parameters

were also studied. Results showed that temperature variations were not consistent between subjects although local LBP pain level correlated with the inter-side average temperature differences of the entire plantar surface where 51% of the subjects showed lower temperatures on the affected side compared with the healthy one. The relationship between the localization of the painful area (diagram) and temperature alteration area did not match entirely. Inter-side average temperature differences of the plantar surface in patients with referred leg pain were higher than in the controls.

In summary, studies suggest that IRT can be a reliable tool to measure the skin thermal effects of different treatment approaches on trigger points, LBP, coccygodynia, whiplash injuries and lumbar disk herniation, among others. The most common analyses consisted in correlating the pain severity data with the degree of asymmetries and by comparing the skin temperature asymmetries between two different groups (treated and non-treated sides, experimental and controls, etc) before and after an intervention.

2.3.5 Summary of Infrared thermography

Due to its components and characteristics IRT has been used by a variety of studies with different research objectives. As mentioned before, this technology is widely used in the field of medicine for diagnostic purposes or to observe thermal changes coming from an injury / illness or pain. Three criteria are used for interpreting thermograms: by examining the absolute temperature of a segment and comparing it with its healthy counterpart, by observing the presence of hot/cold spots in a specific area, or by analyzing the degrees of asymmetry between corresponding parts. Regarding this last criterion, since the values of normal asymmetry vary from study to study, there is no predetermined value of normal

asymmetry, however the literature seems to support that in the presence of health, the body is irrigated in a uniform and parallel way.

2.4 Musician's health problems

When referring to musicians' health issues related to their activity, the terms accumulative trauma, repetitive strain injuries, and/or overuse, are frequently used (Fry, 1986; Lockwood, 1989; Zaza, 1998), however; it is safe to say that all of those terms belong to neuro-musculoskeletal disorders syndromes (Sahrmann, 2002) that can be defined as localized painful conditions arising from irritation of the system components (nerves, muscles, bones, joints) and commonly as a result of repeated use, excessive load or faulty body alignment over a prolonged period of time that is beyond the tolerance of the tissue involved and can eventually lead to tissue damage and disability (Kendall, McCreary, Provance, Rodgers & Romani, 2005; Sahrmann, 2012).

In this regard, Fishbein and Middlestadt (1988) studied the prevalence of medical problems among 2212 professional orchestra musicians performing in the International Conference Orchestras of Symphony and opera Musicians (ICSOM). For the collection of data, participants were asked to complete a detailed questionnaire containing a list of 59 common health problems including locations, symptoms, diagnoses and medical treatments. Results showed that 82% were having at least one medical problem, of which 76% described as "severe" and reported it was affecting their performances, the females had a higher prevalence (89%) and 86% of musicians between 35 and 45 years were most likely to report them. String players were the most affected by medical problems (84%), and musicians under the "other instruments" category the least (7%). Stage fright, eye strain and depression resulted first in the non-musculoskeletal problems (24%, 24% and 17%, respectively) and as

for what musicians were using to treat those problems, 40% rely on medication; whilst massage and somatic approaches were the least used treatments. Musculoskeletal problems were most likely located at the neck (22%), lumbosacral spine (22%) and shoulders (20%) and the most frequently tried treatments/approaches were rest and stop playing (37%), and heat application (32%).

Likewise, Zaza (1992) studied the prevalence of playing-related health problems among 300 music students performing in several bands, orchestras, choirs and ensembles from a leading Canadian institution. Assessments were taken by questionnaire created by the author, which surveyed the participants in terms of prevalence of playing-related health problems (PRHP) and its repercussion on their musical practices, risk factors, knowledge of PRHP and familiarity with common health methods used by musicians. Results showed that 43% of the musicians had to stop playing due to the presence of a PRHP, 28% had been affected by very mild injuries; 4% by mild injuries, 7% by moderate injuries and 4% by severe injuries; while 57% stated that they had not sustained an injury severe enough to prevent them from performing. Female students were more likely to report PRHP than males (OR=1.98, CI 0.9-3.8) and string player were most likely to report those problems (OR: 0.86, CI 0.29-2.47).

More recently, Lonsdale and Boon (2016) investigated the prevalence of playing-related health problems among music students as well as their knowledge of those problems. A total of 98 students enrolled in undergraduate and post-graduate university music courses at a university in Malaysia were recruited for this and responded to an online survey that assessed educational background; prevalence of playing-related physical problems, management and prevention; as well as general lifestyle. Results revealed that 57% of the

participants considered themselves to be in good health, 29.9% in fair health and 6.2% in poor health. At the time of the survey, 28.9% of respondents suffered from playing-related pain and 49.5% were not, however 46.4% had experienced pain at some point, which in some cases was serious enough to distract them when playing (11.3%) or had them take a period off playing (6.2%). Additionally, more than a third of the group (36.8%) reported that the level of pain tended to determine the length of their practice session. The prevalence of current pain varied from 21.0% in pianist/keyboardist to 38.5% in guitarists; while string players (64.7%) were the most affected by pain at some time in the past. Pain was most likely to occurred in the fingers and hands (45.9% left; 37.8% right), upper arms (32.7% left; 29.6% right) and neck (39.8%) which 10.5% treated with painkillers, 51.6% used massage, 5.3% used Chinese medicine, homeopathy, or naturopathy; while the rest (42.1%) did nothing to treat their pain.

2.4.1 Prevalence of neuro-musculoskeletal disorders and pain among musicians.

According to the reviewed literature on musicians' health, there is a high incidence of medical issues related to their occupation, with neuro-musculoskeletal disorders leading the statistics. For example; Abreu-Ramos & Micheo (2007) studied the prevalence of musculoskeletal (MSK) problems on a group of 75 professional orchestra instrumentalists. Data were collected using a pre-tested questionnaire which surveyed the musicians in terms of playing habits, instruments played, medical history and presence of pain including symptoms' characteristics. Results showed that 80% of the participants had or have had a MSK problem that affected their ability to play and 83.6% of them associated pain with their musical activity. Problems were mostly found in the low back, neck and shoulders and women and low-string players were the most affected. Rest alleviated the symptoms in 77% of the

musicians and inability to play was an effect of MSK problems in 21% of the participants. Similar results were obtained by Fotiadis and group (Fotiadis et al., 2013) after investigating the frequency of MSK disorders on 147 professional musicians. Data were collected using the Standardized Nordic Questionnaire (SNQ) to examine the prevalence of musculoskeletal disorders and a Likert scale to assess their level of muscular discomfort. Results revealed that 81.6% of the musicians experienced some kind of MSK disorder at least once during their career which 66.4% considered to have affected their performances. Women were again the most affected and pain was the primarily reported symptom.

Due to the purpose of this study, special attention was given to string players and pianists; therefore, the prevalence of neuro-musculoskeletal disorders among these two specific groups is presented in this thesis. In this regard, Vinci, Smith & Ranelli (2015), investigated the prevalence of MSK problems (PRMS); defined by the author as problems which affect soft tissue such as muscles, tendons, and nerves and also include focal dystonia, and disorders (PRMD) such as weakness, lack of control, numbness, and tingling or pain affecting the musician's ability to perform as usual on 65 adolescent string orchestra musicians. Participants were surveyed on their experience with playing related problems and/or disorders, symptoms, along with other physical measurements (BMI, hands span, and joint mobility). Results showed that 73% of the musicians showed PRMS and 27% reported PRMD. The most reported symptoms were soreness, pain, discomfort, tingling, and weakness. Prevalence was no significantly different among instrumentalists and joint hypermobility seemed to influence the presences of disorder. MSK problems in string instrumentalists were also studied by Ajidahun and Phillips (2017) who aimed to examine the prevalence of the former among 114 orchestra musicians using a specially designed online and paper-based questionnaire to collect data on their experience with MSK problems,

characteristics and risk factors. According to the results, MSK problems in one or more regions were reported by 77% of musicians and 37% of those felt it had affected their performance at some time. The most reported symptoms were pain, soreness, fatigue and tightening and were majorly located in the low back, left shoulder and the neck.

Similarly, Kochem and Silva (2017) investigated the prevalence of PRMD among 106 violinists and used the Standardize Nordic questionnaire (SNQ) and the Disabilities of the Arm, Shoulder, and Hand (DASH) instruments to collect data on musculoskeletal symptoms and the ability to perform certain upper limbs activities, respectively. Outcomes revealed that almost 90% of violinists had at least 1 painful region during the previous year and 77.4% during the previous week. Eight percent of participants had to temporarily stop playing because of these disorders, and only 10 % sought professional help.

Pianists have also been studied by several authors. For example, Shields and Dockrell (1999) investigated the prevalence of MSK injuries in 159 non-beginner piano musicians by means of a specially designed questionnaire which collected data on practice characteristics, injury prevalence, and treatment preferences and showed that 41% of the musicians sustained an injury caused by playing the piano. For 46.3 % of the pianists "practice habits" were the main cause of injury, followed by posture (39%) and overuse (39%). Pain was by far the most reported symptom (97%), stiffness (49%) and weakness (39%) coming behind. Symptoms were predominantly located in wrists (36.6), fingers (14.6) and back (9.8). Another study (Pak et al., 2001) focused on studying the prevalence upper-extremity musculoskeletal problems of 455 keyboard instrumentalists. Data was derived from the University North Texas Musicians Health Survey conducted online which assessed the prevalence of MSK problems, pain severity and the association with their musical lifestyle (practice habits, daily playing time and musician type) and demographics. The obtained

outcomes indicated that pain severity was mostly reported as grade 1 (mild); follow by grade 3, 2, 4 and 5 with a highest prevalence in females. Jazz instrumentalist were the most affected (81.4%) followed by classical keyboardists (63, 3%) and composers (60%). Musician type and playing time factors did not showed statistically significant results. Pain was more frequently reported in the right and left wrist (17.4% and 13.2%, respectively).

In a similar kind of study, Furuya and colleagues (Furuya et al, 2006) studied the occurrence of playing related musculoskeletal disorders (PRMD) in 203 all-female experienced pianists including piano students and professional classical pianists using a specially developed questionnaire made of 40 questions which asked about personal and musical life style, history of PRMD associated with their musical practice, and their experience with different treatments and health practitioners. Their results exhibited that a total of 77% of pianists had experienced PRMD in some region of their bodies. Of the 77%, 41% were college students, 30% were seniors and 26% were high school students. The most affected areas were the hand/fingers follow by shoulders, neck and trunk. There was a higher rate of PRMDs at the neck/trunk for those who considered themselves nervous and those who reported feeling stage fright all the time. Rest was the preferred option for the majority of musicians, followed by a changing in the technique and self-massage, while 44% sought medical treatment. The majority did not feel left-right side differences, although 20% did indicate that the problem was limited to one side.

Within neuro-musculoskeletal disorders, pain is by far the most reported symptom by musicians (Abreu-Ramos et al., 2007; Kreutz et al., 2008; Fotiadis et al., 2013; Fishbein et al., 1988; Pak et al., 2001; Zaza, 1992). The frequency, characteristics and consequences of this symptom were studied by Steinmetz and colleagues (Steinmetz et al., 2015) based on 408 professional orchestra musicians through the examination of their medical history,

location and frequency of pain. A total of 89.5% of musicians reported MSK pain related to their occupation and 43.4 % were affected in more than 5 regions. String players and women were the most affected and pain was mostly allocated in the neck/cervical spine, followed by shoulders, wrists and lumbar spine. Recently, Stanek, Komes & Murdock (2017) also examined the prevalence of pain by means of an online survey which assessed its prevalence, anatomical locations and management in 996 music students. Their results showed that more than 60% of students suffered from performance-related pain which 37% felt both during and after playing. Women were the most affected, as were woodwind instrumentalist and singers. Across groups, pain was mostly located in the upper and lower back and affected the ability to play of 75% of the surveyed musicians; less than 25% looked for professional help.

2.4.2 Musicians' treatment preferences and needs. Although there has been an important growth in the field of musicians' health, there is still limited information in regard to how to treat them properly (Zaza, 1997; Wood, 2014). According to some authors there is a lack of individualised treatments (Chan & Ackermann, 2014; Lederman, 2003) that understand and effectively treat the consequences of the demands put on the musician's neuro-musculoskeletal system as a result of their activity (Lederman, 2003). In this regard, a study performed by Ioannou and Altenmüller (2015) studied the treatment preferences of 108 music students by collecting information on their attitude towards their medical problems and how teachers react to students' playing related problems, among other parameters and discovered that students tended to seek help from their teachers first (48.4%) before going to a health professional, whilst 35% did not seek help at all. Interestingly, 28.2% students who visited the doctor considered that it fully helped them solve their problems, 64.1% said it helped them partially and 7.7% stated that the doctor was unable to help them. Of all the

students who experienced playing related problems 25.3% continued playing while experiencing pain “very often,” 49.4% “sometimes,” 16.5% “rarely,” and only 8.9 % “never.” The most frequent reaction of teachers towards health issues reported by students was “you occasionally have to take some time off” (44.6%), “it’s nothing serious, it happens” (33.1%), and “I believe that your bad technique is the main reason” (25.7%); nevertheless, 76.1% of musicians reported that their tutors tended to remind them the importance of having a healthy body. Similar aims were of the interest of Guptill, Zaza & Paul (2005) which examined the treatment preferences of 53 injured music students by surveying them with the open question: “What would you want from a health professional who might treat you for musicians’ injuries?”. Results showed that almost the entire sample (94.3%) had experienced physical problems related to their instrument; of which 69.8% consulted with a health professional and 39.6% received treatment from a health professional. Students’ responses to the open-ended question gave rise to six themes: (1) Stress, which made reference to the physical and emotional stress that students reported as common in the music environment: (2) Minimal Interference With Playing theme showed students’ desire for treatments that do not obstruct their playing routine and the necessity of health professionals that understand their essentials as performers; (3) Active Involvement in Treatments theme, revealed the students’ request to actively participate in their treatment and the need for an accurate diagnose of their problem, expressed as “find out what exactly is the problem so I can fix it”; (4) Sympathy, Compassion, and Understanding theme, revealed that musicians would like their potential health professional to be empathic to their situation as music students ; (5) Arms and Back revealed student’s complaints about upper extremity and back discomfort and their desire to finding a professional that would help them find a solution; and lastly (6) the Need for Professionals with Specialized Knowledge theme, indicated that specialised knowledge of the musical

environment and the occupation of being a musician was something that they would appreciate health professionals who might treat their injuries. Particularly a student stated that “sports therapists have knowledge of what affects athletes. The same should apply for musicians”.

2.4.3 Summary of musicians’ health problems. As suggested by the literature, musicians can suffer from different medical problems; however, neuro-musculoskeletal disorders (NMD) seem to have the highest prevalence. Within this category, pain was the most reported symptom in the totality of the reviewed studies; although intensity levels went from mild (Pak et al., 2001; Zaza, 1992) to severe (Fishbein et al., 1988; Kreutz et al., 2008) and was mostly allocated in the neck and shoulders among the general population of musicians (Fishbein et al., 1988; Fotiadis et al, 2013; Rodriguez-Romero, 2016; Steinmetz et al., 2015); on hands, fingers and wrists among pianist (Allsop et al., 2010; Furuya et al., 2006; Pak et al., 2001; Shields et al., 1999) and in the neck, shoulders and wrist among violinists (Ajidahun et al., 2017; Kochem et al., 2017; Lahme, Eibl & Reichl, 2014). A significant number of performers reported that the presence of pain had an adverse effect on their performances (Kreutz et al., 2008; Kochem et al., 2017; Lonsdale et al, 2016; Rodriguez-Romero et al., 2016) and in regards to what musicians did to address this pain, a great number rely on self-medication, others in rest and a small; yet relevant percentage, stopped playing as a way to calm the pain (Fishbein, 1988; Lonsdale et al, 2016).

CHAPTER 3: RESEARCH QUESTIONS

According to several epidemiological findings, musculoskeletal pain has high prevalence among musicians. Since a number of studies suggest the effectiveness of the global postural re-education method on this type of disorders and pain, it is reasonable to consider that this approach could be a reliable treatment for musicians suffering from pain or discomfort with biomechanical origins. Furthermore, no studies have been found that treat musicians using the Global Postural Re-Education method under any context. In addition, due to the presence of studies suggesting that infrared thermography can monitor and detect physiological changes of the skin surface and that asymmetries between the left and right sides of a person's body can also indicate a pain disorder, the research questions for this thesis are:

1. Can infrared thermography in combination with our image analysis approach detect physiologic changes associated with pain in the targeted group of musicians?
2. Is there a difference in left-right temperature asymmetry between musicians (pianists and violinists) with nonspecific musculoskeletal pain and those without pain?
3. Can Global Postural Re-education be an effective approach for musicians suffering from nonspecific musculoskeletal pain:
 - a. As measured by changes in self-report pain, disability and quality of life surveys, scales and questionnaires?
 - b. As measured by left-right temperature asymmetries obtained with infrared imaging?
 - c. By correlating pain intensity values with the degree of thermal asymmetries?

CHAPTER 4: STUDY 1

Can we detect the presence of musculoskeletal pain on musicians by measuring their skin temperature asymmetries using infrared technology?

4.1 Introduction

Due to its characteristics as non-invasive, non-radiating, painless and fast testing time infrared thermography (IRT) has been used as a reliable diagnostic and monitoring tool in the field of medicine since more than 60 years ago. Medical infrared thermography was first used to detect cancer (Lawson, 1956) and progressively spread into the diagnosis and assessment of diabetic neuropathies, disc herniation (Kim et al., 1995); rheumatic diseases (Snehalatha, Anburajan, Sowmiya & Venkatraman, 2012), dental diagnosis (Gratt, Shetty, Dent, Saiar & Sickles, 1995; Sikdar, Khandelwal, Ghom, Diwan & Debta, 2010); and pain (Michales, 2005; Herry, 2002), among other health processes.

In many cases pain is a physiological response to the presence of a pathological event or a potentially harmful stimulus. It is also a highly subjective and personal symptom, which makes it difficult to evaluate (Herry, 2002). Due to its complexity and heterogeneity, musculoskeletal pain represents a challenge to health professionals when trying to find a cause or measure its intensity. Infrared thermography does not provide a picture of the patients' pain but according to the literature, it can offer a more objective demonstration of the sympathetic skin thermal changes that suggest the existence of pain or injury (Bardhan, Bhowmik, Nath & Bhattacharjee, 2015; Michaels, 2005; Nahm, 2013). The rise or drop of temperature in a skin area or abnormal temperature zones might suggest the presence of a pathophysiologic process or pain (Uetmatsu, 1988; Vaviov, Vaviova & Popov, 2001).

Although today there is a greater understanding of the consequences that a musical occupation can have on the health of performers, there is still scarce information about how

to assess them properly (Wood, 2014; Zaza & Farewell, 1997). According to a large number of epidemiological studies neuro-musculoskeletal disorders are the most reported problems (Allsop, & Ackland, 2010; Rodríguez-Romero, Pérez-Valiño, Ageitos-Alonso, Pérttega-Díaz, 2016; Fotiadis, Fotiadou, Kokaridas & Mylonas, 2013; Furuya, Nakahara, Aoki & Kinoshita, 2006; Lederman, 2003; Steinmetz, Zeh, Delank & Peroz, 2015) with pain and disability as the most reported symptoms (Fishbein, Middlestadt, Ottai, Straus & Ellis, 1988; Kreutz & Ginsborg, 2008; Pak & Chesky, 2001). Although some IRT studies used musicians as their population (Clemente, Coimbra & Silva, 2011; Herry, Frize, Giubran & Comeau, 2005; Lourenço, Clemente, Coimbra & Silva, 2011; Mohamed, Frize & Comeau, 2011) literature on the examination of musculoskeletal pain in the targeted group is still limited. Therefore, the purpose of this study was to evaluate the temperature of the back (from the cervical to the lumbosacral region) using a thermography technique in musicians with and without pain and determining the reliability of results by comparing the temperature asymmetries between groups.

4.2 Research questions

Based on the review of the literature, infrared thermography seems to be a reliable tool for the identification of temperature abnormalities as a consequence of an injury or disease. However, the effectiveness of the method in recognizing the physiological changes of the skin surface related to the presence of pain with unknown origin remains uncertain as results varied across studies. Additionally, because of the difficulty of objectively assessing musculoskeletal pain in musicians and due to the assumption that temperature asymmetries between a left and right sides of a person's body can also indicate a pain disorder, the research questions for this study are:

1. Can infrared thermography in combination with our image analysis approach detect physiologic changes associated with pain in the targeted group of musicians?
2. Is there a difference in left-right temperature asymmetry between musicians with musculoskeletal pain and those without pain?

4.3 Methods

The purpose of this study was to corroborate what is suggested by the literature: that a certain level of thermal asymmetries between body hemispheres can indicate the physiological changes associated with pain (Uematsu, 1986). This was done by designing an image analysis approach that examined the skin temperature of the back (Cervical/shoulders, dorsal and lumbosacral area) of a selected group of musicians. The thermal asymmetries between the right and left sides of the body were compared between healthy and non-healthy participants, and further analysis were done using a variety of statistical tests. Data collection was done with the approval of the Ethics Committee of the University of Ottawa.

4.3.1 Participants

Twenty-four (24) participants between 18 and 30 years old with (N=12) and without (N=12) musculoskeletal pain were recruited for this phase. The participants' main instruments were piano, violin or viola and they all had a minimum of grade of 8 from the Royal Conservatory of Music (RCM) or that were enrolled at a postsecondary music institution or had previously studied at such at a level. Participants suffering from ongoing acute or chronic musculoskeletal pain, neurological damage signs, neoplasms processes, infections, recent spinal surgery, recent physical trauma, acute illness, psychiatric illness, diabetic diseases, cardiovascular diseases or disorders, pregnancy or subjects that were being treated with steroidal or anti-inflammatory drugs were excluded. Volunteer recruitment was

made by poster advertisement, email, and by personally asking musicians in the city of Ottawa.

4.3.2 Scales and questionnaires

After obtaining a written informed consent (Appendix B) from all the participants, demographic data was collected using a specially designed questionnaire (Appendix C) that collected personal information, musical background, occupation, pain history and current pain to guarantee that musicians fulfilled our inclusion criteria. The pain section included a body diagram extracted from The Musculoskeletal Pain Intensity and Interference Questionnaire for Musicians (MPIIQM) (Berque, Gray, McFadyen, 2014) which asked participants to shade the areas where they were feeling pain. A 10cm horizontal Visual Analog Scale (VAS) was also part of the questionnaire and was used to measure pain intensity (Huskinsson, 1974; Sriwatanakul, Lasagna, 1983). Participants with pain were asked to fill the original version of the MPIIQM and underwent a physical examination to corroborate and deepen into their reported pain.

4.3.3 Infrared Thermography

All participants underwent a one-session thermal assessment which recorded the skin temperature of their backs (Cervical/shoulders, dorsal and lumbosacral areas) with the purpose of documenting the possible asymmetries between opposite sides of the body and compare these asymmetries with the group with pain.

4.3.3.1 Camera. A FLIR E8 Infrared Thermal Imaging Camera was used to record the thermal data. This equipment has a thermal sensitivity of 0.06°C, an image resolution of 320 x 240 pixels and a temperature thermal range from -20 to 250°C. The emissivity level was set to 0.98 (human skin).

4.3.3.2 Room. . In order to obtain reliable results, the infrared thermography technique demands certain parameters to be fulfilled in regards to the room temperature, humidity and airflow. Therefore, pre-defined protocols were followed. Thermograms were taken in a laboratory where ambient temperature was controlled and kept at 22.2 °C (Ring & Ammer, 2000), with a humidity of 40-45 % (Uematsu, 1988), free from direct air draft and exposure to ultraviolet rays (e.g the sun) and lighted with fluorescent lights (Schwartz, Elliott, Goldberg, Govindan, Conwell & Hoekstr, 2006)

4.3.3.3 Participants. Volunteers received detailed instructions (Appendix D) that they had to follow for a few days and a few hours prior to the assessment. These instructions were gathered from recognized thermography guidelines (Ammer, 2008; Ring & Ammer, 2000, Schwartz et al., 2006). Measurements were taken during the morning either at 8, 9 or 10 am and all assessments were performed at the same time for each participant to avoid circadian rhythm variations (Jones, 1998; Sund-Levander & Grodzinsk, 2009).

4.3.3.4 Image station. An image station was set-up to follow the suggested standards for medical thermographic experiments (Figure 1). Two wood panels were covered with a blue matte fabric to avoid reflective radiation (Costello et al., 2012) and were used as background when taking the images. The same fabric covered a podium positioned in front of participants for them to rest their arms and a tape rectangle was draw on the floor to indicate where participants should stand. The camera was placed on a tripod and positioned perpendicular to the region of interested at distance of 1.6 meters approximately (Ammer, 2008; Bach, Stewart, Minett & Costello, 2015; Lahiri, Bagavathiappan, Jayakumar & Philip, 2012; Ring, 2000).

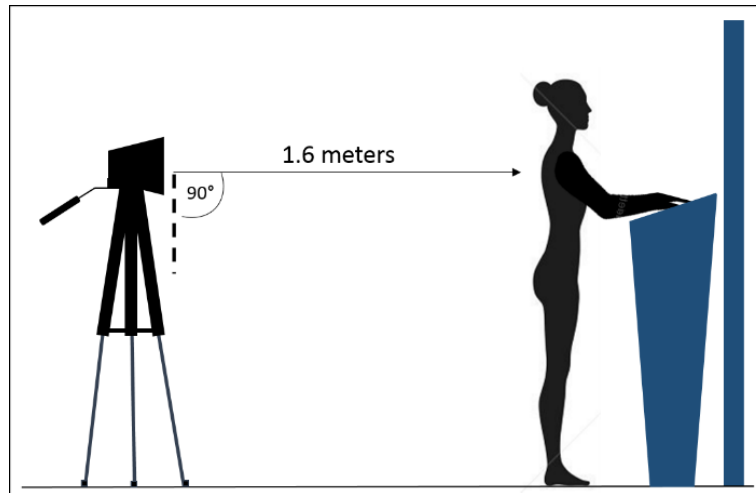


Figure 1. Image station set-up. The camera was positioned perpendicularly and at 1.60 meters away from the participant. The background consisted of two wooden panel covered with a non-reflective blue fabric and a podium where participants could rest their arms.

4.3.4 Experimental protocol

On arrival at the laboratory, participants were asked to remove their clothes above the waist. Women were provided with a loose paper robe that only covered their front. Afterwards, 4 reflective markers were positioned in C3, CD1, L1, L5. This type of markers are made with Styrofoam, are covered with reflective tape and have a plastic base which makes it easier to place them on a surface. These were used because of their thermal characteristic (previously tested on a pilot) which enabled us to identify them when analysing the thermograms. Participants were then instructed to sit on a bench with no back support, feet on the ground and hands resting on the thighs and to watch a video (TED talk) on a screen positioned in front of them. The video was of common interest and lasted approximately 15 minutes; enough so participants could acclimatize to the room temperature. The camera was also turned on at the same time to get it stabilized (Park et al., 2007; Ring, 2000). After, musicians were asked to stand in the photo station in a relaxed position, remove the robe, rest their arms on a podium positioned in front of them and look straight, then the

first photo was taken (T1). Next, they were asked to play scales, arpeggios and chords for 12 minutes which were tailored to each instrument type and were an adaptation of a previous study (Slade, Comeau, & Russell, 2018) (Appendix E) and afterwards, a second photo was taken (T2). Finally they were asked to sit on the bench again and watch another video (15min) following the instructions mentioned above and then stand in the station for one final photo (T3).

4.3.5 Image Analysis

Image analysis started with a raw thermal image. Pictures were extracted from the infrared camera using the FLIR Tools Thermal Analysis and Reporting Software and then analyzed using MATLAB[®] software (Matrix Laboratory) developed by MathWorks.

The first step was to segment the images to only consider data corresponding to the body and exclude the background. This segmentation process for most studies is a challenging process. In our case, we decided to select a temperature threshold based on trial and error of 28° Celsius. All areas with a temperature less than the threshold temperature were excluded from analysis (Figure 2a). In order to be certain that a certain an edge effect did not influence the analysis, all pixels within 5 pixels of the background temperature were excluded (Figure 2b and c).

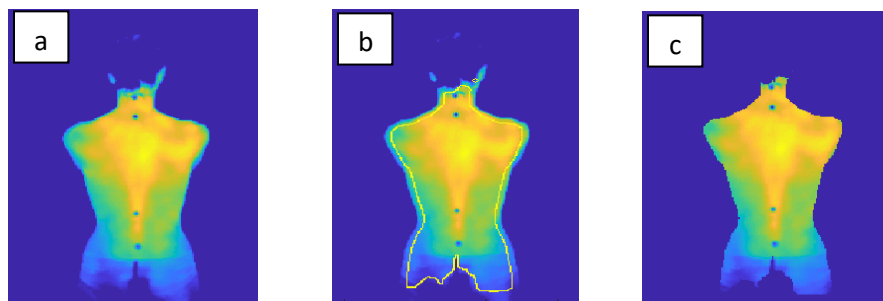


Figure 2 (a) All temperatures less than the threshold temperature has been indicated with a dark blue colour. Figure (b) shows the definition of an edge 5 pixels in from the background, and (c) shows the remaining area to analyze

In our study, the regions of interest (ROIs) were defined by using 4 markers (Filho et al, 2012) positioned on 4 specific spinal vertebrae: third cervical (C3), first thoracic (D1), first and fifth lumbar (L1 and L5 respectively). The location of the markers was manually identified on the images. Based on their location, we then selected a region of the centre of the body (middle line) to distinguish left from right and moved two pixels left and two pixels right of the markers' coordinate (Figure 3a). This portion was not included in the analysis, because we wanted to be sure that the colder temperature from the markers were not included in the analysis. The initial regions resulting from the identification of all markers, were then divided the central region was divided into four parts while the top and bottom regions were divided into two parts, resulting in 16 rectangles or regions of interest (8 on each side). Lastly, we computed the mean temperature of each region and its counterpart along with the difference between those two and inserted this values as text (Figure 3b).

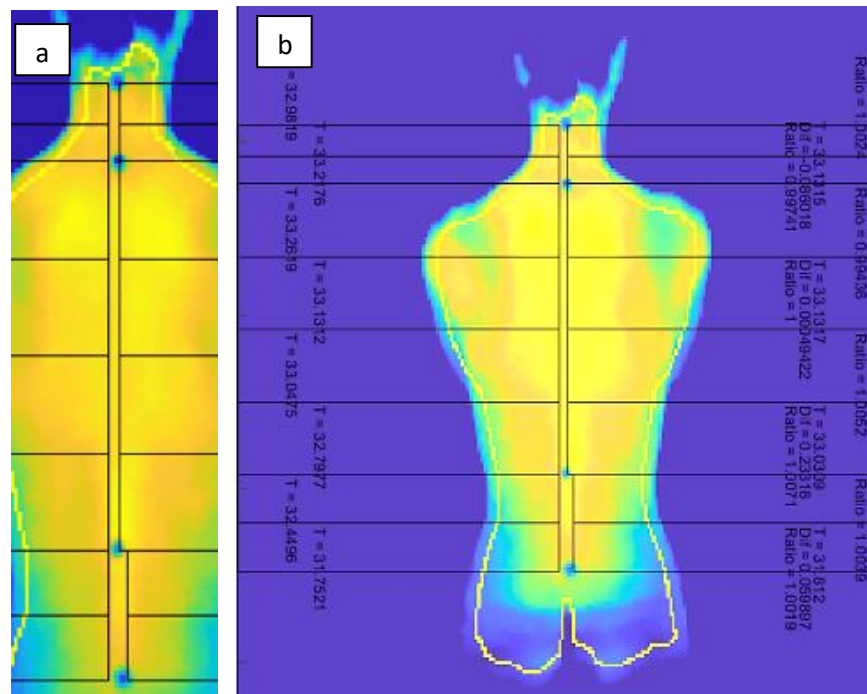


Figure 3. Allocation of the middle line (a). Final 16 ROIs with the respective temperature and asymmetry values.

4.3.6 Statistical Analysis

Asymmetry. The mean, median, standard deviation and minimum and maximum temperature values were obtained for each region of interest of healthy and non-healthy participants. Thermal asymmetry was calculated by taking the mean temperature of the left and right sides (of each region) and then subtracting one from the other. Our data were tested for normality using the Shapiro-Wilk test which rejected the null hypothesis ($p < .05$), meaning that our data was not normally distributed. Therefore, we use the non-parametric Mann Whitney U test to determine if there were statistically significant differences in average asymmetry between healthy and non-healthy participants.

In addition to the results obtained with the MATLAB-based examination, we decided to deepen the analysis and ask two evaluators to visually analyze the images and use a Likert scale to quantify the degree of asymmetry from 1 very symmetrical, to 5 very asymmetrical (Figure 4). Raters were asked to draw an imaginary line crossing all 4 markers and then compare one side to the other. To make this assessment, examiners were asked to look at the color patterns and considered not only the blue areas (colder) but also the yellow areas (warmer) and the brightness of the yellow areas (warmest). The purpose of this was to determine if the evaluators would see something similar to the results obtained with MATLAB; in other words, if the results of the evaluators would show similar levels of asymmetry. To check for normality, linearity and homoscedasticity of the data we performed a scatterplot to ensure there was no violation of assumptions and then we tested the strength of the relationship between both variables (Likert scale vs asymmetry values) and consistency with the rater's scores using the Pearson's Correlation test. As a second method to compare these two variables, an independent-sample T-test was conducted to compare the

Likert scores and asymmetry levels of healthy versus non-healthy participants; a similar comparison was performed with the asymmetry values from MATLAB.

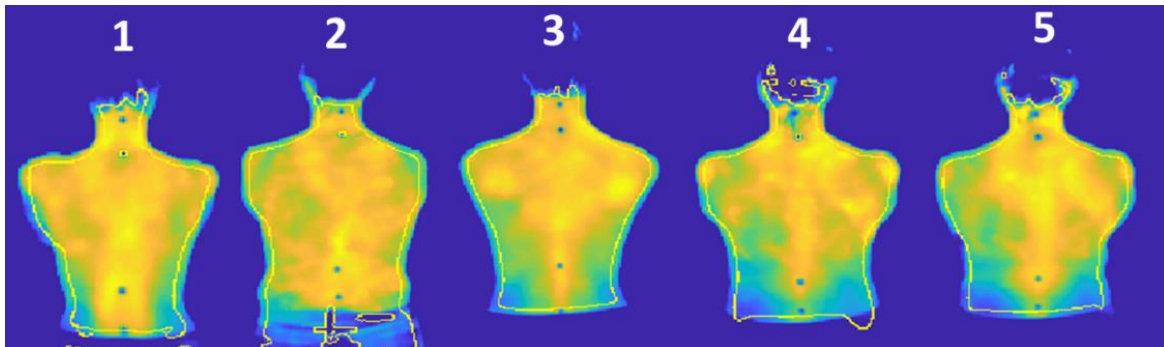


Figure 4. Examples used as a reference for the Likert scale going from 1 (very symmetrical) to 5 (very asymmetrical). The blue represents colder areas, the yellow warmer areas and the brightness of the yellow are the warmest areas. The average asymmetry values for these images going from 1 to 5 are as follow 0.07°C, 0.17°C, 0.26°C, 0.30°C, 0.33°C.

Cut-off value. According to the literature; skin temperature asymmetry above a certain level is a strong indicator of an abnormality (Uematsu, 1986; Goodman, Murphy, Siltanen, Kelley, Rucker, 1986). Thus, this study assessed the impact of choosing different cut-off values going from 0.20°C based on previous studies (Uematsu, 1986) and increase it by 0.10°C increments up to 0.70 °C. This limit was chosen based on the measured data (See below). The number of significant asymmetries across groups (healthy versus non-healthy) and the probabilities of those results happening for either group were compared using a binomial test.

Relation between pain and temperature of non-healthy participants. According to their answers on the MPIIQM and physical examination, participants' pain was manually allocated on a side (right or left) and in one or more of the 8 zones. For example, if a participant had pain in the neck with a prevalence on the right side, their pain was assigned to zone 1 and 2 on the left side. The purpose of this was to examine whether the side with pain would show a temperature tendency when compared with the opposite side. A binomial

test was conducted to check the proportion of these results happening. Secondly, a correlation between the pain intensity scores obtained with the VAS and the asymmetry values obtained for the same areas was studied. If the pain occupied more than one zone, we obtained the average value of the pertinent zones. A Pearson correlation test was performed to obtain these results.

4.4 Results

Statistical analysis was performed with the Statistical Package for the Social Science (SPSS). A total of 72 images of the cervical/shoulders, dorsal and lumbosacral were recorded from 24 subjects (3 for each participant). Demographic data are presented in Table 1.

Table 1

Demographic data for participants in the healthy and non-healthy group

Demographic variables	Healthy group	Non-healthy group
Number of participants	12	12
Age years (Mean $\pm$ SD)	23.58 $\pm$ 3.74	25.9 $\pm$ 2.9
Males/Female	4/8	2/10
Instrument		
Piano/strings	10/2	7/5

Asymmetry

A Mann-Whitney U test was used to determine if there were differences in the average temperature asymmetry values of all 8 regions where non-healthy participants reported pain, against the same regions of the healthy group at 3 different times (T1 after acclimatization period; T2 after playing; T3 after 15 from playing). This revealed no significant differences as shown in Table 2. a. There were 16 incidences in which the non-healthy participants' asymmetry was higher, compared to 8 incidences in the healthy group.

However, when comparing only the zones where the pain was reported against the same zones of the healthy group, results showed more incidences of higher levels of asymmetry in the healthy group (10 non-healthy versus 13 healthy) (Figure 5 and 6).

Table 2

Average asymmetry differences between healthy and non-healthy

Time Period	Participant Type	Mean (°C)	Median (°C)	SD (°C)	<i>U</i>	<i>z</i>	<i>p</i>	<i>r</i>
T1	Healthy	0.16	0.13	0.13	1591	-1.15	0.25	0.10
	Non-healthy	0.14	0.10	0.14				
T2	Healthy	0.20	0.16	0.16	1645	-0.88	0.38	0.08
	Non-healthy	0.22	0.19	0.15				
T3	Healthy	0.21	0.21	0.17	1776	-0.24	0.81	0.02
	Non-healthy	0.20	0.17	0.16				

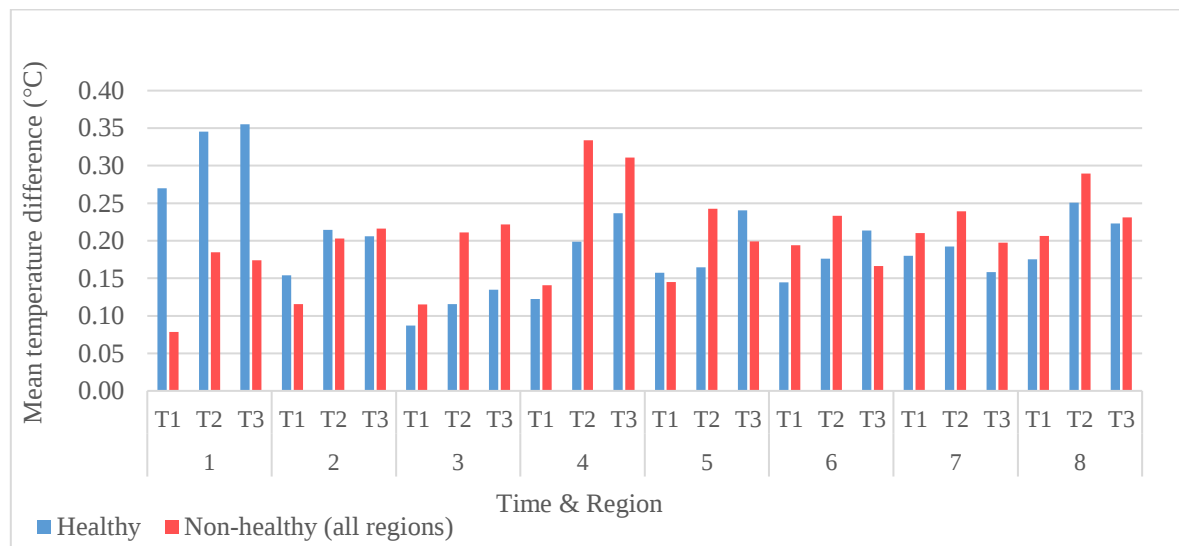


Figure 5. Comparison of asymmetry levels between healthy and non-healthy participants (all regions)

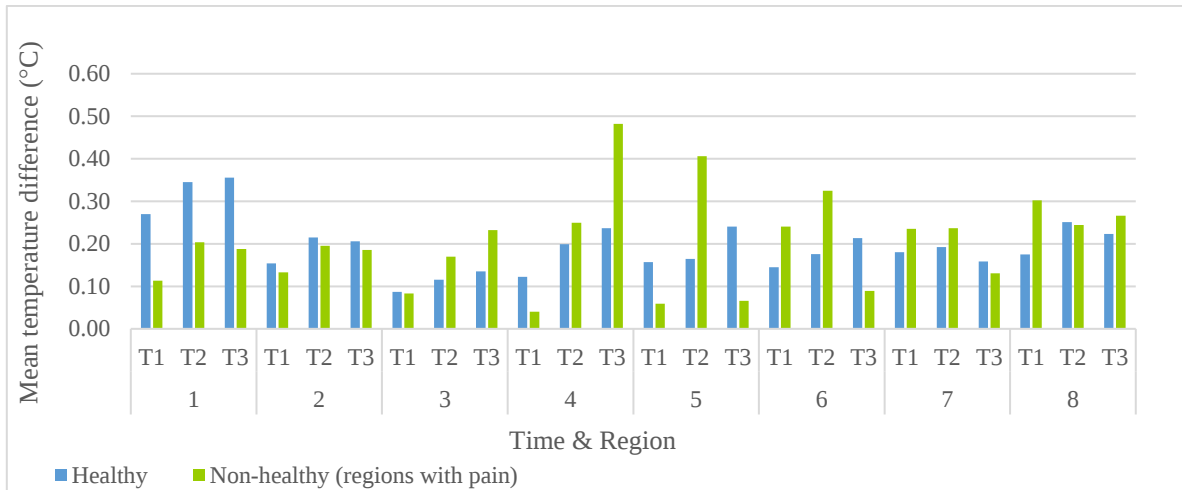


Figure 6. Comparison of asymmetry levels between healthy and non-healthy participants (regions with pain)

A Pearson's correlation test was performed to determine the strength of the relationship between the visual assessment of asymmetries performed by each rater (R1 and R2) and the results obtained with the MATLAB code. Scatter plots showed a linear relationship with both variables being normally distributed for both raters. There was a moderate positive correlation between the results obtained by both raters and our code (R1, $r=0.42$, $n=27$, $p=0.03$; R2, $r=0.40$, $n=27$, $p=0.03$). An independent sample T-test was conducted to examine if there was a difference between the means of the values obtained by the rater and by the code. There were no significant differences in scores for healthy (R1, $M=2.42$, $SD=0.79$; R2, $M=2.92$, $SD=0.67$) and non-heathy (R1, $M= 2.92$, $SD= 1.62$; $t(22)=0.96$, $p = 0.35$; R2, ($M= 2.58$, $SD= 0.9$; $t(22)=-1.030$, $p = 0.31$ two-tailed). The magnitude of the differences in the means (mean difference = 0.5, 95% CI: R1 -0.6 to 1.60; R2 -1.0 to 0.34) was very small.

Cut-off value

Assessment of the impact using different cut-off went from 0.20 °C to 0.70 °C because when reaching this value results showed no asymmetries (only 1 participant exhibited this level). The binomial test showed no statistical significance when comparing the number of incidences between the healthy and non-healthy group (Table 3).

Table 3

Impact of different cut-off values on the presence left-right temperature asymmetries.

Cut-off value	Healthy	Pain	<i>p</i>
0.20	39	43	0.74
0.30	23	24	1.00
0.40	10	14	0.42
0.50	7	5	0.77
0.60	3	1	0.63
0.70	0	1	

Relation between pain and temperature of non-healthy participants

Initial inspection of the data showed that the side with pain was colder than the opposite side. Only in 10 cases the side with greater temperature corresponded with the pain location, against 23 cases where the opposite happened (If a participant had pain in three zones we counted each zone as a separate case for a total of 33 cases). Three cases were excluded because participants reported pain on both sides of the body (on different areas). A binomial test indicated that these results were statistically significant ($p = 0.03$). A Pearson coefficient was computed to assess the relationship between the pain intensity scores obtained with the VAS and the asymmetry values obtained with the code. Outcomes revealed no association between the two variables $r = 0.085$, $n = 12$, $p = 0.793$. The VAS and asymmetry values did not have a statistically significant linear relationship ($p > .05$). A scatterplot summarizes the results (Figure 7).

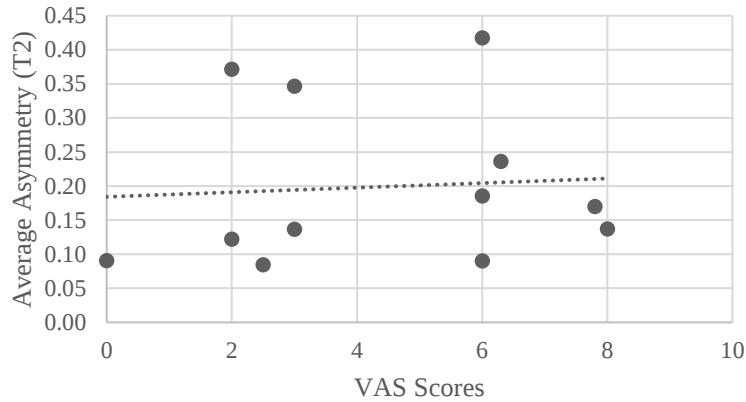


Figure 7. Scatter plot correlation between VAS and average asymmetry values at T2.

4.5 Discussion

According to our findings, participants with pain showed more cases of left-versus-right-side average asymmetries compared to the healthy group, however, these results were not statistically significant. These outcomes agree with the ones found by Filho (Filho et al., 2012) which used thermography to analyse the upper trapezius muscle temperature in women with and without neck pain but found no significant difference between the groups regarding the absolute temperature values of the upper left and right trapezius muscles, nor with comparisons of temperature asymmetries. Results are also in agreement with Filho and colleagues (Filho, Parker, Costa & Rodrigues-Bigaton, 2013) who assessed the accuracy of IRT in diagnosing myogenic temporomandibular disorders by assessing a central point in the masseter and anterior temporalis muscles of healthy and symptomatic patients. Thermography was unable to provide accurate information for diagnosis. In another study, IRT was also not able to relate thermal changes with the presence of pain (Rodrigues-Bigaton et al., 2013). Conversely, Mohamed and others (Mohamed et al., 2011) compared the differences in upper extremity temperature of pianists with and without pain and found that

symptomatic musicians showed higher temperatures in their hands compared to the healthy group. These results were statistically significant. Lourenço and group (Lourenço, Clemente, Coimbra, Silva, Gabriel & Pinho, 2011) were also able to identify inter-side asymmetrical heat patterns on pianist suffering from pain in the trapezius muscle compared to the healthier. However, this study was methodologically weak and results lacked statistical significance.

When comparing only the areas where participants reported pain with the same areas in healthy volunteers, inverse results were observed across groups, where the non-healthy musicians showed cooler temperatures than the corresponding contralateral region of the healthy ones. This type of inverse correlation was also found by Rossignoli and colleagues (Rossignoli et al., 2016) who observed that the higher the pain was, the lower the thermal asymmetry.

Additionally, the symptomatic sides, without distinction of any of the 8 specific regions of interest, was in most cases the side with the lowest temperature. These results are consistent with what is found in the literature, which suggests that the points of local pain do not always represent the point with the highest temperature or asymmetry when compared with its counterpart (Pogrel, McNeill & Kim, 1996; Haddad et al, 2012). In addition to this, since the skin temperature is a function of blood flow controlled by the autonomic nervous system, the presence of a trigger point frequently existing and responsible for musculoskeletal pain, can generate a constant sarcomeric contraction of the muscle fibre, and would be likely to compromise circulation producing local ischemia (reduced blood flow), thus reducing local muscle oxygenation and temperature (Haddad et al., 2012; Simons, 2004; Uematsu et al., 1988). Additionally, and as mentioned before, even without a presence of trigger points, a sustained contraction of a muscle, compromises blood supply and oxygen

supply to muscle tissue which according to Barret (Barret et al., 2006, p.170) can soon cause pain. The pain persists until blood flow is re-established.

Moreover, because musculoskeletal pain is a very subjective symptom, assumptions such as that the injury is unilateral, or that the pain is greater on one side rather than the other, which are based on the sensations reported by the patient, may not always be accurate. For example, a person may report feeling pain only on one side but the chance that he/she also has discomfort on the other side at a lower intensity, or that the tissue irritation/disorder is bilateral is possible, which would make the thermogram more symmetrical. In this regards, Pogrel and colleagues (Pogrel et al., 1996) used liquid crystal thermography to assess the temperature of trapezius muscle of patients with myofascial pain associated with temporomandibular disorders and were able to identify statistically significant right-versus-left temperature asymmetries between controls and patients as they showed higher asymmetry values on the symptomatic hemisphere. Ninety-five percent of the symptomatic group showed an increased temperature over the trapezius muscle, however assuming that these temperature asymmetry values could be used for the identification of myofascial symptoms as a reflection of an orofacial disorder seems too naïve, since they can also be the representation of other processes happening somewhere else in the stomatognathic system or spine.

These results are also in agreement with those of Haddad and colleagues (Haddad et al, 2012) who were interested in identifying and correlating myofascial trigger points in the masticatory muscles, using thermography and algometry. In their study, they were also able to identify the symptomatic hemisphere from the healthy one. However, when obtaining the average of the temperature of a complete muscle they observed symmetrical temperature

levels between hemispheres that they qualified as "false" since their image analysis was based on identifying targeted “hot spots” and no overall right-left asymmetry of larger segments as the current study. The same approach was adopted by other studies which also obtained similar results (Hakgüder et al., 2003; Filho et al., 2015).

Nevertheless, throughout the literature, there are a large number of studies which indeed found relevant differences between sides, however, most of the studies used IRT for the examination of temperature changes related to the presence of injuries or diseases and not musculoskeletal pain with unknown origin. Some of the studies the physiological thermal signs on rheumatoid diseases which cause inflammation and joint damage (Borojevic et al., 2011; Snekhalatha et al., 2012), neuropathies syndromes and radiculopathies (Kim and Cho, 1995, Tkacova, Foffova, Hudak, Svehlik & Zivcak, 2010; Uematsu, 1986; Zivcak et al., 2011), which cause changes in temperature due to responses from the peripheral or central nervous system, Complex Regional Pain Syndromes which causes a vasodilation among other symptoms (Friedman, 1994), and neoplastic processes which show a noticeable increase in blood flow (Head, Lipari, Wang, Davidson, Elliott, 1996; Lawson, 1956) among others. Pain with a more subjective nature such as those resulting from overuse or musculoskeletal origin were less studied and the results were less significant.

An important and determining factor in the variability of results seems to be the lack of standardized study protocols and the scarce studies with normal and abnormal skin temperature data (Chojnowski, 2017; Herry, 2008; Zaproudina et al., 2008). Image analysis differs across studies as well. Specifically for the delimitation of regions of interest, Uematsu (1986) manually selected the regions of interested based on the approximate distributions of dermatomes and compared the level of asymmetry between left and right sides to obtain

normal asymmetry values of healthy participants. Other studies also chose a manual selection of regions (Park, Hyun, Seo, 2007). Head, Wang, and Lipari (2000) used anatomical landmarks for the analysis of breast thermograms and possible diagnosis of breast cancer when comparing counterparts. Mabuchi (Mabuchi & Haeno, 1997) first divided the body into two symmetrical parts (left and right) and then further divided each segment into trapezoidal pairs and compare the counterparts, similar to the approach used by Goodman (Goodman et al., 1986). Geometric shapes were also used in other studies (Herry et al., 2005; Mohamed et al., 2011; Vaviov et al., 2001). Our novel method for the image analysis resembles the above mentioned (Goodman et al., 1986; Mabuchi et al., 1997) where a middle line was selected and then each hemisphere was divided into equal and coherent parts. In our code the selection of ROIs was done automatically and by taking into consideration the morphology of each participant and not by predetermining the ROI's which would compromise the image acquisition process (Barcelos, 2014). Analysis of temperature variations also differs across studies where some authors performed different statistical analysis methods of the skin temperature distribution (Hooshmand, 1997; Kim et al., 1995; Tkáčová, Foffová, Hudák & Švehlík, 2010), an image processing method (Herry, 2008; Lee et al., 2008; Vardasca, 2008) or a combination of both (Herry et al., 2002).

One of the purposes of this study was to examine whether the image analysis algorithm was able to identify the physiological thermal changes associated with pain. A secondary analysis was performed by two raters to qualitatively assess the data by examining the entire image and using a Likert scale to quantify the degree of asymmetry from 1 to 5. Both researchers found essentially the same results. Other studies also used similar scoring

indexes in an effort to further quantify findings (Head, Lipari & Elliot, 1998; Head et al., 1996; Keyserlingk, Ahlgren, & Belliveau, 1997).

Furthermore, despite following known procedures for collecting thermal images and providing detailed recommendations regarding participants' activities before the experimentation, we have limited control over individual and external factors that can certainly influence the measurements. Factors as sleep deprivation, chronotype (morning/evening type of person), depression, hormonal changes, BMI and emotions among others can potentially affect the body temperature (Kelly, 2007; Mcfarland, 1985).

4.6 Limitations

A limitation of this study is that since half of the participants reported mild to moderate pain it may be possible that the intensity of pain was not enough to generate major asymmetries in temperature. Additionally, individual factors such as the ones mentioned before and the level of uncertainty on whether participants follow the provided recommendations and the size of the sample might also be considered as limitations to this research.

In this study IRT was only used to examine the temperature changes of the back of 24 participants, future studies should extend the evaluation to other regions of the body as well as to study a larger sample. Additionally, to date, there are not enough studies that used infrared technology to examine musicians, even less that have assessed the thermal representation of musculoskeletal pain in this group. More studies could provide knowledge about how to better evaluate and understand this collective.

As mentioned above, there is a lack of standardized study protocols and databases with normal and abnormal skin temperature data (Herry et al, 2008; Zaproudina et al., 2008). Correlations between different pathophysiological processes and temperature findings could allow for a better understanding of a patient's health problems.

4.7 Conclusion

Based on our analysis, average asymmetry values between right and left sides of the back (from the cervical to the lumbosacral region) of pianists and violinists who reported musculoskeletal pain were not statistically significantly different when compared to healthy controls. Based on our analysis and obtained results we believe that finding changes in the level of temperature asymmetries as measured by infrared technology is not a reliable indication of the presence of musculoskeletal pain of uncertain origin.

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CHAPTER 5: STUDY 2

Assessment of the effects of Global Postural Re-education Method in Musicians with Nonspecific Musculoskeletal Pain: A randomized controlled trial

5.1 Introduction

Over the last decades, there has been increasing attention to medical problems affecting musicians. The consequences of factors such as intensive and prolonged practice, poor physical preparation, postural imbalances and faulty playing techniques seem to affect the health of many musicians as reported by several epidemiological studies. (Fishbein, Middlestadt, Ottai, Straus & Ellis, 1988; Furuya, Nakahara, Aoki & Kinoshita, 2006; Lonsdale & Boon, 2016). Neuro-musculoskeletal disorders (NMD) seem to have the highest prevalence with pain and disability as the most reported symptoms (Fishbein et al., 1988; Kreutz & Ginsborg, 2008). The presence of pain tends to have an adverse effect on the performance of these musicians (Kreutz & Ginsborg, 2008; Kochem & Silva, 2017; Lonsdale et al., 2016; Rodriguez-Romero, Pérez-Valiño, Ageitos-Alonso & Pérttega-Díaz, 2016) and a great number of performers rely on self-medication, others on rest, and a small yet relevant percentage stop playing as a way to calm their pain (Fishbein, 1988; Lonsdale et al, 2016).

Although important advancements have happened in the field of musicians' health, there is still limited information regarding proper treatment (Wood, 2014). According to some authors, there is a lack of individualized treatments (Chan & Ackermann, 2014; Lederman, 2003) that understand and effectively treat the consequences of the demands put on the musician's neuro-musculoskeletal system as a result of their activity (Lederman, 2003). Musicians' needs for a tailored treatment can potentially be answered by a method called Global Postural Re-education (GPR) which has proven to be an effective tool for the

treatment of postural disorder and symptoms with a mechanical origin, this is, symptoms that worsen with movement and improves with rest (Bonetti, Curti, Mattioli, Mugnai, Vanti, Violante & Pillastrini, 2010; De Amorim, Gracitelli, Marques & Dos Santos, 2014; Dimitroval & Rohleva 2014; Lawand, Lombardi, Jones, Sardim, Ribeiro & Natour, 2015; Oliveri, Caltagirone, Loriga, Pompa, Versace, Souchart & Philippe, 2012). The aim of the GPR method is to stretch tonic muscles (also known as postural muscles due to their function) using the properties of viscoelastic tissue and enhancing the contraction of the relative antagonist muscles (Oliveri., et al., 2012), while taking into consideration the neuromuscular chain to which they belong. As a method, GPR has its own way of evaluating and diagnosing the disorders that affect the neuro-musculoskeletal system, and with the use of its specific "treatment postures", along with a physiotherapist's manual adjustments, it manages to provide a tailored treatment and modify the situation (morphological and/or functional) identified as responsible of the problem.

In addition, due to its characteristics as non-invasive, non-radiating, painless and efficient testing time, infrared thermography (IRT) has been used as a reliable diagnostic and monitoring tool in the field of medicine for more than 60 years. According to the literature, several authors have used this tool to assess the degree of thermal asymmetries between corresponding parts (symptomatic versus asymptomatic, treated versus non-treated, etc.) and have correlated temperature results with pain severity as a way to assess the effects of a treatment technique and evaluate the success of a treatment procedure.

To our knowledge, no studies have been done using Global Postural Re-education on musicians. Therefore, this study aimed to evaluate the effects of GPR in musicians suffering

from nonspecific musculoskeletal pain by means of self-reported questionnaires and scales and infrared thermography.

5.2 Research questions

As seen in the literature, GPR is extensively used for the treatment of pain related to neuro-musculoskeletal disorders (Castagnoli et al., 2015; Cunha et al., 2008; De Amorim et al., 2015; Lawand et al., 2015; Monteiro, Da Gama, Dos Santos, Grecco, Neto & Oliveira, 2013; Pillastrini et al., 2016). According to the reviewed literature, this manual therapy method can provide statistically significant improvements in pain, disability and quality of life variables (among other parameters) which seem to be observable at follow-up evaluations (Bonetti et al., 2015; Castagnoli et al., 2015, Cunha et al., 2008; De Amorim et al., 2015). Additionally, infrared thermography has been widely used for monitoring the effects of different treatments on the sympathetic thermal responses of the body (Kim et al., 1995, Zaproudina et al., 2006) and for correlations between pain and temperature changes. The work of several authors indicates that IRT can provide reliable results when comparing these two variables.

Based on the fact that most musculoskeletal related pain is associated with mechanical disorders of the system (Blanco-Piñeiro, Pino Díaz-Pereira, & Martínez, 2017; Chaitow, 2001; Nyman, Wiktorin, Mulder & Johansson, 2007; Petty & Moore, 2001; Sahrman, 2013) it is reasonable to consider that the GPR method could be an effective tool for the treatment of nonspecific musculoskeletal pain in a group of musicians. Nonspecific pain is commonly defined “as tension, soreness and/or stiffness in a region for which it is not possible to identify a specific cause. Several structures, including the joints, discs and connective tissues, may

contribute to symptoms” (Haydock, Whitehead & Fritz, 2014, p.30). Additionally, Infrared thermography could be a reliable technique to measure the effects of GPR on skin temperature parameters and their association with pain. Therefore, the research question for this study is:

1. Can Global Postural Re-education be an effective approach for musicians suffering from nonspecific musculoskeletal pain:
 - a. As measured by changes in self-report pain, disability and quality of life surveys, scales and questionnaires?
 - b. As measured by left-right temperature asymmetries obtained with infrared imaging?
 - c. By correlating pain intensity values with the degree of thermal asymmetries?

5.3 Methods

This study was framed under a randomised control trial design, which is considered to be a reliable option when dealing with confounding factors and biases (Katz, 2006). Data collection was designed to assess the effects of the GPR method on pain intensity, disability and quality of life using a group of scales and questionnaires, by examining the degree of skin thermal asymmetries between body hemispheres (Cervical/shoulders, dorsal and lumbosacral areas); and by correlating pain and asymmetry variables. All three parameters were compared before and after the intervention. The sample was divided into an experimental and a control group where the former received the GPR intervention, and the latter received no treatment at all. The thermal assessment was used to evaluate whether the presumed asymmetrical heat patterns showed any change after the intervention and if they were associated with changes in pain. Questionnaires and scales examined pain, disability and quality of life variable before and after the intervention. Additionally, all participants

underwent a health history interview, a physical evaluation and a GPR characteristic examination. Data collection was done with the approval of the Ethics Committee of the University of Ottawa.

5.3.1 Participants

Thirteen (13) participants who reported musculoskeletal pain were recruited for this phase and were randomly divided into an experimental group (N=7) and a control group (N=6). Musicians in the experimental group received the GPR intervention and the control group received no treatment at all. Participants in the control group were invited to receive the treatment as soon as all initial measurements were taken (after 6 weeks). Three of the 6 participants in the control group agreed and therefore were included in the analysis as part of the experimental group.

5.3.2 Scales and questionnaires. After signing the consent form and the collection of demographic information, all participants completed several questionnaires and scales which assessed different aspects of quality of life, disability and pain. A 10cm horizontal Visual Analog Scale (VAS) with gradients was used to measure pain intensity prior to the treatment, and pain relief after (Appendix F). This scale consisted of a continuous line that usually goes from 0 (no pain) to 10cm (worst pain ever) of where participants selected the severity of the pain experience. According to Huskisson (1974), when estimating pain relief it is not appropriate to compare scores before and after treatment because the magnitude of this difference is limited by initial mark placement. Instead, he recommends using a rating of pain relief such that each respondent has the same range of potential response, regardless of initial pain level. Therefore, the VAS used after the treatment was anchored by “no relief” and “complete relief” (instead of “no pain” and “worst pain ever”). Validity and reliability of the VAS scale have been widely examined (Huskinsson, 1974; Sriwatanakul et al., 1983).

Section 3, 4 and 5 of the Musculoskeletal Pain Intensity and Interference Questionnaire for Musicians (MPIIQM) were used (Appendix G). Section 3 assessed the presence of playing-related musculoskeletal symptoms and its interference with their ability to play their instruments as they were used to during the last 12 months, 4 weeks and 7 days. Section 4 and 5 involved a body diagram on which subjects marked the location of their pain and 9 questions which measured the intensity of pain, the impact of pain on mood and quality of life and the impact of pain in their playing technique. The rest of the sections were not used because they collected additional demographic information. Some aspects of quality of life were examined through the Short-Form-36 Health Survey (SF-36) (Appendix H). Data were collected on site before the first GPR session, two days after the last session and two weeks after the end of the intervention. Follow-up assessments (2-weeks after) were only collected from participants in the experimental group.

5.3.3 Infrared thermography. Participants underwent three thermal assessment sessions which recorded the skin temperature of their backs (Cervical/shoulders, dorsal and lumbosacral areas), before the GPR intervention, 2 days after and 2 weeks after the last session. A FLIR E8 Infrared Thermal Imaging Camera was used to collect the thermal data and was equipped with a thermal sensitivity of 0.06°C , an image resolution of 320×240 pixels and a temperature thermal range from -20 to 250°C . Emissivity level was set to 0.98 (human skin). Experimental details have been presented previously (Mercado-Lozada, Comeau, Russell, Swirp, 2018, in preparation).

5.3.4 Physical Evaluation. Each musician underwent a clinical interview prior to the intervention to collect information on several health parameters such as: previous health issues or traumatic accidents, presence of other symptoms, daily activities, vision disorders, visceral or psychological problems, among others that could help identify conditions that

contributed to causing pain and could provide a general view of the musician overall health (Petty & Moore, 2011). Additionally, each participant went through a particular evaluation specific to the GPR method to select the appropriate manoeuvres and intentions for each one. This evaluation comprised an initial visual morphological evaluation, an interview that collected information about activities or postures that caused or made the pain worse, an examination of joint mobility, muscular retractions, and a re-equilibration section in which participants' morphological imbalances were momentarily corrected to observe possible compensations. These evaluations were done one day prior to the thermal examinations.

5.3.5 Intervention

Each participant in the experimental group underwent 8 GPR treatment sessions with a duration of 60 minutes that were provided twice a week across 4 weeks, each with a physiotherapist with 10 years of experience in the field and 5 years of experience in the GPR method. During the first 5 minutes of each session, a manual therapy manoeuvre was done to the diaphragm muscle which consisted of two steps: firstly, in applying firm and sliding pressure with the finger tips from of the xiphoidal process until the lower ribs on their inner side; and secondly, applying the same type of pressure across the abdominal area in radial lines directed to the belly button. These manoeuvres allow greater flexibility to the diaphragm in preparation for the stretching. Next, a few minutes were dedicated to instructing participants on the characteristic breathing used during Souchart's approach which consists in inhaling calmly through the nose and slowly exhaling through the mouth lowering the ribcage and extending (an inflating action) the abdominal muscles while keeping the shoulders and head close to the table (back). This breathing benefits the stretching of respiratory muscles. If possible, participants maintained this breathing across the entire session. Since this breathing is an important part of the method, more than 5 minutes of day

1 were devoted to this task or until they understood what they needed to do. Following the breathing practice, musicians were treated with two different postures: the supine posture with abducted arms and the bending-forward posture with flexion of the trunk ("Ballerina/skier posture") for 25-30 minutes each for a total of 55 minutes approximately.

The supine position (also called "frog on the ground") emphasizes the stretching of the anterior muscle chain and starts with participants lying on their backs with upper limbs abducted at approximately 30° (or according to their level of comfort) and supine forearms. The pelvis is arranged in retroversion with the help of the physiotherapist who performs an axial traction of the sacrum in the caudal direction to straighten and align the lumbar spine. Hips are flexed, abducted and externally rotated with feet soles together. After this initial position is reached, the therapist sits at the end of the table and performs a cephalic traction of the cervical region. This action along with the sacral traction will be repeated across the entire session in order to maintain an alignment of the spine in association with maximum articular decompression. The posture progresses to the extension of knees, diminution of the flexion and external rotation angles of the hips and the changing of feet from feet soles being together to a dorsal flexion with contact between both internal malleoli.

The bending-forward posture (also known as the "ballerina or skier posture"), is focused on stretching the posterior muscle chain. In the initial position the participant was standing with internal malleoli in contact, calcaneus together if possible and a forefoot separation of 15° approximately (it varies across participants since it depends on the current position of their calcaneus and whether they have a tendency to a valgus or varus position), knees in flexion (usually 25-30°), external rotation of hips and tibia, and forward flexion of the trunk until they felt a stretching sensation (typically on legs). Most participants rested

their elbows on the clinical table in front of them to reduce the load on the lower limbs, only two participants leaned on their hands. All of this is performed while keeping the occipital bone, the thoracic spine, and the sacrum aligned. During the stretching, the physiotherapist placed her hands on the occipital bone and the sacrum and performed intermittent passive traction action and alignment maneuvers across the spine; by doing a cephalic and caudal traction (respectively). The posture progresses to an accentuation of bending forward flexion with the extension of the knees (an increase of the coxo-femoral joint flexion). The posture was maintained for 3 minutes, repeated three times with a 2 minutes interval in between times.

To progress in the postures, the targeted muscles are gently and progressively stretched by asking the participant to actively contract them (muscles) against the physiotherapist hand (isometric contractions) for three seconds to induce post-isometric contraction and then an active contraction of the antagonist's muscles is required from the participant which holds the new "reached" position. Progression of the postures always adjusts to participants' limits instead of getting to the "final" stage of the postures. Constant attention is taken to avoid postural compensations due to a response to muscular tightness.

Verbal commands and manual contact have a key role during the session. The verbal commands keep the patient engaged and lets them know when and how to contract a specific muscle, reminds them not to lose a position and provides any other feedback needed in the process. Manual contact creates traction/decompression and realignment of targeted joints and segments with the purpose of effectively stretching muscles by taking into consideration all their lines of actions. Participants were allowed to take breaks when needed. If participants

could not reach the suggested initial position, they were positioned into the closest position where they felt comfortable.

Finally; participants executed an integration exercise during the last minutes which consisted in global movements designed to reproduce the desired 'normal' movement with the purpose of creating a new proprioceptive scheme (Souchart, 2012). Depending on the condition of the subjects, the sessions focused on different individualized issues. Every participant received all the session's components, however, the balance of each component depended on the needs of each person. The musicians were also prescribed home exercises of approximately 10 minutes, to do on the days they were not receiving the treatment. Those are based on the same treatment postures but do not require the manual assistance of a GPR practitioner. These postures are known in the method as self-postures or active postures (Souchart, 2012).

5.3.6 Image Analysis

Pictures were extracted from the infrared camera using the FLIR Tools Thermal Analysis and Reporting Software and then analyzed using MATLAB[®] software (Matrix Laboratory) developed by MathWorks. Details of the analysis are presented elsewhere (Mercado-Lozada et al., 2018).

5.3.7 Statistical Analysis

Questionnaires and scales. The non-parametric Wilcoxon Signed Rank test was used to compare the results from the MPIIQM, SF-36 and VAS before and after the intervention. Categorical data from the first two were analyzed using a Chi-square test for independence. Comparison of the VAS scores between the control and experimental participants was done using the Mann-Whitney U Test.

Asymmetry. The mean, median, standard deviation and minimum and maximum temperature values were obtained for each region of interest in both the experimental and control group before and after the treatment. Thermal asymmetry was calculated by taking the mean temperature of the left and right sides (of each region) and then subtracting one from the other. Pre-treatment and post-treatment results and post-and follow-up results within each group were analyzed with the Wilcoxon Signed Rank test. Since our data were not normally distributed as assessed with a Shapiro-Wilk test, we were unable to statistically compare the results between groups with a parametric test. Data will be presented in the next section and the results will be further explained.

Relationships between pain and temperature asymmetries. A Pearson correlation test was performed to correlate the presence of pain (VAS) on a specific area with the presence of inter-side thermal asymmetries. If the pain occupied more than one zone (according to the divisions used to analyze the thermograms), we obtained the average of the asymmetry values of the pertinent zones. Temperature asymmetries were correlated with three variables: the pre-treatment VAS, the post-treatment VAS (pain relief) and with the follow-up VAS scores.

5.4 Results

Statistical analysis was performed with Statistical Package for the Social Science (SPSS). Thermograms of the cervical/shoulders, dorsal and lumbosacral areas were recorded from 15 subjects (3 for each participant). Demographic data are presented in Table 4.

Table 4*Demographic data for participants in the control and experimental group*

Demographic variables	Experimental group	Control group
Number of participants	10	5
Age years (Mean $\pm$ SD)	22.9 $\pm$ 2.29	21.4 $\pm$ 1.94
Males/Female	2/8	1/4
Instrument		
Piano/strings	5/5	2/3

Questionnaires and scales

Results from the MPIIQM in the experimental group revealed statistically significant changes before and after the treatment when asked if current pain/problems (in the last 7 days) interfered with their ability to play their instruments at the level they are accustomed (P= 0.046). Additionally, the severity of pain and the impact of pain on mood and quality of life also improved after the GPR treatment for the experimental group and were maintained at the follow-up assessment (Table 5 and 6). These results were statistically relevant. On the other hand, no significant changes were observed in any of the examined parameters for the control group.

Table 5

Results from the MPIIQM. GPR group (pre compared to post)

Questions/pain	Mean	SD	Min	Max	Median	Z	p	r
Worst in the last week						-2.41	0.02	0.57
Pre	5.1	2.2	2	8	5.5			
Post	3.4	1.4	1	5	3.5			
Least in the last week						-2.07	0.04	0.49
Pre	1.6	1.3	0	4	2			
Post	0.8	1.4	0	4	0			
Average in the last week						-2.33	0.02	0.55
Pre	3.5	1.8	1	6	3.5			
Post	2.3	1.7	0	5	2			
Right now						-2.07	0.04	0.49
Pre	2.8	2.1	1	6	2			
Post	1.9	2.1	0	5	1			

Interfered with mood						-2.23	0.03	0.52
Pre	3.9	3	0	8	3.5			
Post	1.8	1.8	0	5	1			
Interfered with the enjoyment of life						-2.23	0.03	0.52
Pre	3.8	3	0	8	3.5			
Post	1.6	2.1	0	6	1			
Using usual technique						-2.21	0.03	0.52
Pre	3.4	2.9	0	8	4			
Post	1.5	1.7	0	4	1			
Playing your instrument						-2.14	0.03	0.50
Pre	3.8	2.4	0	7	4			
Post	2	1.9	0	5	1.5			
Playing as you would like						2.39	0.02	0.56
Pre	0.4	3	0	8	5			
Post	1.8	2.4	0	6	0.5			

Table 6

Results from the MPIIQM. GPR group (post compared to follow-up)

Questions/pain	Mean	SD	Min	Max	Median	Z	p	r
Worst in the last week						-0.09	0.93	0.02
Post	3.4	1.4	1	5	3.5			
Follow-up	3.4	2.2	0	7	3			
Least in the last week						0	1	0
Post	0.8	1.4	0	4	0			
Follow-up	0.8	1	0	3	0.5			
Average in the last week						-0.45	0.66	0.11
Post	2.3	1.7	0	5	2			
Follow-up	2.1	1.6	0	5	2			
Right now						-1	0.32	0.24
Post	1.9	2.1	0	5	1			
Follow-up	1.6	1.8	0	4	1			
Interfered with mood						-0.45	0.66	0.11
Post	1.8	1.8	0	5	1			
Follow-up	1.9	2	0	6	1.5			
Interfered with the enjoyment of life						-0.38	0.71	0.09
Post	1.6	2.1	0	6	1			
Follow-up	1.5	2.3	0	7	1			
Using usual technique						0	1	0
Post	1.5	1.7	0	4	1			
Follow-up	1.5	1.2	0	3	1.5			
Playing your instrument						-1	0.32	0.24
Post	2	1.9	0	5	1.5			
Follow-up	2.5	1.9	0	5	3			
Playing as you would like						-0.42	0.67	0.10
Post	1.8	2.4	0	6	0.5			
Follow-up	2.1	1.6	0	4	2.5			

Some aspects of quality of life were examined with the SF-36 questionnaire. When asked whether they had specific problems doing their work or regular daily activities as a result of their physical health, results were not statistically significant before and after the intervention for neither of the groups. However, there was a trend in the experimental group that showed an apparent improvement. Results from questions on their general health, their current health compared to 1 year ago, and the impact of their condition on their social life were also not statistically relevant. Nevertheless, significant results were obtained from the experimental group when asked about their degree of bodily pain ($p=0.02$) and their ability to perform normal work ($p=0.04$), both during the past 4 weeks, after the treatment and when compared to controls. Outcomes were maintained when examined two weeks after the end of the treatment (follow-up). In addition to this, the group who received the GPR intervention showed marginally significant results ($p=0.06$) when asked if they considered their health to be excellent at the post-treatment assessment.

The pain relief variable (after the treatment) was compared between groups and results are shown in Table 7. Table 8 reports the results of pain intensity from the experiment group (as measured by the VAS) comparing the pre-treatment and follow-up evaluations.

Table 7

Pain relief results obtained from VAS (Pre compared to follow-up)

Group	Mean	SD	Min	Max	Median	Z	p	r
Control	2.3	2.96	0	6.9	1	-2.22	0.03	0.59
GPR	6.2	2.70	0.7	9	7.9			

Table 8

Pain intensity results obtained from VAS (GPR group)

Time	Mean	SD	Min	Max	Median	Z	p	r
Pre	4.5	2.49	2	8	3	-2.49	0.01	0.59
Follow-up	2.6	2.30	0.2	6.4	2.5			

Asymmetry

Results from the control group showed that temperature asymmetries seemed to slightly decrease between the pre and post measurements. Outcomes from the experimental group revealed the opposite, meaning that average asymmetries values increased after receiving the intervention. No trends were observable at the follow-up examination when compared with the post-treatment results. However, these changes from both groups were not statistically significant according to the results obtained with the Wilcoxon Signed Rank Test (Table 9, 10, 11).

Table 9

Thermal asymmetries changes between pre and post evaluations within the control group

Time Period	Pre/Post Treatment	Mean	SD	Min	Max	Median	Z	p	r	N
T1	Pre	0.14	0.10	0.01	0.28	0.12	-0.41	0.68	0.13	5
	Post	0.14	0.09	0.05	0.26	0.13				5
T2	Pre	0.27	0.09	0.14	0.37	0.24	-0.27	0.79	0.09	5
	Post	0.22	0.08	0.17	0.36	0.20				5
T3	Pre	0.21	0.06	0.14	0.31	0.20	-0.27	0.79	0.09	5
	Post	0.20	0.08	0.13	0.34	0.18				5

Table 10

Thermal asymmetries changes between pre, post evaluations within the GPR group

Time Period	Pre/Post Treatment	Mean	SD	Min	Max	Median	Z	p	r	N
T1	Pre	0.10	0.06	0.03	0.21	0.08	-1.58	0.11	0.35	10
	Post	0.19	0.14	0.07	0.49	0.15				10
T2	Pre	0.22	0.12	0.09	0.42	0.19	-1.68	0.09	0.38	10
	Post	0.31	0.13	0.09	0.45	0.34				10
T3	Pre	0.20	0.10	0.08	0.37	0.18	-0.51	0.61	0.11	10
	Post	0.22	0.10	0.06	0.38	0.23				10

Table 11*Thermal asymmetry changes between the post and follow-up evaluations within the GPR group*

Time Period	Post/follow up Treatment	Mean	SD	Min	Max	Median	Z	p	r	N
T1	Post	0.19	0.14	0.07	0.49	0.15	-1.07	0.28	0.24	10
	Follow-up	0.21	0.10	0.07	0.34	0.18				10
T2	Post	0.31	0.13	0.09	0.45	0.34	-0.36	0.72	0.08	10
	Follow-up	0.28	0.16	0.04	0.54	0.29				10
T3	Post	0.22	0.10	0.06	0.38	0.23	-0.56	0.58	0.13	10
	Follow-up	0.20	0.14	0.03	0.44	0.16				10

Relationships between pain and temperature asymmetries

A Pearson coefficient was computed to assess the relationship between the pain intensity scores obtained with the VAS (Pre-VAS, relief-VAS and Follow-up-VAS) and the asymmetry values obtained with the MATLAB analysis. If participants had pain in more than one area, the pain scores were averaged. Outcomes revealed no association between asymmetry values and Pre-VAS scores ($r=0.085$, $n=12$, $p=0.79$). A small correlation was found with the relief-VAS scores ($r=0.26$, $n=12$, $p=0.40$), where the higher the relief, the higher the asymmetry value. A small negative correlation was observed between the follow-up-VAS and the asymmetry values ($r=-0.21$, $n=10$, $p=0.50$). However, none of these results were statistically relevant. Three scatterplots summarize the results (Figure 8).

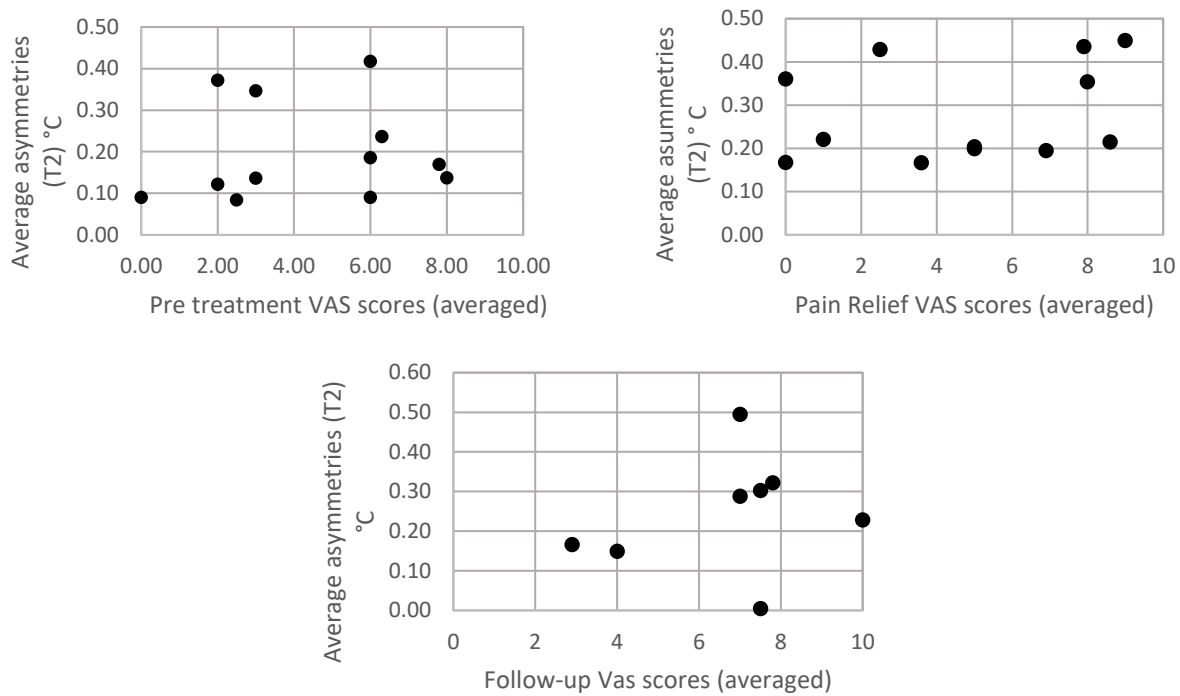


Figure 8. Scatter plots from correlations between pain intensity scores obtained with the VAS (Pre-VAS, relief-VAS and Follow-up-VAS) and the asymmetry values obtained with the MATLAB analysis.

5.5 Discussion

Our results obtained with the questionnaires and scales indicate that the GPR method was effective in alleviating pain, disability and some aspects of quality of life in the studied sample. According to the used methodological instruments, the GPR group revealed a significant reduction of most of the examined parameters. Furthermore, the follow-up evaluation revealed that all gains were maintained after two weeks of the end of the treatment. Participants in the control group did not show significant changes in the assessed variables when compared either within themselves or with the experimental group.

These results are in agreement with the ones found by Pilllastrini and group (Pilllastrini et al., 2016) in which a GPR intervention induced a better improvement on pain and disability in patients with persistent low back pain (LBP) as compared to controls. Jeon and Kim (2017) examined the effectiveness of 8 GPR sessions on 16 patients with neck and shoulder pain before and after the intervention and compared the results with the controls who received the segmental stretching intervention. Their results also showed that the GPR treatment induced greater improvement of pain and disability and quality of life and their outcomes were also maintained four weeks after In Cunha's study (Cunha et al., 2008) outcomes were similar for both the control and experimental group. In that study, the sample included participants with neck pain who were treated either with GPR or with conventional stretching, both in combination with manual therapy. Their outcomes showed that the two interventions were equally effective in improving pain, the range of motion and quality of life with a slight reduction at follow-up time. Similar results were obtained by Maluf and colleagues (Maluf et al., 2010) in their study to assess the effectiveness of GPR compared to segmental stretching in the treatment of myogenic temporomandibular disorders. Both groups showed equal improvements in pain intensity, increased pain thresholds and decrease electromyographic activity, however, the GPR group showed a reduction in the severity of headaches. Conventional physiotherapy and GPR were equally effective in the treatment of chronic LBP according to the study performed by Castagnoli and group (Castagnoli et al., 2015). However, a follow-up evaluation showed that improvements were maintained only for the GPR group. GPR improvements were kept at a follow-up evaluation.

A great number of studies have shown the effectiveness of the Global Postural Re-education methods not only in pain but in the treatment of isthmic spondylolisthesis

(Barroqueiro & Morais, 2014), temporomandibular disorders (Basso, Corrêa & Da Silva 2010), herniated disks (Di Ciacco, 2012), and at neurological gait and movement disorders (Agosti et al., 2016; De Amorim et al., 2014; Smania, Corato, Tinazzi, Montagnana, Fiaschi & Aglioli, 2003).

The poor understanding of muscle physiology, specifically the knowledge that static and dynamic muscles have different physiologies and therefore must be treated differently is a common error in conventional physiotherapy. For example, if we picture two children are on opposite ends of a seesaw, and one of the two weighs more than the other, it would seem absurd to ask the thin child to gain weight in order to balance the seesaw, when the obvious answer would be each that child approaches their optimal weight. If now, instead of two children we imagine the action that a muscle with an increase of tone (offensive) causes in its complementary antagonist (no muscle opposes entirely to other) and instead of a metal pivot, we imagine that two (or more) muscles are arranged as bridges over the joints (pivot), an increase in the muscle tone of the "weak" (increasing the weight of the thin) would cause an increase in joint compression, a possible narrowing of joint space, deviation of the segments, and pain (Souchart & Lorono, 2008). A clear example is the intention to strengthen the quadriceps muscle when the first step would be to tackle a clear shortening of the hamstring muscles. The effectiveness of the method lies in the understanding that each person has a unique way of responding to an injury or potential injury in combination with a clear understanding of the biomechanical processes that the body goes through before the injury or the pain. Additionally, the GPR method is based on widely known muscle physiology concepts that allow the professional to provide an effective treatment that is tailored to each structure (Bonetti et al., 2010; Souchart, 2012, p.70)

On the other hand, the degree of thermal asymmetries did not show statistically significant changes before and after the GPR intervention. Correlations between pain intensity (as assessed by VAS) and the degree of thermal asymmetries across neither of the groups or times (before and after the intervention, and two weeks after) were also not relevant. These findings agree with the results found by Park, Hyun and Seo (2007) in their study to evaluate patients with shoulder impingement syndrome using infrared thermography for the objective detection of shoulder pain and limitation among other variables. Their results were unable to correlate pain with infrared results, either with absolute temperature values or between the asymptomatic versus symptomatic temperature asymmetries. Rossignoli and colleagues (Rossignoli, Fernández-cuevas, Benito & Herrero, 2016) found significant inverse relationships between shoulder pain and skin thermal asymmetries implying that the higher the pain the lower the thermal asymmetry and vice versa. In our study the relief of pain of pain also associated with the presence of higher asymmetries, however, in our case the outcomes had no statistical relevance.

Unlike our study, however, findings from Wu and colleagues (Wu et al., 2009) did show a statistically significant correlation between pain scores and temperature values as they indicated a decrease in both pain intensity and temperature asymmetries. These findings were also true for Hakgüder and group (Hakgüder et al., 2003) and Lee (Lee et al., 2015).

IRT has been widely used to assess the effects on skin temperature as a response to different interventions. However, to our knowledge, no studies have used this instrument to examine the sympathetic thermal changes after the treatment of nonspecific musculoskeletal pain and more studies are needed to guarantee the robustness of results. Additionally, in another article associated with this study (Mercado-Lozada, Comeau, Russell & Swirp,

2018), IRT was unable to identify the presence of nonspecific musculoskeletal pain when comparing participants with and without this type of pain.

5.6 Limitations

This study had some limitations. Despite following established procedures for collecting thermal images and providing detailed recommendations regarding participants' activities before the experimentation, we had limited control over individual and external factors that can certainly influence the measurements. Factors as sleep deprivation, chronotype (morning/evening type of person), depression, hormonal changes, BMI and emotions among others can potentially affect the body temperature (Kelly, 2007; Mcfarland, 1985). The sample size and the inconsistency in participants' pain severity scores (from mild to severe) should also be considered as limitations to this studies. Additionally, the use of other approaches for the collection of additional empirical data was used in other studies to aid, validate and compare the data obtained with IRT (Hakguder et al., 2003; Kanai et al., 2011).

Secondly, the use of self-report questionnaires and scales, as this data can rarely be independently verified and there are potential sources of bias implied in these of type of methodological instrument. Moreover, future research should also compare the effectiveness of the GPR method with other therapeutic approaches.

5.7 Conclusion

Based on the findings of the present study, GPR proved to be an effective tool for the treatment of nonspecific musculoskeletal pain as well as in disability and some aspects of quality of life in a specific group of musicians according to the results obtained with questionnaires and scales. However, no relationship was found between pain and left-right asymmetry values either before or after the intervention nor between groups. No significant

changes were observed in the degree of thermal asymmetries after undergoing the GPR intervention.

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CHAPTER 6. GENERAL DISCUSSION AND CONCLUSION

6.1 Discussion

The overall results obtained from the first part of our study suggest that there are no statistically significant differences between healthy participants and those with musculoskeletal pain in terms of left-right skin thermal asymmetries. The algorithm developed using MATLAB proved to provide reliable results as confirmed by secondary analysis. In the second part of this thesis we examined the effectiveness of the Global Postural Re-education method by measuring its effects on pain, disability and quality of life using common questionnaires and scales and also by means of infrared thermography (IRT). Despite not finding differences between participants with and without pain, we decided to use this approach to assess the effects of the method since in this case we were evaluating participants under the same condition (with pain) and due to several studies which used this tool to examine the effects and/or success of different treatment methods. Details about the experimental protocol and research questions answered in this thesis are presented in detail below.

6.1.1 Infrared thermography challenges. Without a doubt, the use of infrared thermography as a data collection instrument was the most challenging part of this thesis. Although there are detailed guidelines on participants' preparation and some procedures for adequate collection of thermograms, there is still a lot to be clarified when using this tool. Because IRT is used in a variety of fields, its application varies across studies and tends to be personalised to every author's research question. Specifically in our study, we struggled with four major problems: the use and type of markers, the best position for participants to be for the photo to be taken, the development of a MATLAB algorithm, and the timing for

the data collection. In regard to the use and type of markers, we initially struggled with finding the best idea to determine a middle line and define a left and a right side. Our initial thought was to define the middle after obtaining the image and having downloaded it in Matlab, just by placing a line in the centre as determined by measuring equidistant from each edge. However, this would not have taken into account the morphology of each participant (i.e: the presence of a scoliosis or any other segment deviation disorder). Therefore, we decided to use markers as was done by other studies (Filho et al., 2012). A pilot was performed to test the insulating characteristics of different types of markers. Small (1cm diameter) Styrofoam spheres covered with reflective tape were chosen.

In our study participants stood in front of a podium and were asked to put their hand on top of it. The idea of not including the arms was a practical solution to simplify our data analysis as we only planned to examine the skin temperature of the torso. In a previous pilot we also determined that the use of a stool without back support as the best option for when participants were watching the videos, as other chairs showed an significant change on the skin temperature of their backs.

The development of a MATLAB algorithm required sessions of brainstorming and the help of engineers familiarized with the software. In our initial code we divided the torso in 4 major regions and then defined 3 more by taking half of the previous zone and half the following. This analysis was confusing, as regions were overlapped and was not viable when averaging the thermal asymmetries of each zone. Lastly, we were conflicted on whether we should take the thermograms right after the end of the treatment and not two days after, as we ended up doing. The idea behind this was that we did not consider it was objective to take a photo of the immediate effects that the technique may have produced on the participants

skin thermal as they would not had been different from the body response to any other intervention such as massage, or simply by touching the participant during an hour.

6.1.2 Differences in left-right skin temperature asymmetry. According to our findings there were no statistically significant differences between musicians with and without nonspecific musculoskeletal pain. In detail, when comparing each zone, without considering if pain was reported in that region, participants with pain showed more cases of asymmetries than the healthy ones. However, when contrasting the zones where pain was reported against the same ones of the healthy group, the opposite happened. This is, that healthy participants showed more cases of asymmetries. Nevertheless, these outcomes were not statistically significant. Our findings were in agreement with the results of Rossignoli and colleagues (Rossignoli et al., 2016) which showed that the higher the pain the lower the asymmetries. Interestingly, in our study, the side with greater pain was also the side with lowest temperature which shows consistency with the literature. Musculoskeletal pain is usually a consequence of an increase in the muscle tone, which is followed by rigidity, retraction and shortening of its morphology. According to Barret and group “If a muscle contracts rhythmically in the presence of an adequate blood supply, pain does not usually result. However, if the blood supply is occluded, contraction soon causes pain. The pain persists after the contraction until blood flow is re-established.” (Barret, Brooks, Boitano & Barman, 2010, p.170). Moreover, because musculoskeletal pain is a very subjective symptom, assumptions such as that the injury is unilateral, or that the pain is greater on one side rather than the other, which are based on the sensations reported by the patient, may not always be accurate.

Despite the fact that in our study there were no differentiations between participants with and without pain, there are a large number of studies which indeed found relevant differences between body sides. However, most of the studies used IRT for the examination of temperature changes related to the presence of injuries or diseases (Borojevic et al., 2011; Head, Lipari, Wang, Davidson, Elliott, 1996; Lawson, 1956; Zivcak et al., 2011) and not musculoskeletal pain with unknown origin for which in most cases it is not possible to identify a specific cause (Haydock, Whitehead & Fritz, 2014).

6.1.3 Measuring the effects of Global Postural Re-education

The results obtained with scales and questionnaires suggested that GPR can be an effective approach for the treatment of musculoskeletal pain. Disability and quality of life variables also improved after the treatment. These results were statistically relevant and were maintained two weeks after the end of the treatment as determined by a follow-up evaluation. The effectiveness of the method on these parameters has been study widely throughout the years and a large number of studies support our findings. Results from Pillastrini (Pillastrini et al., 2016) also showed improvements in a similar type of pain. In their study a GPR intervention induced better improvement on pain and disability in patients with persistent low back pain (LBP) as compared to controls. Similarly, Jeon and Kim (2017) showed that the GPR treatment induced greater improvement of pain, disability and quality of life on the experimental group compared to controls and their outcomes were also maintained four weeks after. Conversely, outcomes from Cunha and group suggested that GPR was as effective as segmental stretching (Cunha et al., 2008). In Maluf's study (Maluf et al., 2010) GPR was used for the treatment of myogenic temporomandibular disorders and their results

showed that both groups equally improved their pain and showed a decrease myoelectric activity, however, the GPR group showed a reduction in the severity of headaches.

A poor understanding of muscle physiology, especially the knowledge that static and dynamic muscles have different physiologies and therefore must be treated differently is a common error in conventional physiotherapy. Additionally, the effectiveness of the method lies in the understanding that each person has a unique way of responding to an injury or potential injury in combination with a clear understanding of the biomechanical processes that the body goes through before the injury or the pain. A thorough training in the GPR method and a proper understanding of widely known muscle physiology allows the professional to provide an effective treatment that is tailored to each structure and to each person (Bonetti et al., 2010; Korell, 2005; Souchard, 2012)

As an exploratory analysis, participants were invited to answer additional questions once the study was finished, to better understand the effects that the GPR method may have had on their occupation and everyday life from a personal point of view. By no means, was this an intention to develop a qualitative analysis as neither the questions nor the methodology used, meet the nature of those type of studies. Firstly, participants were asked whether they felt changes in their playing that they attributed to the GPR treatment. A common response was that they felt an increase in their range of motion in different areas of their bodies which brought benefits to their practice in different ways. For example, one participant who reported pain on the high cervical vertebrae area said: "... I think that the range of motion of in my neck is better. I don't think it had an effect on my playing but, I think is making it a bit easier to practice more..." Other expressed: "...I feel I have more movement in my upper half. I feel looser...During one of my (hardest) pieces my hands get really tight and now they don't

get tight anymore. My arms do get tight but not as much as before...” A violinist in the sample expressed: “...The first time I was like: woah I can move my head, that hasn’t happened in years...I tend to tense up when things (pieces) are hard, but because I have been more relaxed and open I felt things (pieces) weren’t as hard...I feel pieces get harder when I am tense...and I have so much more arm movement. I feel I can bow better...”

Even after the GPR treatment is finished and after correcting the muscular retraction it cannot be assumed that the morphological changes will be memorized completely (Soucard, 2012, p.147). For this reason, the method emphasises on integrating the outcomes by asking the patient to reproduce the desired physiological movement which is usually a common movement but yet personalized to each person. The objectives of this action is to create a new proprioceptive scheme and develop a new body awareness (Soucard, 2012). In this regard, the second question inquired about their ability to be aware of the position of their bodies and recognised if they felt that certain position was not comfortable or beneficial for them. Two piano performers responded: “...I have a tendency to move my head forward and now I noticed more when I am practicing, and I try to correct it more often than I did before...” and “I feel that my posture is better. I now noticed myself slouching and try to correct it and feel I can do it”. One participant expressed the following: “I learn a lot about my body and how I can move so I don’t have to feel pain. The new posture that I developed makes me feel more comfortable, more relaxed. Just by simply adjusting my posture slightly I feel less pain. I know how to adjust myself better, before I felt I was locked in a position and didn’t know how to be myself better”

Lastly, musicians were invited to share their final comments about the changes they felt they obtained after undergoing the intervention besides the ones previously examined throughout this study. A common response was an overall sensation of feeling “taller” or

more “straight”, one of them reported that her sleeping habits improved after the treatment and one found it easier to breathe. Specifically, musicians expressed: “...I feel that my spine is straighter. I first felt taller and now I feel straighter than usual...”; “...I think I have more energy and I can breathe better...” “...I haven’t been having problems when sleeping. I sleep better, and don’t curl anymore so when I wake up I don’t feel the back pain I was feeling before. I am more conscious of what I can do to not be uncomfortable” “...also I feel straighter, my posture is better, my shoulders are more backwards. Before I felt my pain when I lifted groceries or heavy things or when I was just standing but now I only feel it sometimes when I am playing... I feel I can play longer without having pain. The hours are not as exhausting as before, I can relax and play more. I can sit back and rest for 15 minutes and go back to playing and I’m pain free for most of the times...”

On the other hand, correlations between the degrees of thermal asymmetries and the pain severity scores as measured with the VAS were not statistically relevant. Nor were the changes in temperature asymmetries before and after the intervention. These findings agree with the results found by Park, Hyun and Seo (2007) whose results showed no correlation between pain and the infrared results, either with the absolute temperature values or between the asymptomatic versus symptomatic temperature asymmetries. Although without statistical relevance, our study found that the relief of pain was associated with the presence of higher asymmetries. This inverse relationship was also present in Rossignoli’s study (Rossignoli et al., 2016) where outcomes revealed that the higher the pain the lower the thermal asymmetry and vice versa.

Unlike our study, however, findings from Wu and colleagues (Wu et al., 2009) did show a statistically significant correlation between pain scores and temperature values as they

indicated a decrease in both pain intensity and temperature asymmetries. These findings were also true for Hakgüder and colleagues (Hakgüder et al., 2003) and Lee (Lee et al., 2015). IRT has been widely used to assess the effects of different interventions on well-known diseases or injuries. However, to our knowledge, no studies have used this instrument to examine the sympathetic thermal changes after the treatment of nonspecific musculoskeletal pain and more studies are needed to guarantee the robustness of results. Additionally, in the first part of our study IRT was unable to identify the presence of nonspecific musculoskeletal pain when comparing participants with and without this type of pain. In addition to this, the use of other approaches for the collection of additional empirical data was used in other studies to aid, validate and compare the data obtained with IRT.

6.2 Limitations

Firstly, despite following established procedures for collecting thermal images and providing detailed recommendations regarding participants' activities before the experimentation, we had limited control over individual and external factors that can certainly influence the measurements (Kelly, 2007; Mcfarland, 1985). The sample size and the inconsistency in participants' pain severity scores (from mild to severe) should also be considered as limitations to this study.

Secondly, the use of self-report questionnaires and scales, as this data can rarely be independently verified, and the potential sources of bias implied in these of type of methodological instrument are a limitation. Lastly, the lack of standardized study protocols, databases with normal and abnormal skin temperature data (Herry et al, 2008; Zaproudina et

al., 2008) and the variability in the images analyses, makes it difficult to entirely compare our results with other available literature.

6.3 Conclusion

Based on our results, there are no differences in skin thermal asymmetries between participants with nonspecific musculoskeletal pain and healthy controls as assessed by the algorithm developed for this study. Many available studies proved that this approach can be a valuable tool when assessing the body thermal pathophysiological responses to diseases or injuries. Based on our findings and the methodology used for this study, we believe that infrared thermography is not the optimal tool to study the pain targeted in this thesis. We suggest that future studies explore the impact that different images analysis could also bring to this question.

The results obtained with common questionnaires and scales showed that the Global Postural Re-education method is an effective tool for the treatment of nonspecific musculoskeletal pain as well as for disability and some aspects of quality of life in studied pianists and string players. The need for a tailored treatment that understands and considers the demands put on the musicians' body can possibly be addressed with this approach. We encouraged future research on the effects of the method in a larger sample and across different types of performers. We also suggest the need to compare the effectiveness of the GPR method with other therapeutic approaches on the community of musicians.

On the other hand, the use of IRT to examine the effects of GPR on the change in thermal asymmetries and also by correlating asymmetries with pain levels did not showed relevant results. However, we recognize these results contradict several studies in the literature that either compared the results obtained using thermography with other objective measurements

such as algometers or electromyography (among others) or examined the effects of well-known diseases. We encouraged future studies to assess the changes in nonspecific musculoskeletal pain after an intervention on a larger sample, and also by testing different types of analysis in order to confirm the results found by this study.

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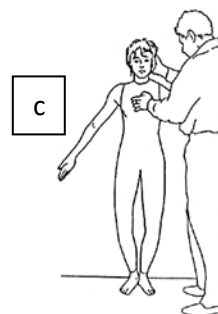
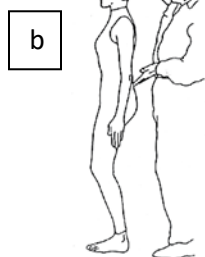
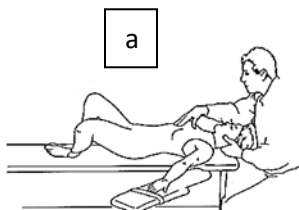
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APPENDIX A
Treatment Postures Used in the Global Postural Re-Education Method

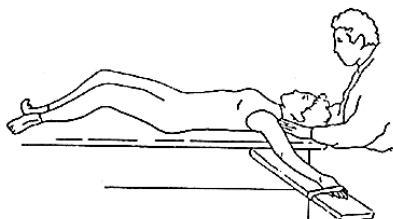
Family 1. Opening of the coxofemoral joint. Adducted arms

- a. Frog on the ground
- b. Standing against the wall
- c. Standing in the centre



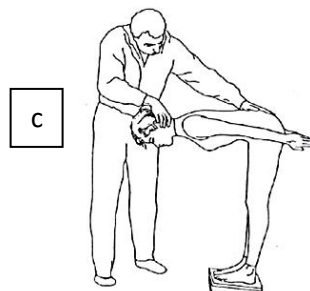
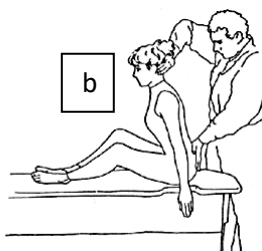
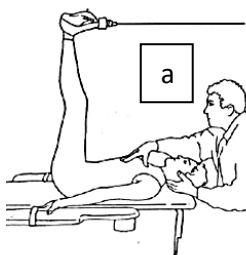
Family 2. Opening of the coxofemoral joint. Abducted arms

- a. Frog on the ground



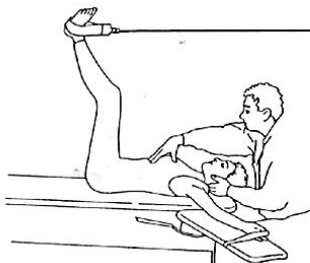
Family 3. Closure of the coxofemoral joint. Adducted arms

- a. Frog on the air
- b. Seating
- c. Bending-forward



Family 4. Closure of the coxofemoral joint. Abducted arms

- a. Frog on the air



APPENDIX B

Consent Forms

CONSENT FORM (Experimental group)

Title of the study:	Effectiveness of The Global Postural Re-education Method on Musicians with Neuro-musculoskeletal Pain as Assessed by Infrared Thermography	
Principal Investigator:	Dapne Mercado School of Human Kinetics University of Ottawa	
Project Supervisors:	Dr. Gilles Comeau Department of Music University of Ottawa	Dr. Donald Russell Faculty of Engineering University of Carleton
Invitation to Participate:	I am invited to participate in the abovementioned research study conducted by Dapne Mercado in partial fulfilment of the requirements for the degree Master of Science in Human Kinetics, supervised by Dr. Gilles Comeau.	
Purpose of the Study:	This study will aim to evaluate the effects of the global postural re-education on pianists and violinists suffering from neuro-musculoskeletal pain, specifically in the cervical, shoulder, thoracic and lumbar areas as assessed by infrared thermology.	
Participation:	Participants must: ▪ Be of age 18 to 28 ▪ Be fluent in English ▪ Have achieved grade 10 RCM or are studying piano/violin performance at a University level Participants will be required to attend to 3 thermal sessions and 8 GPR sessions. Activities and time commitments are as follows: • Day 1 [60 min]: Participants will complete a general demographic questionnaire, and 5 more questionnaires to assess intensity and characteristics of pain, quality of life and disability. The physical evaluation will take place after filling the questionnaires. This data will be collected the day before the first thermal assessment. • Day 2 (Baseline) [35min]	

Participation
(continued):

First thermal-assessment session. This examination will be done using an infrared camera in three occasions: at baseline (T1), after playing their instruments for 8 min (T2) and after 20 min from T2 (T3). Participants will be asked to uncover the area of interest if possible and stay in the experimentation room for 15 to acclimatize before the first examination (baseline).

- Day 3 to 4 weeks later [60min per session]

Beginning of the GPR sessions which will be provided twice a week across 4 weeks (N=8) with duration of 60 min each by means of a trained professional in the GPR method. During the first 5 minutes of each session, a manual maneuver will be done to the diaphragm muscle.

- Right after the last session [45 min]

Second thermal-assessment session. This session will take place right after the last GPR session and will follow the same scheme as before (before and after the musical activity and after 20 min). After, participants will be asked to fill the post-treatment scales and questionnaires mentioned above.

- 1 week after the last session of GPR [45min]

Third and last thermal-assessment session. This session will happen 1 week after the last GPR session as a follow up evaluation and following the same scheme (before and after the musical activity and after 20min). After, participants will be asked to fill the follow-up treatment scales and questionnaires mentioned above.

***Preparation:**

Participants should follow the following instructions prior to the thermal assessment:

Days before the examination

- Avoid sunburn or excessive exposure to the sun for a week prior to the examination.
- Avoid physical therapies, hot or cold presses, manipulations, occupational therapy, acupuncture, saunas, the use of TENS or electric muscle stimulation units or any other type of manipulation of the body 24 hours prior to imaging
- Avoid alcohol intake twelve hours prior to the imaging.
- Keep physical exertion to the minimum (Exercise) twenty-four hours prior of the session.

Hours before the examination

- Avoid using ointments or cosmetic products, such as talcum powder, perfume, body lotions, hair spray, hair cream, topical analgesics, etc. 8 hours prior to the examination
- Not to take hot or cold drinks one hour prior to the imaging.
- Nicotine and caffeine products should be discontinued 4 hours prior to examination.

Participation
(continued):

	- The participant should bathe on the day of the visit and at least 2 hours prior to the assessment avoiding hot or cold showers.
	On the examination
	- Avoid tight fitting clothing or anything binding against the skin.
	Wear loose clothing to the test and expose the area as much as possible for the examination
Musical requirements	Pianists will be required to play the following: 1) Play all major scales going up by half a tone (starting from C, C#, D, D#...), and then all minor scales (harmonic and melodic) going up by half a tone (starting from C, C#, D, D#...), hands together, in 16th notes with a tempo of ♩= 120 beats per minute, four octaves, continuously ascending and descending for 4 min. 2) Play a C major arpeggio, hands together, in 16th notes with a tempo of ♩= 92 beats per minute, four octaves, continuously ascending and descending for 4 min. Likewise, violinists will play the following: 1) Play all major scales going up by half a tone (starting from G, G#...), and then all minor scales (harmonic and melodic) going up by half a tone (starting from G, G#...), in 16th notes with a tempo of ♩= 90 beats per minute, three octaves, continuously ascending and descending for 4 min. 2) Play a G major arpeggio, in 16th notes with a tempo of ♩= 108 beats per minute, four octaves, continuously ascending and descending for 4 min.
Time commitment:	Participants will approximately devote a total of 15 hours to the study distributed within 8 weeks.
Benefits:	Participants in the experimental group will receive 4 weeks of GPR over the course of the study. This study will help to determine the effectiveness of GPR method on musicians struggling with neuromusculoskeletal pain in addition to examine the reliability of infrared thermography to assess pain in a more objective manner.
Risks:	There is minimal risk for participants in the research. They may feel mild discomfort in to uncovered the area of interest or wear thigh clothes. If so, participants are free to propose a different clothes that suits their comfort preferences.
Confidentiality and anonymity:	All participant information and data collected in this study will remain strictly anonymous and confidential and are used for research purposes only. Only the primary researcher, Dapne Mercado, supervisors: Dr. Gilles Comeau and Dr. Donald Russell, and authorized research members at the Piano Pedagogy Research Laboratory will have access to this data. Participants will only be identified through alphanumerical codes that will be used in place of names during analysis and publication. All collected data will be

kept on secure computers under password protection inside the Piano Pedagogy Research Laboratory, which is locked and armed with security alarms when unoccupied. Access to all computers is strictly monitored by lab administration.

Conservation of data: All audio and thermal data will be destroyed five years after the completion of this study.

Compensation: Participation in this study is strictly on a voluntary basis. Participants will not receive any form of compensation for participating in this study.

Voluntary participation: Participation in this study is strictly voluntary and *participants have the right to refuse to answer any questions or continue the sessions without fear of reprisal or ill treatment*. Participants can choose to withdraw from the study at any time while the experimental sessions are being conducted. After the testing session, participants will not be able to withdraw from the study since it will not be possible to identify the data associated with them. Participants do not have to provide any reason or justification to withdraw.

Information about study results: We would be pleased to share the results of this project with you. In order to receive a summary of the results, please contact the primary investigator or supervisors.

If you have any questions with regards to the ethical conduct of this study, you may contact the Protocol Officer for Ethics in Research, University of Ottawa, Tabaret Hall, 550 Cumberland Street, Room 154, Ottawa, ON, K1B 6N5. tel: 613-562-5387 or ethics@uottawa.ca.

If you have any questions or require more information about the study itself, you may contact the researcher or her supervisors. Please keep this form for your records.

I, _____, confirm that I have read and understood the information presented in the consent form above, and acknowledge the risks of participation as they have been described. I understand that I am under no obligation to participate, and that I have the right to withdraw from the study at any point, for any reason. By signing this form I confirm that I meet the criteria for participation as described and that I participate at my own risk.

Signature of participant

Date

Signature of researcher

Date

APPENDIX B (continued)

CONSENT FORM (Control group)

Title of the study:	Effectiveness of The Global Postural Re-education Method on Musicians with Neuro-musculoskeletal Pain as Assessed by Infrared Thermography	
Principal Investigator:	Dapne Mercado School of Human Kinetics University of Ottawa	
Project Supervisors:	Dr. Gilles Comeau Department of Music University of Ottawa	Dr. Donald Russell Faculty of Engineering University of Carleton
Invitation to Participate:	I am invited to participate in the abovementioned research study conducted by Dapne Mercado in partial fulfilment of the requirements for the degree Master of Science in Human Kinetics, supervised by Dr. Gilles Comeau.	
Purpose of the Study:	This study will aim to evaluate the effects of the global postural re-education on pianists and violinists suffering from neuro-musculoskeletal pain, specifically in the cervical, shoulder, thoracic and lumbar areas as assessed by infrared thermology.	
Participation:	Participants must: ▪ Be of age 18 to 28 ▪ Be fluent in English ▪ Have achieved grade 10 RCM or are studying piano/violin performance at a University level Participants will be required to attend to 3 thermal sessions. Activities and time commitments are as follows: • Day 1 [60 min]: Participants will complete a general demographic questionnaire, and 5 more questionnaires to assess intensity and characteristics of pain, quality of life and disability. The physical evaluation will take place after filling the questionnaires. This data will be collected the day before the first thermal assessment. • Day 2 (Baseline) [35min] First thermal-assessment session. This examination will be done using an infrared camera in three occasions: at baseline (T1), after playing their instruments for 8 min (T2) and after 20 min from T2 (T3). Participants will	

Participation
(continued):

be asked to uncover the area of interest if possible and stay in the experimentation room for 15 to acclimatize before the first examination (baseline).

- 4 weeks later [45min]

Second thermal-assessment session. This session will take place right after the last GPR session and will follow the same scheme as before (before and after the musical activity and after 20 min from the previous). After, participants will be asked to fill the post-intervention scales and questionnaires mentioned above.

- 1 week after [45min]

Third and last thermal-assessment session. This session will happen 1 week after the last GPR session (of the experimental group) as a follow up evaluation and following the same scheme as before (before and after the musical activity and after 20min). After, participants will be asked to fill the follow-up intervention scales and questionnaires mentioned above.

***Preparation:**

Participants should follow the following instructions prior to the thermal assessment:

Days before the examination

- Avoid sunburn or excessive exposure to the sun for a week prior to the examination.
- Avoid physical therapies, hot or cold presses, manipulations, occupational therapy, acupuncture, saunas, the use of TENS or electric muscle stimulation units or any other type of manipulation of the body 24 hours prior to imaging
- Avoid alcohol intake twelve hours prior to the imaging.
- Keep physical exertion to the minimum (Exercise) twenty-four hours prior of the session.

Hours before the examination

- Avoid using ointments or cosmetic products, such as talcum powder, perfume, body lotions, hair spray, hair cream, topical analgesics, etc. 8 hours prior to the examination
- Not to take hot or cold drinks one hour prior to the imaging.
- Nicotine and caffeine products should be discontinued 4 hours prior to examination.
- The participant should bathe on the day of the visit and at least 2 hours prior to the assessment avoiding hot or cold showers.

On the examination

- Avoid tight fitting clothing or anything binding against the skin.

Wear loose clothing to the test and expose the area as much as possible for the examination

Participation
(continued):

Time commitment:

Participants will approximately devote a total of 3 hours to the study distributed within 8 weeks.

Benefits:

This study will help to determine the effectiveness of GPR method on musicians struggling with neuromusculoskeletal pain in addition to examine the reliability of infrared thermography to assess pain in a more objective manner. Participants in this group will be invited to receive three weeks of GPR after the study is finished.

Risks:	There is minimal risk for participants in the research. They may feel mild discomfort in to uncovered the area of interest or wear thigh clothes. If so, participants are free to propose a different clothes that suits their comfort preferences.
Confidentiality and anonymity:	All participant information and data collected in this study will remain strictly anonymous and confidential and are used for research purposes only. Only the primary researcher, Dapne Mercado, supervisors: Dr. Gilles Comeau and Dr. Donald Russell, and authorized research members at the Piano Pedagogy Research Laboratory will have access to this data. Participants will only be identified through alphanumerical codes that will be used in place of names during analysis and publication. All collected data will be kept on secure computers under password protection inside the Piano Pedagogy Research Laboratory, which is locked and armed with security alarms when unoccupied. Access to all computers is strictly monitored by lab administration.
Conservation of data:	All audio and thermal data will be destroyed five years after the completion of this study.
Compensation:	Participation in this study is strictly on a voluntary basis. Participants will not receive any form of compensation for participating in this study.
Voluntary participation:	Participation in this study is strictly voluntary and <i>participants have the right to refuse to answer any questions or continue the sessions without fear of reprisal or ill treatment</i> . Participants can choose to withdraw from the study at any time while the experimental sessions are being conducted. After the testing session, participants will not be able to withdraw from the study since it will not be possible to identify the data associated with them. Participants do not have to provide any reason or justification to withdraw.
Information about study results:	We would be pleased to share the results of this project with you. In order to receive a summary of the results, please contact the primary investigator or supervisors.

If you have any questions with regards to the ethical conduct of this study, you may contact the Protocol Officer for Ethics in Research, University of Ottawa, Tabaret Hall, 550 Cumberland Street, Room 154, Ottawa, ON, K1B 6N5. tel: 613-562-5387 or ethics@uottawa.ca.
If you have any questions or require more information about the study itself, you may contact the researcher or her supervisors. Please keep this form for your records.

I, _____, confirm that I have read and understood the information presented in the consent form above, and acknowledge the risks of participation as they have been described. I understand that I am under no obligation to participate, and that I have the right to withdraw from the study at any point, for any reason. By signing this form I confirm that I meet the criteria for participation as described and that I participate at my own risk.

Signature of participant

Date

Signature of researcher

Date

APPENDIX B (continued)

CONSENT FORM (Healthy participants)

Title of the study: Effectiveness of The Global Postural Re-education Method on Musicians with Neuro-musculoskeletal Pain as Assessed by Infrared Thermography

Principal Investigator: Dapne Mercado
School of Human Kinetics
University of Ottawa

Project Supervisors: Dr. Gilles Comeau
Department of Music
University of Ottawa

Dr. Donald Russell
Faculty of Engineering
University of Carleton

Invitation to Participate: I am invited to participate in the abovementioned research study conducted by Dapne Mercado in partial fulfilment of the requirements for the degree Master of Science in Human Kinetics, supervised by Dr. Gilles Comeau.

Purpose of the Study: This study will aim to evaluate the effects of the global postural re-education on pianists and violinists suffering from neuro-musculoskeletal pain, specifically in the cervical, shoulder, thoracic and lumbar areas as assessed by infrared thermology. Skin temperature will be compared between healthy and musicians with pain.

Participation: Participants must:

- Be of age 16 to 28
- Be fluent in English
- Have achieved grade 8,9 or 10 RCM or are studying piano, violin or viola performance at a University level

Participants will be required to attend to 1 thermal session. Activities and time commitments are as follows:

- Day 1 [15 min]:
Participants will complete a general demographic questionnaire and the consent form.
- Day 2 [50min]
Thermal-assessment session. This examination will be done using an infrared camera in three occasions: at baseline (T1), after playing their instruments for 12 min (T2) and after 15 min from T2 (T3). Participants will be asked to uncover the area of interest if possible and stay in the experimentation room for 15 to acclimatize before the first examination (baseline).

Participation
(continued):

***Preparation:**

Participants should follow the following instructions prior to the thermal assessment:

Days before the examination

- Avoid sunburn or excessive exposure to the sun for a week prior to the examination.
- Avoid physical therapies, hot or cold presses, manipulations, occupational therapy, acupuncture, saunas, the use of TENS or electric muscle stimulation units or any other type of manipulation of the body 24 hours prior to imaging
- Avoid alcohol intake twelve hours prior to the imaging.
- Keep physical exertion to the minimum (Exercise) twenty-four hours prior of the session.

Hours before the examination

- Avoid using ointments or cosmetic products, such as talcum powder, perfume, body lotions, hair spray, hair cream, topical analgesics, etc. 8 hours prior to the examination
- Not to take hot or cold drinks one hour prior to the imaging.
- Nicotine and caffeine products should be discontinued 4 hours prior to examination.
- The participant should bathe on the day of the visit and at least 2 hours prior to the assessment avoiding hot or cold showers.

On the examination

- Avoid tight fitting clothing or anything binding against the skin.

Wear loose clothing to the test and expose the area as much as possible for the examination

Time commitment: Participants will approximately devote a total of 1 hour and 15min to the study distributed within 2 days.

Benefits: This study will help to determine the effectiveness of GPR method on musicians struggling with neuromusculoskeletal pain in addition to examine the reliability of infrared thermography to assess pain in a more objective manner.

Risks: There is minimal risk for participants in the research. They may feel mild discomfort in to uncovered the area of interest or wear thigh clothes. If so, participants are free to propose a different clothes that suits their comfort preferences.

Confidentiality and anonymity: All participant information and data collected in this study will remain strictly anonymous and confidential and are used for research purposes only. Only the primary researcher, Dapne Mercado, supervisors: Dr. Gilles Comeau and Dr. Donald Russell, and authorized research members at the Piano Pedagogy Research Laboratory will have access to this data. Participants will only be identified through alphanumerical codes that will be used in place of names during analysis and publication. All collected data will be kept on secure computers under password protection inside the Piano Pedagogy Research Laboratory, which is locked and armed with

security alarms when unoccupied. Access to all computers is strictly monitored by lab administration.

Conservation of data: All audio and thermal data will be destroyed five years after the completion of this study.

Compensation: Participation in this study is strictly on a voluntary basis. Participants will not receive any form of compensation for participating in this study.

Voluntary participation: Participation in this study is strictly voluntary and *participants have the right to refuse to answer any questions or continue the sessions without fear of reprisal or ill treatment*. Participants can choose to withdraw from the study at any time while the experimental sessions are being conducted. After the testing session, participants will not be able to withdraw from the study since it will not be possible to identify the data associated with them. Participants do not have to provide any reason or justification to withdraw.

Information about study results: We would be pleased to share the results of this project with you. In order to receive a summary of the results, please contact the primary investigator or supervisors.

If you have any questions with regards to the ethical conduct of this study, you may contact the Protocol Officer for Ethics in Research, University of Ottawa, Tabaret Hall, 550 Cumberland Street, Room 154, Ottawa, ON, K1B 6N5. tel: 613-562-5387 or ethics@uottawa.ca.

If you have any questions or require more information about the study itself, you may contact the researcher or her supervisors. Please keep this form for your records.

I, _____, confirm that I have read and understood the information presented in the consent form above, and acknowledge the risks of participation as they have been described. I understand that I am under no obligation to participate, and that I have the right to withdraw from the study at any point, for any reason. By signing this form I confirm that I meet the criteria for participation as described and that I participate at my own risk.

Signature of participant

Date

Signature of researcher

Date

APPENDIX C

Demographic Questionnaire



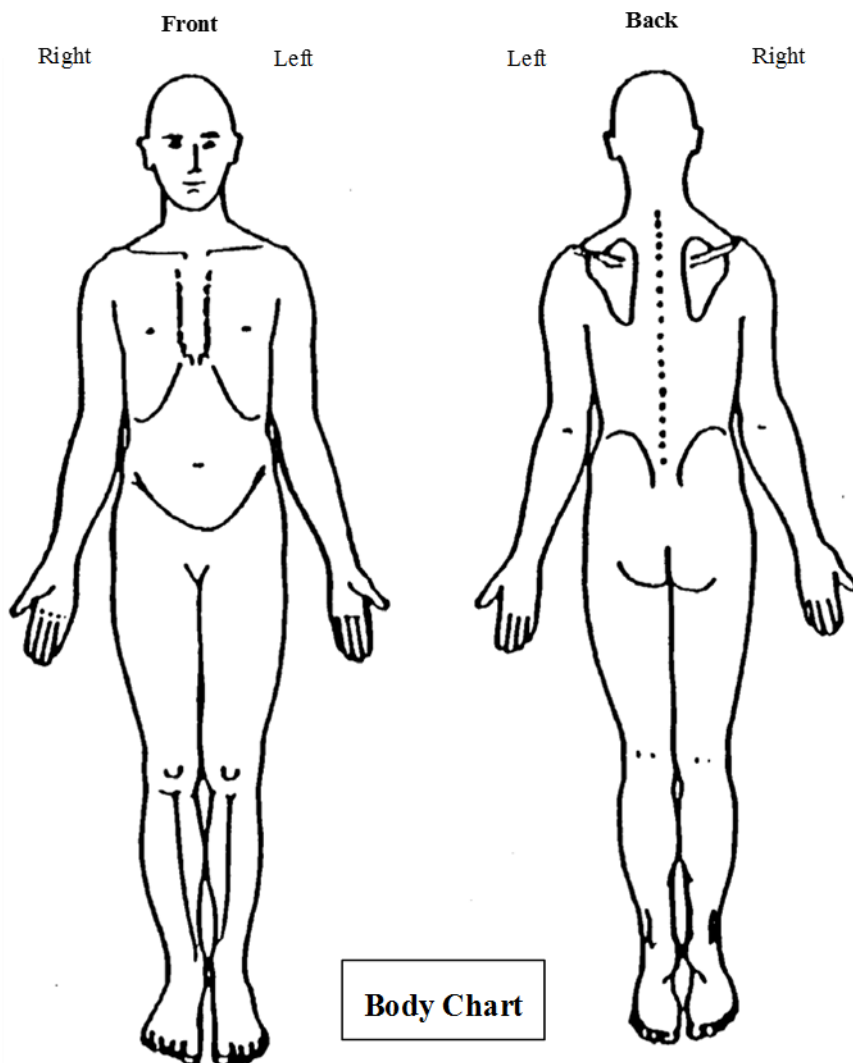
Demographic Questionnaire

Alpha numeric code: _____

Personal Information		
	First name	Last name:
1	Gender:	
2	Date of birth	
3	Email (optional):	
4	Weight	
5	Height	
6	Dominant hand (Left, right or both:	
Musical Background		
7	Primary instrument:	
8	Number of years playing your instrument	
9	Are you currently maintaining practice on your instrument?	Yes___ No___
10	Highest degree of music training attained (degree/RCM certificate/etc.)	
11	How many hours (or minutes) do you play every day?	
12	How many days do you play every week?	
13	Which musical genre you usually play?	
14	Second instrument:	
15	Number of years playing your instrument	
16	Highest degree of music training attained (degree/RCM certificate/etc.)	
17	How many hours (or minutes) do you play every day?	
18	How many days do you play every week?	
19	Do you take breaks before, while or after playing?	
20	Do you do any type of warm up before playing?	
Occupation		
21	Do you ever experience pain caused by playing your instrument? (or have you ever)	Yes___ No___
22	Based on self-assessment, do you think the pain is (or was) the result of:	
a	Inappropriate technique	
b	Poor body posture	
c	Extensive practice	

d	Poor physical condition	
e	Others	
23	Is music your major occupation?	
24	Do you have an additional occupation besides your music profession? (such as an office job, part-time job, housekeeping, etc) If yes, please describe briefly and indicate the amount of hours you spend on this activity every day	
	Pain history	
25	Do (or Did) you ever experience physical pain or discomfort while playing, right after or later that day?	Yes___ No___
	If yes please indicate when you feel it (mark with and x):	
a.	While playing	_____
b.	Right after playing	_____
c.	Later on the same day	_____

26 . Are you currently experiencing any pain? If yes, please shade in each of the areas where you experience pain/problems. And put an X on the ONE area that hurts the most



27	Would you say your pain is greater in one side than in other? If yes, please indicate	left side _____ Right side _____
28	Does your pain gets better when you rest and worsen after an activity or by the end of the day?	Yes_____ No_____
29	For how long have you been feeling this pain? # Months, days, weeks	
30	Have you seek any help to treat this pain?	Yes___ No___
31	If yes, please indicate from whom:	
a	Musical teacher/Tutor	_____
b	Health professional (Doctor, physiotherapist, etc)	_____
c	Friends/ family/colleagues	_____
d	Others	_____
32	Was this person able to help with your pain?	
a	Fully helped me	_____

APPENDIX D

Participants' Preparation before the collection of thermograms

Thermographic Evaluation

Days before the examination

- Avoid sunburn or excessive exposure to the sun for a week prior to the examination.
- Avoid physical therapies, hot or cold presses, manipulations, occupational therapy, acupuncture, saunas, the use of TENS or electric muscle stimulation units or any other type of manipulation of the body 24 hours prior to imaging
- Avoid alcohol intake twelve hours prior to the imaging.
- Keep physical exertion to the minimum (Exercise) twenty-four hours prior of the session.

Hours before the examination

- Avoid using ointments or cosmetic products, such as talcum powder, perfume, body lotions, hair spray, hair cream, topical analgesics, etc. 8 hours prior to the examination
- Not to take hot or cold drinks one hour prior to the imaging.
- Nicotine and caffeine products should be discontinued 4 hours prior to examination.
- The participant should bathe on the day of the visit and at least 2 hours prior to the assessment avoiding hot or cold showers.

On the examination

- Avoid tight fitting clothing or anything binding against the skin.
- Wear loose clothing to the test and expose the area as much as possible for the examination.

Acceptance: I, _____ agree to follow the above instructions requested by Dapne Mercado of the School of Human Kinetics, at the University of Ottawa in order for her to succeed in the data collection.

Signature of participant

Date

Signature of researcher

Date

Student in charge: Dapne Mercado.

APPENDIX E

Participants' Playing Requirements

Pianists playing requirements

- 1) Play all major scales going up by half a tone (starting from C, C#, D, D#...), hands together, in 16th notes with a tempo of ♩= 88 beats per minute, four octaves, continuously ascending and descending during 4 minutes.
- 2) Play a C major arpeggio, hands together, in 16th notes with a tempo of ♩= 69 beats per minute, four octaves, continuously ascending and descending during 4 minutes.
- 3) Play major four-note broken chords going up by half a tone (starting from C, C#, D, D#...), hands together, in 16th notes with a tempo of ♩= 80 beats per minute, two octaves, continuously ascending and descending during 4 minutes.

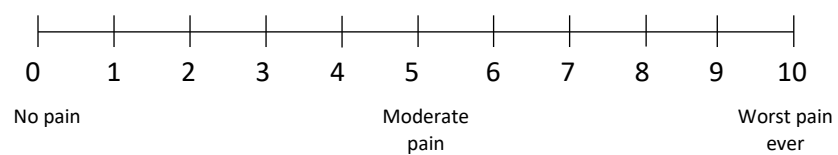
Violinists playing requirements

- 1) Play all major scales going up by half a tone (starting from G, G#...) in 16th notes with a tempo of ♩= 80 beats per minute, three octaves, continuously ascending and descending during 4 minutes.
- 2) Play a G major arpeggio, in 16th notes with a tempo of ♩= 84 beats per minute, three octaves, continuously ascending and descending during 4 minutes.
- 3) Play major double stops in thirds, broken chords going up by half a tone (starting from G, G#...), in half notes with a tempo of ♩= 80 beats per minute, two octaves, continuously ascending and descending during 4 minutes.

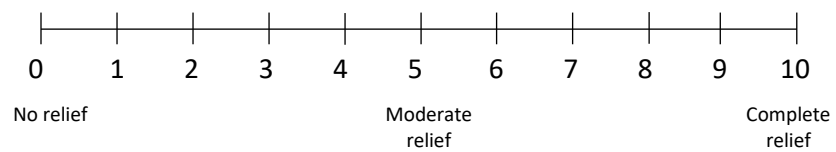
APPENDIX F

Visual Analog Scale (VAS)

Pain Intensity



Pain Relief



APPENDIX G

The Musculoskeletal Pain Intensity and Interference Questionnaire for Musicians (MPIIQM)

1. What is your age? _____ years
2. Gender: ☐ Male ☐ Female
3. What instrument do you play in the orchestra? _____
4. With respect to your position in the orchestra, do you work: ☐ Full time ☐ Part time
5. For how many years have you played your instrument? _____ years
6. For how many years have you played professionally in an orchestra? _____ years

7. On average, how many hours per week do you spend playing your instrument **in the orchestra** (this includes rehearsals, performances, recordings)? _____ hours per week
8. On average, how many hours per week do you spend playing your instrument **outside** orchestra duties (this includes individual practice, chamber music, solo performances, demonstration when teaching, gigs, other)? _____ hours per week

Playing-related musculoskeletal problems are defined as "pain, weakness, numbness, tingling, or other symptoms that interfere with your ability to play your instrument at the level to which you are accustomed". This definition does not include mild transient aches and pains.

9. Have you **ever** had pain/problems that have interfered with your ability to play your instrument at the level to which you are accustomed? ☐ Yes ☐ No
10. Have you had pain/problems that have interfered with your ability to play your instrument at the level to which you are accustomed **during the last 12 months**? ☐ Yes ☐ No
11. Have you had pain/problems that have interfered with your ability to play your instrument at the level to which you are accustomed **during the last month (4 weeks)**? ☐ Yes ☐ No
12. **Currently (in the past 7 days)**, do you have pain/problems that interfere with your ability to play your instrument at the level to which you are accustomed? ☐ Yes ☐ No

If your answer to questions 11 and/or 12 is YES, please continue. Otherwise stop here, and hand your survey back or post it back using the stamped addressed envelope provided.

APPENDIX H

Medical Outcomes Study Questionnaire Short Form 36 Health Survey

Medical Outcomes Study Questionnaire Short Form 36 Health Survey

This survey asks for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities. Thank you for completing this survey! For each of the following questions, please circle the number that best describes your answer.

1. In general, would you say your health is:	
Excellent	1
Very good	2
Good	3
Fair	4
Poor	5
2. Compared to one year ago,	
Much better now than one year ago	1
Somewhat better now than one year ago	2
About the same	3
Somewhat worse now than one year ago	4
Much worse now than one year ago	5

3. The following items are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?

(Circle One Number on Each Line)

	Yes, Limited a Lot (1)	Yes, Limited a Little (2)	No, Not limited at All (3)
a. Vigorous activities, such as running, lifting heavy objects, participating in strenuous sports	1	2	3
b. Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	1	2	3
c. Lifting or carrying groceries	1	2	3
d. Climbing several flights of stairs	1	2	3
e. Climbing one flight of stairs	1	2	3
f. Bending, kneeling, or stooping	1	2	3

APPENDIX H (continued)

g. Walking more than a mile	1	2	3
h. Walking several blocks	1	2	3
i. Walking one block	1	2	3
j. Bathing or dressing yourself	1	2	3

4. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?
(Circle One Number on Each Line)

	Yes (1)	No (2)
a. Cut down the amount of time you spent on work or other activities	1	2
b. Accomplished less than you would like	1	2
c. Were limited in the kind of work or other activities	1	2
d. Had difficulty performing the work or other activities (for example, it took extra effort)	1	2

5. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?
(Circle One Number on Each Line)

	Yes	No
a. Cut down the amount of time you spent on work or other activities	1	2
b. Accomplished less than you would like	1	2
c. Didn't do work or other activities as carefully as usual	1	2

6. During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups?	
Not at all	1
Slightly	2
Moderately	3
Quite a bit	4
Extremely	5

APPENDIX H (continued)

7. How much bodily pain have you had during the past 4 weeks?	
None	1
Very mild	2
Mild	3
Moderate	4
Severe	5
Very severe	6
8. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?	
Not at all	1
A little bit	2
Moderately	3
Quite a bit	4
Extremely	5

These questions are about how you feel and how things have been with you **during the past 4 weeks**. For each question, please give the one answer that comes closest to the way you have been feeling. **(Circle One Number on Each Line)**

9. How much of the time during the past 4 weeks . . .

	All of the Time	Most of the Time	A Good Bit of the Time	Some of the Time	A Little of the Time	None of the Time
a. Did you feel full of pep?	1	2	3	4	5	6
b. Have you been a very nervous person?	1	2	3	4	5	6
c. Have you felt so down in the dumps that nothing could cheer you up?	1	2	3	4	5	6
d. Have you felt calm and peaceful?	1	2	3	4	5	6
e. Did you have a lot of energy?	1	2	3	4	5	6

APPENDIX H (continued)

	All of the Time	Most of the Time	A Good Bit of the Time	Some of the Time	A Little of the Time	None of the Time
f. Have you felt downhearted and blue?	1	2	3	4	5	6
g. Did you feel worn out?	1	2	3	4	5	6
h. Have you been a happy person?	1	2	3	4	5	6
i. Did you feel tired?	1	2	3	4	5	6

10. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)? (Circle One Number)	
All of the time	1
Most of the time	2
Some of the time	3
A little of the time	4
None of the time	5

11. How TRUE or FALSE is each of the following statements for you.
(Circle One Number on Each Line)

	Definitely True	Mostly True	Don't Know	Mostly False	Definitely False
a. I seem to get sick a little easier than other people	1	2	3	4	5
b. I am as healthy as anybody I know	1	2	3	4	5
c. I expect my health to get worse	1	2	3	4	5
d. My health is excellent	1	2	3	4	5