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THE IMPORTANCE OF PROPER UPPER-BODY POSTURE IN THE PREVENTION AND TREATMENT OF PLAYING-RELATED MUSCULOSKELETAL DISORDERS (PRMDS) IN PIANISTS

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ABSTRACT

The purpose of this study was to investigate the impact of appropriate upper-body posture on the prevention and treatment of PRMDs on pianists. Pianists are a group of instrumentalists at high risk for developing Playing-Related Musculoskeletal Disorders (PRMDs). While these disorders stem from many factors, the most often reported cause is inappropriate posture. In the experiment, the performance of two teams of pianists was compared. Thirteen teenaged piano students, seven beginners and six advanced, performed two specific major scales in five octaves in two pre-determined different tempi (slow and fast). Twenty-seven reflective markers were placed on selected parts of the upper body, with a 10-camera Vicon Nexus 2 system capturing the motion. Variables observed were: hand sway over the keyboard, spinal angles in selected moments of the performance, and overall sway of the upper body in relation to the instrument. The results showed that advanced students presented less hand sway and more economical hand movements than beginners over the keyboard. Statistically significant differences in spinal angles between the two teams were noted only at the start of the performance; advanced students positioned their upper body in more upright spinal angles than the beginners, while the most upright spinal angle recorded was 164,58 degrees. The results suggested that pianists ignored the significance appropriate posture has on the quality of their playing and physical health, leading themselves to early onset of PRMDs. This study aims to contribute to the limited existing bibliography, since this field of study requires further research.

ΠΕΡΙΛΗΨΗ

Στόχος της παρούσης έρευνας ήταν η επίδραση της κατάλληλης στάσης του άνω σώματος στην αποφυγή και αποκατάσταση PRMDs (μυοσκελετικών προβλημάτων σχετιζόμενων με το παίξιμο πιάνου) σε πιανίστες, ομάδα υψηλού κινδύνου για την εμφάνιση PRMDs. Παρ’ ότι οι παθήσεις αυτές οφείλονται σε πολλούς παράγοντες, η πιο συχνά αναφερόμενη αιτία είναι η ακατάλληλη στάση σώματος. Στο πείραμα έγινε σύγκριση δύο ομάδων πιανιστών, αρχάριων και προχωρημένων. Συμμετείχαν δεκατρείς έφηβοι σπουδαστές πιάνου, οι οποίοι έπαιξαν δύο συγκεκριμένες κλίμακες σε πέντε οκτάβες, σε δύο προκαθορισμένες ταχύτητες η κάθε μια (αργή, γρήγορη). Είκοσι επτά ανακλαστήρες τοποθετήθηκαν σε επιλεγμένα σημεία του άνω σώματος κάθε εθελοντή. Η καταγραφή της κίνησης έγινε με δέκα κάμερες, στο σύστημα Vicon Nexus 2. Οι μεταβλητές που παρατηρήθηκαν ήταν κίνηση του χεριού πάνω στα πλήκτρα, γωνίες της σπονδυλικής στήλης σε συγκεκριμένες στιγμές του παιξίματος, και η ολική κίνηση του άνω σώματος σε σχέση με το όργανο. Τα αποτελέσματα έδειξαν λιγότερη κινητικότητα του χεριού πάνω στα πλήκτρα στην ομάδα των προχωρημένων. Στατιστικά σημαντικές διαφορές στις γωνίες της σπονδυλικής στήλης καταγράφηκαν μόνο στην αρχή κάθε κλίμακας, όπου οι προχωρημένοι σπουδαστές τοποθέτησαν το σώμα τους σε περισσότερο όρθια στάση από τους αρχαρίους, με την καλύτερη γωνία να είναι 164,58 μοίρες. Τα αποτελέσματα υποδεικνύουν ότι οι πιανίστες αγνοούν τη σημαντική επίδραση της κατάλληλης στάσης σώματος πάνω στην ποιότητα του παιξίματος και τη σωματική τους υγεία, με αποτέλεσμα την πρώιμη εμφάνιση PRMDs. Η παρούσα εργασία επιδιώκει να συμβάλλει στην περιορισμένη βιβλιογραφία πάνω στη σχέση στάσης και PRMDs σε πιανίστες, ένα πεδίο μελέτης το οποίο απαιτεί επιπλέον έρευνα.

CONTENTS

INTRODUCTION

Music performance, a profession rarely thought of as harmful, is considered a highly demanding activity which challenges the physical and mental limits of the musicians (Gong et al, 2014; Ioannou, DiS & Altenmüller, 2014; Nawrocka et al, 2014; Rietveld, 2013; Steinmetz, Scheffer, Esmer, Delank, & Peroz, 2015). Playing-related musculoskeletal disorders (PRMDs) are the most common ailments of performing musicians (Dommerholt, 2009, 2010; Lederman, 2003; Nawrocka et al, 2014; Steinmetz, Seidel, & Muche, 2010; Rietveld, 2013), affecting an alarmingly high percentage of professional, student and amateur instrumentalists (Beacon, Comeau, Payeur, & Russel, 2017; Blanco-Piñeiro, Díaz-Pereira, & Martínez, 2017; Kok, Huisstede, Voorn, Schoones, & Nelissen, 2016).

PRMDs appear in musicians of all instrumental groups; the specifics of each instrument define the affected body parts. Pianists are regarded as a group at high-risk for developing PRMDs, with more than 60% of professional and student pianists affected by these disorders (Furuya & Kinoshita, 2008; Lai et al, 2015; Nawrocka et al, 2014; Rosety-Rodriguez et al, 2003). Ailments most often reported by pianists include pain in low back, spine, neck, shoulders, upper trapezius muscles, forearm and wrist, also tendonitis, focal dystonia, carpal-tunnel syndrome, and nerve-entrapment syndrome (Bruno, Lorusso, & L'Abbate, 2008; Gong et al, 2014). Untreated PRMDs might develop to conditions serious enough to require complete cease of playing for a period of time ranging from few weeks to more than a year; more severe cases have reportedly been career-ending (Bruno et al, 2008).

Recent research findings suggest that PRMDs stem from many factors, several of which are related to the body of the performer such as limited body strength and endurance, increased static load, and inappropriate postures, with the later considered a crucial factor for the appearance of these disorders (Ackermann, Driscoll, & Kenny, 2012; Carter & Grahn, 2016; Dommerholt, 2009; Kok et al, 2017; Mastnak, 2017). It has also been stressed that a significant percentage of pianists lack basic knowledge on anatomy, physiology and ergonomics of the human body, adopt and encourage the attitude "no pain no gain", and accept the appearance of pain during playing as normal (Bruno et al, 2008; Dick et al, 2013; Forde, Punnet, & Wegman, 2002; Furuya & Kinoshita, 2008; Hagberg, Thiringer, & Brandström, 2005; Stanhope, 2016; Zosso & Schoeb, 2012). As a result, they engage in harmful practicing habits which, as shown by research, eventually lead to development of PRMDs, potentially deteriorating or permanently damaging musicians' careers (Allsop & Ackland, 2010; Hagberg et al, 2005). Given that a professional pianist's career may start as early as elementary school and span into more than eight decades (Horton, Baker, & Schorer, 2008) as numerous examples of elite level performers demonstrate, further exploration of PRMDs seems crucial.

The movement of upper limbs is related to and depends on the activity of muscles originating from the spine and shoulder blades, whose proper function is essential for achieving optimal piano performance (Steinmetz et al, 2010). Nevertheless, research on this part of the pianist's body still very limited leading several scholars to regard performing musicians an underserved occupational group which, while faces physical demands similar to those of athletes, is deprived of the quality of health expertise other occupations and sports people enjoy (Chan & Ackermann, 2014; Dick et al, 2008; Dommerholt, 2009; Mastnak, 2017; Stanhope, 2016). Considering the lack of studies and related literature on pianists' posture and the high percentages of pianists affected by musculoskeletal disorders as well, the present research aims to explore the importance of proper upper body posture in the prevention and treatment of PRMDs in pianists. In addition, it aims to help establishing performing musicians as athletes who need specially designed exercise and strengthening programs in order to avoid injuries and reach elite level of performance (Horton et al, 2007; Stanhope, 2016; Mastnak, 2017).

For the purpose of the present study an experiment was conducted relying on a high-accuracy optical motion capture system, in which the performance of two teams pianists, beginner and advanced, was compared exploring their perspective body postures and hand movements over the keyboard. The main goal of the experiment was to examine the differences in body posture between the two teams, aiming to investigate if appropriate posture is a crucial element of piano training, and if piano training is efficient in protecting pianists from PRMDs.

The results of the present research aim first to reach the population most affected by PRMDs, that is professional performers, piano educators, students and amateur pianists. Secondly, a wider area of specialists might be involved including health professions dealing with musicians' injuries such as orthopedics and physiotherapists, especially when considering that many musicians affected by PRMDs express great dissatisfaction with the available medical treatment (Dommerholt, 2009; Quarrier, 1993). In addition, the field of physical education and sports sciences would also be connected, contributing to pianists' well-being and strength by offering them valuable protection mechanisms against PRMDs (Dick et al, 2013; Mastnak, 2017).

Despite the increasing interest in performing musicians' health, the available literature is still very limited and the main bulk of research focuses on hand and fingers ignoring the importance of the upper body in preventing PRMDs in pianists. The present research aims to contribute in covering this gap and help in pursuing further studies on the field of performing musicians' health.

CHAPTER 1: LITERATURE REVIEW

Music has been integrated with human activities since the very first historical records of society. Present in all phases of human life, music functions as a pleasant activity, glorification of God, significant part of important celebration, and an essential aspect of education. Humans are exposed to music during their whole life, most of the time without even realizing it (Lederman, 2003).

A. THE ISSUE

Despite the strong presence of music in every-day life, the majority of people rarely think of it as a profession, not to mention a dangerous occupation which might cause health risks similar to those of other occupations. Several scholars consider the playing of an instrument as a highly demanding activity (Bruno et al, 2008; Hagberg et al, 2005; Lederman, 2003; Quarrier, 1993; Zasa, Chalres, & Muszynski, 1998). Instrumental musicians are expected to execute complex physical movements at high speed and practice for long hours in uncomfortable body positions; depending on the instrument, these activities require physical strength, flexibility and agility (Quarrier, 1993). The specific demands of performing a musical instrument may burden both physical and mental capacities of musicians, leaving them vulnerable to injuries (Dick et al, 2013; Ioannou et al, 2015; Nawrocka et al, 2014; Rietveld, 2013). The impact on musician's musculoskeletal system is so heavy that performers are currently thought as a specific professional group which is in high risk of pain and musculoskeletal disorders (Nawrocka et al, 2014; Steinmetz et al, 2010).

Performing musicians have to meet complex and highly demanding tasks, the specific technique of which depends on the instrument. Pianists might be expected to play more than 1800 notes per minute (Steinmetz et al, 2010); Mendelssohn's piano fantasy includes 72 bimanual finger movements per second and a total of 5.595 notes to be played in few minutes music (Nolet, 2013). A 20-year old performance-area student has already practiced up to 10.000 hours; upon graduation, the practicing hours reach up to 15.000 approximately (Ostwald, Baron, Byl, & Wilson, 1994; Steinmetz et al, 2010). Practicing, performing and rehearsing could occupy up to eight hours daily of an active musician's time; a regular orchestral performance runs approximately two hours and an opera more than three hours (Nolet, 2013). It is not surprising, then, that injury rates are very high among professional musicians (Bruno et al, 2008; Chan & Ackermann, 2014; Ioannou et al, 2015; Lederman, 2003; Mastnak, 2017; Rietveld, 2013; Steinmetz et al, 2010; Zaza et al, 1998).

i) Review

While playing-related injuries have been tormenting musicians for a long time, musicians' health did not received sufficient attention from health sciences. The first available source on musicians' diseases comes from 1713, when Bernardino Ramazzinin warned musicians on the damages that could be caused by exaggeration in practicing (Kok et al, 2016; Rosenbaum, Vanderzanden, Morse, & Uhl, 2012). There is a considerable gap in relevant bibliography until 1880s, a decade in which interest in musicians' health increased. Forbes published in 1884 a report on tenotomies of the accessory branch of the extensor digitorum communis muscle in pianists suffering from lack of dexterity in their fourth finger (Forbes, 1884). In 1887, Poor announced his research on pianists' occupational cramps, followed by Ortmann's "Physiological Mechanics of Piano Techniques" (1889), Wolff's work on violinists (1890), and

Turner's on cornetists (1893) (Dommerholt, 2009; Minneti, Ardigó, & McKee, 2007). Few new publications enriched the literature until 1932, when Singer published the first textbook on performing arts medicine, "Diseases of the Musical Profession: a systematic presentation of their causes, symptoms and methods of treatment". The following four-decade gap started gradually being covered since the 1970s with a steady increase in scientific literature focusing on musicians' health (Dommerholt, 2009).

It should be stressed here that the scientific interest in musicians' injuries was initiated via sports medicine, which opened the field for research on musicians' health and well-being. Music medicine took more than four decades to develop; currently, specialist clinics, performing arts medicine organizations, conferences and thousands of scientific publications are available to musicians, as it will be discussed in following sections (Dommerholt, 2009; Ledermann, 2003; Zaza et al, 1998). However, the existing literature is mainly concerned with the most prevalent types of pathology, while possible causes of injury are not considered and the methodology is rarely criticized. Moreover, the effect that poor body postures have on music performance and interpretation has received very little attention, possibly because of the difficulty of evaluating the artistic value of the performance (Blanco-Piñero et al, 2017).

ii) Statistics

Research findings suggest that high percentages of musicians suffer from playing-related musculoskeletal disorders (PRMDs), without, though, reaching a consensus on the actual percentage. In fact, the health of musicians is still a new scientific field. Scholars have expressed skepticism on the great variety in research methods and the lack of important methodological information in many recently published studies

(Blanco-Piñeiro et al, 2017; Kok et al, 2016). Nevertheless, the available information reveals alarmingly percentages of musicians affected by PRMDs.

In 1993, Quarrier estimated that 76% of musicians were affected by work-related medical problems. In the following year, a survey on American orchestral musicians showed that 82% had experienced playing-induced medical problems at some point, and 76% reported at least one serious health issue impeding their playing (Ostwald et al, 1994). Surveys on 485 orchestral musicians revealed that 64% suffered from playing-related pain, either recurring or permanent. A large-scale survey on 48 orchestras found that 58% of musicians reported a musculoskeletal problem, which was severe at some point in their career (Lederman, 2003).

Recent studies place the occurrence of PRMDs in musicians between 30% and 90%. Dommerholt mentioned that 72% of 672 musicians treated in a performing arts clinic were diagnosed with musculoskeletal disorders (Dommerholt, 2009). Steinmetz gave an alarming 80% percentage of musicians affected by PRMDs (Steinmetz et al, 2010). In the Netherlands, a country with approximately 13.000 professional and 1.600.000 amateur musicians, 60% of them had to stop playing their instrument entirely at some point due to playing-related musculoskeletal injuries (Rietveld, 2013). Research in USA showed that 80% of musicians suffered from occupational health injuries at some point in their career, while up to 40% were facing problems serious enough to deteriorate their playing (Nolet, 2013). Nawrocka et al (2014) raise the percentage of musicians affected by PRMDs to 97%, while Li, Savvidou, Willis, and Skubic (2014) showed that a 12% of affected musicians are forced to quit their profession permanently. A large epidemiological research on professional orchestral musicians revealed that 82% was experiencing medical problems attributed to their playing, and

76% was suffering by work-related health issues affecting their musical career (Ioannou et al, 2015).

A recent systematic literature review on musculoskeletal complaints among musicians presented worrying results: musculoskeletal complaints ranged between 9% to 68%; 12-month prevalence of playing-related complaints ranged between 41 and 93%; and lifetime prevalence of playing-related complaints varied from 62 to 93% (Kok et al, 2016). Beacon et al (2017) estimated the percentage of affected musicians between 39 and 47%, while Blanco- Piñeiro et al (2017), in a literature review of the same year, raised the numbers between 25 and 93%, with a percentage of 37% reporting disorders that prevent their performing to a serious extent The considerable variety of percentages shows the lack of consensus among researchers. It could possibly reveal the lack of solid epidemiological research on musicians' health and well-being.

iii) Student musicians

The disturbingly high percentages of affected musicians are not limited to professional performers only; research findings have shown that PRMDs appear early in the life of musicians. Music education starts as early as elementary school, given that playing a musical instrument on a professional level requires many years of intense, systematic training, and daily practice for the entire career of the musician. Interestingly, musculoskeletal pain has been reported to appear as early as the first years of training, in elementary school (Ioannou et al, 2015; Nawrocka et al, 2014; Stanhope, 2016).

In 1989 Fry and Rowley compared the prevalence of pain in students of two schools, a specialist music secondary school and a regular secondary school. The results showed that the prevalence of pain in the music school reached a percentage of 71%, while in the regular school it was placed at 50%. Music students attributed the appearance of pain in the playing of musical instruments, while regular school students reported as cause of pain activities such as writing and sports. Music students and professional instrumental musicians report significantly more musculoskeletal and neuromuscular disorders than teachers and amateurs (Lederman, 2003). More recently, rates of PRMDs in students were placed between 43 and 63% (Steinmetz, 2010), percentages high enough to call for measures taken against the danger PRMDs place on musicians' training and career.

iv) Pianists

Each instrument has its own specific characteristics and imposes different challenges to performers. Piano playing is a complex neuromuscular activity which requires the simultaneous execution of many movements and the participation of the whole body (Gong et al, 2014). It is physically very demanding in muscle strength, accuracy, and endurance. A considerable part of the standard piano repertoire requires the body of the pianist to reach the limits of its musculoskeletal and coordination systems, and motor capacities of the arm, since they include fast execution of notes, extreme levels of dynamics, wide chords, abrupt jumps and finger independence (Allsop & Ackland, 2010; Minetti et al, 2007). Professional and amateur pianists, along with string players and guitarists, are considered groups at high-risk for PRMDs. In these instrumental groups students approach the same percentage of injuries as professionals (Allsop & Ackland, 2010; Bruno et al, 2008; Dommerholt, 2009; Lederman, 2003). Research findings revealed that musculoskeletal disorders are the most common music-related injuries in pianists, while a survey showed that 65,1% of pianists were suffering from repetitive strain injury (Lai et al, 2015; Rosety-Rodriquez et al, 2003). Furuya, Aoki, Nakahara, and Kinoshita (2012) consider the prevalence of PRMDs in pianists as granted, mentioning that more than 60% of performers and teachers have been affected at some point.

The prevalence of upper extremity disorders in pianists reaches a percentage as high as 77,5% (Dommerholt, 2009). Instrumental practice is most often associated with pain in the neck and shoulder. Research on 214 musicians affected by PRMD showed that 137 had discomfort in the wrist, hand or finger, 109 in the neck or shoulder, 80 in the back, 56 in the forearm and elbow, and 12 in the upper arm (Allsop & Ackland, 2010). Piano players suffer from pain on neck, shoulders and wrist, and pain and weakness of intrinsic muscles as well (Gong et al, 2014). In a study conducted on piano students in 1989, 53% suffered from pain on neck and back, 22% from pain on forearm and wrist, and 21% from pain on shoulders and upper trapezius, while the findings were considered unusually frequent for young subjects (Grieco et al, 1989). Moreover, research on the incidence of tinnitus, impaired hearing and musculoskeletal disorders among music students in tertiary education revealed that pianists had a very high disorder rate (Hagberg et al, 2005).

The frequency of PRMDs among pianists is alarmingly high and calls for thorough research of this phenomenon. As it will be discussed in the following section, the studying of this subject poses significant difficulties concerning definition, specific characteristics and differentiation from other types of musculoskeletal disorders.

B. PRMDs

While the term "PRMD" has been widely used and accepted in recent years for describing the musculoskeletal ailments of musicians, the process of creating and establishing it was a rather complicated task.

Strong connections have been observed between musculoskeletal disorders and occupational ergonomic exposures such as repetitive motions, sustained static muscle loading, forced and awkward body postures, lack of rest or no sufficient rest, temperature, and high demand-low control jobs. The musculoskeletal disorders appearing due to these occupational ergonomic exposures are defined as work-related musculoskeletal disorders (WRMD) (Forde et al, 2002). According to the American Institute of Medicine, WRMD develop gradually in months or years, are a source of pain and disability for the worker, cause absence from work and loss of employment (Bruno et al, 2008).

Similarly to other occupational workers, such as line workers and computer keyboardists, musicians' musculoskeletal system is severely affected by their work (Zaza, 1998). The seemingly harmless activity of playing a musical instrument could prove to be hazardous for the musculoskeletal system of the performers (Nawrocka et al, 2014). The music equivalent of WRMD is "Playing-Related Musculoskeletal Disorders" (PRMDs), first defined by Zaza et al in 1998 (Bruno et al, 2008). This term, at present widely accepted and used, is based on Zaza's research and describes musicians' disorders as any pain, weakness, numbness, tingling or other physical symptoms interfering with musicians' ability to play their instrument at the level they are accustomed, excluding mild transient aches or pains (Ackerman et al, 2012).

Musicians report that PRMDs impair the performance; their symptoms are chronic, unusual, and severe to the point of being characterized as "excruciating," "burning," and "horrible"; they are defined by the musician, since the player is the first and often the only person to notice something different in his/her sense of normality when playing; they are beyond the control of the musician; they are considered serious problems because they affect musicians' profession: if they would not intervene with playing, musicians would not paid much attention to them (Zaza et al, 1998).

Reaching a solid and universally accepted definition of PRMDs is not an easy task. Zaza, who was the first to define PRMD, had to rely on musicians as experts on defining PRMD, since there were no golden standard criteria for WRMD and musculoskeletal disorders in the first place. Zaza mentioned that injured instrumentalists were not able to clarify the criteria they used to define themselves as injured, nor to set the point of injury onset (Zaza et al, 1998). Ioannou et al (2015) noted that 11% of the participants in their study could not clarify if their pain was attributed to playing. Furthermore, it is not currently possible to rely on WRMD research for definition and criteria, because WRMD researchers argue about common epidemiological endpoints. In addition, there is no consensus yet on WRMD symptoms, physical examination findings, and if they show pathogenic developments at the tissue and cellular levels. Similarly to musicians, the symptoms describing WRMD in other occupations are self-reported. In WRMD, various stages of progress have been clinically observed, ranging from very gradual (weeks, months) to sudden worsening within days or hours. However, it is not known how the slow or fast progress of the disorder is connected to the type and intensity of exposure to risk factors, the body part affected and the pathology mechanisms. Under these circumstances, a clear understanding of the pathogenesis of WRMD would be crucial for achieving appropriate diagnosis, detecting risk factors, and developing treatment and prevention strategies (Forde et al, 2002; Zaza et al, 1998), but research has not reached this stage yet. Consequently, the same arguments apply to PRMDs, the music equivalent of WRMD.

The term PRMD describes pain and musculoskeletal disorders and refers to mechanical strain and soft tissue conditions such as muscle, ligament and tendon related to it, and also bone, cartilage and nerves. Diagnoses include acute tendonitis, de Quervain's disease, Depyutren's contracture, rotator cuff syndrome, carpal tunnel syndrome, tennis player's elbow, and focal dystonia among others. When the symptoms do not allow the diagnoses mentioned above, the terms "overuse syndrome" or "repetitive strain injury" are often used to indicate microtraumas to muscles and ligaments. (Allsop & Ackland, 2010; Furuya et al, 2012; Nawrocka et al, 2014; Steinmetz et al, 2015; Zaza, 1998).

Lederman stresses that only one-third of instrumentalists' musculoskeletal disorders can be specifically diagnosed, including shoulder impingement, rotator cuff disruption, and ligament sprain encompassing joint hypelaxivity, tendinits, tenosynovitis, arthritis and epicondylitis. The remaining two-thirds are classified as "overuse traumas/syndromes" because a specific, clarified diagnosis cannot be reached (Lederman, 2003). In fact, the terms "overuse", "repetitive strain injury" and "cumulative trauma disorder" have raised controversy, because they assume a casual relationship which has not been justified yet by any epidemiological evidence. They are considered imprecise and they suggest knowledge related to pathogenesis that may or may not be scientifically proved yet (Gong et al, 2014; Lederman, 2003).

Taking the above into consideration, the aggregated term PRMD is thought as more appropriate for covering musicians' injuries and is used more extensively in recent years (Gong et al, 2014; Lederman, 2003; Zaza et al, 1998).

Depending on the instrument played, pain appears in different body areas, because each instrument imposes different strains to the human body (Dick et al, 2013; Ioannou et al, 2012). Most affected body parts are the neck, upper extremities and lumbar spine; the most affected part in all instrumental groups, apart from brass, is the back (Ioannou et al, 2015). Musicians complain of pain, tenderness, tightness, stiffness, cramping, fatigue, swelling, numbness, perceived impaired motor control, and actual degradation of motor performance (Lederman, 2013; Steinmetz et al, 2015; Zaza, 1998).

Pianists are reportedly at high risk for PRMD. Students, teachers and performers suffer from occupational disorders ranging from acute pain to serious problems like tendonitis, carpal tunnel syndrome, radial nerve compression at the elbow, focal dystonia, and back pain, conditions that have a considerable impact on the affected musicians (Allsop & Ackland, 2010; Bruno et al, 2008) .

The piano-specific factors causing PRMDs are not fully researched and understood yet. Despite the fast growing bibliography and research on ailments of the hand, very few studies have been conducted on the biomechanical factors influencing the physiological load imposed on the upper-extremity muscles by piano playing. The lack of sufficient scientific research on PRMD impedes significantly the prevention and treatment of the most prominent disorders affecting pianists (Allsop & Ackland, 2010; Bruno et al, 2008; Lai et al, 2015).

C. CAUSE

PRMDs are currently accepted as complex, multi-factorial problems affecting significantly the professional and social life of musicians (Dommerholt, 2009). Research has shown that in music, as in any occupation, various human factors and environmental limitations might be connected with the appearance of work-related musculoskeletal disorders (Lai et al, 2015; Linton, 2000). Risk factors commonly reported by musicians are occupational environment, i.e. lack of space and temperature, poor practice habits, over-practicing, biomechanical, psychological, and psychosocial factors. Nevertheless, the cause of these disorders is not fully understood yet, and is still difficult to be explained (Ackermann et al, 2012; Carter and Grahn, 2016; Dommerholt, 2009; Kenny & Ackermann, 2015; Linton, 2000; Mastnak, 2017; Ostwald et al, 1994).

Risk factors

Similarly to a large number of occupations including surgeons, journalists, secretaries and occupational therapists, musicians use their upper extremities in a repetitive, intense, forceful and often awkward manner (Pascarelli & Hsu, 2001). Depending on the shape and type of the instrument and the body characteristics of the performer the playing of an instrument imposes several health risks on the performer (Ostwald et al, 1994).

According to performers, the most dangerous risk factors related with the appearance of PRMDs could be divided in two categories. The first category includes factors under the control of the musician: poor postures, excessive playing force, excessive muscle tension during playing, muscle fatigue caused by playing, inappropriate techniques including practicing habits and learning strategies, long practicing sessions, insufficient resting time, intense training, and previous injuries (Ackermann et al, 2012; Bruno et al, 2008; Carter & Grahn, 2016; Ioannou et al, 2015; Kok et al, 2017; Linton, 2000; Mastnak, 2017; Nawrocka et al, 2014; Zaza et al, 1998). In the second category are conditions beyond musician's control: inadequate work conditions, lack of control over several aspects of their profession including insufficient/poor lighting, improper chairs and lack of space, competitive and stressful work environment, cutbacks in funding to the arts which lead to more shifts per day, overloaded schedules and excessive touring.

These conditions affect significantly the quality of movement and might cause awkward body postures. Furthermore, lack of education on injury prevention leaves musicians unprotected from the hazards of their profession (Dommerholt, 2009; Zaza et al, 1998).

Kenny and Ackermann's population study on instrumental musicians showed that, concerning pianists, there is still lack of evidence sufficient enough to define risk factors in pianists' PRMDs, even though the rate of disorders is very high among this instrumental group (Allsop & Ackland, 2010; Bruno et al, 2008; Kenny & Ackermann, 2013). Pianists specifically report insufficient warm-up time, long practicing sessions, lack of rest, awkward body postures and static muscular activity as most common piano-specific risk factors, but the relationship of these factors to the appearance of PRMDs is not well understood yet (Bruno et al, 2008).

The relevant bibliography and available research findings concerning PRMDs are still relatively limited, despite the increasing scientific interest on the area of performing arts medicine. Research on pianists' PRKD risk factors currently examines the specifics of playing the instrument, posture, early training, practice habits, piano training, health specialists, anthropometrics, work environment, psychological factors and music genre, which will be further discussed in the following sections.

i) Playing the instrument (piano)

Static load

It is essential to study the impact piano playing has on the human body, even in ideal circumstances in order to examine the possible appearance of significant musculoskeletal loads and their impact on the body of the performer.

Piano playing requires the body to sustain prolonged static postures for long practicing sessions. Since piano benches do not include armrests and chair backs, pianists hold their trunk and arms without support subjecting their bodies to early onset of structural stabilization fatigue (Grieco et al, 1989; Li et al, 2014; McAttamney & Corlett, 1993; Quarrier, 1993). Muscular imbalance is then created because, in order to maintain the static posture, some muscles are forced to overwork, causing hypertrophy, while some others are underused, leading to weakening. Reduced peripheral circulation and myalgia appear on overused muscles, calling for restoration of muscle balances and strengthening of underused muscles. Long maintenance of abnormal or prolonged static postures increases the pressure around peripheral nerves or stresses them; this causes more tension within the nerve, resulting in chronic nerve compression (Forde & Punnet, 2008). Furthermore, imbalanced loading of the musculoskeletal system often causes faulty postures when applied to the non-fully developed body of young musicians (Nawrocka & Wołyńska-Ślężyńska, 2008).

Recent research indicates that static loading of the spine is a risk factor for the development of low back pain (Youssef et al, 2008), which is a common complain among pianists (Steinmetz et al, 2010). Prolonged static flexion has been shown to cause growth of creep in the lumbar viscoelastic tissues; this, in turn, is linked with spasms in multifidus muscles and decreased reflexive muscular activity. In addition, it is suggested that periods of static load, insufficient rest between work sessions, repetitive actions, and long duration of work might cause acute inflammation and neuromascular disorder in lumbar spine (Youssef et al, 2008).

In addition, it has been proposed that long periods of static load or forced postures and playing-induced static contraction result in postural abnormalities, which, when co-exist with repetitive motions, create a biomechanical risk factor (Bruno et al, 2008;

Nawrocka & Wołyńska-Ślężyńska, 2008). Piano playing charges the body with static muscle activity and then increases energy expenditure, repetitive movements, and activation of the same muscle groups in a range far exceeding the physiological for these muscles. Eventually, the body is forced to undergo through pathological changes of the musculoskeletal system, and pain appears (Nawrocka et al, 2014), even if pianists possess the perfect technique and work in ideal environments.

Muscle activity

In a simple description, piano playing consists of pressing and releasing the keys. This seemly uncomplicated task, though, demands sufficient technique and long training.

Piano playing requires distal muscular activity. Distal muscles with smaller physiological cross-sectional area are more easily subjected to fatigue than proximal muscles. The onset of fatigue causes loss of control and precision in finger movements, reduction of key-depression force and deterioration of the quality of the performance. At this point, PRMDs start developing (Furuya & Kinoshita, 2008; Quarrier, 1993). Consequently, it is crucial to avoid fatigue at the distal muscles. However, ability to reduce fatigue comes late in a pianists' life, as revealed by research on expert and novice pianists (Furuya & Kinoshita, 2008). When preparing a keystroke, before touching the key, expert pianists had more translational deceleration of the upper arm than novices, initiating greater interaction torques at the elbow and wrist joints. During keystroke, experts presented considerable shoulder flexion and burst of muscular activity in anterior deltoids and biceps muscles, combined with a forward rotation of the finger at the metacarpophalangeal and wrist joints. Novices pressed the key showing a small amount of shoulder and elbow extension, in a manner quite similar to pressing a computer key; moreover, the adaptation of inter-segmental dynamics significantly reduced the physiological efficiency of the muscles. Comparisons of attack-angle formation also indicated that experts had lower levels of muscle coactivation, and stiffness at the joints of wrist and hand than the novices (Furuya & Kinoshita, 2008).

Experts need many years of training to master the synergistically planned multi-joint limb movements which will allow them to reduce the biomechanical load and the muscular effort applied to distal muscles. The novices seem to use a basic synergy of joint motion which originates in everyday-life activities. This synergy, though, given the repetitive nature of piano playing and practicing, could gradually damage muscles, tendons and joints of the upper limbs over time, eventually causing PRMDs (Furuya & Kinoshita, 2008).

Use of gravity

Another seemingly uncomplicated aspect of piano playing, the downswing of the arms, has been related to PRMDs. In 1987, Hmelnitsky and Nettheim suggested that pianists should not support their arms on the keyboard by using the biceps and triceps, but using the force of gravity instead. Gravity, then, would be opposed by the keyboard, the ligamentous integrity of the arm, and the muscle action which stabilizes wrist and fingers. This playing technique, known as "weight-playing", incorporates appropriate use of gravity and it has been suggested that it could possibly prevent overuse syndromes in pianists (Hmelnitsky & Nettheim, 1987).

Furuya, Osu and Kinoshita (2009) researched the same topic focusing on the use of gravity during downswing of the arm in expert and novice piano players. They found that during downswing of the arm expert pianists, in contrast to novice players, limited the anti-gravity muscles (biceps), while they kept the activation of the agonist muscles (triceps) close to the resting level; this way, the elbow extension torque was generated by gravity. To produce high levels of loudness, a larger de-activation of anti-gravity muscles allowed for the use of a greater amount of gravity, in order to increase the movement speed of arm descend and produce bigger sound (Furuya, Osu, & Kinoshita, 2009).

It is suggested by Furuya et al that pianists need many years of training to achieve a transfer from muscular force dependency to gravity dependency in order to initiate a target joint torque. Eventually, pianists reach a level where they are capable to improve the physiological efficiency of limp movement by using non-muscular forces, especially gravity (Furuya et al, 2009); this way, unnecessary muscle work and fatigue are reduced significantly. Given that this ability comes after long years of specialized training, novice players are inevitably exposed to danger for the appearance of PRMDs for a considerable amount of time.

Tempo and loudness

The ability to produce a wide range of tempi and dynamics from the instrument is one of the basic skills of a pianist. Research has shown that the practical application of this skill is not without its risks. Studies on the effect of tempo and loudness on the pianist's joint velocity and muscular activity revealed that the simultaneous increase of loudness and tempo caused increase of mean activity of the upper extremity muscles, and large velocities at the shoulder, wrist and finger joints. The joint stiffness that follows the rising of muscular activity is, however, necessary for achieving movement accuracy, a crucial aspect of piano playing. In other words, to reach a high level of accuracy, pianists should impose a certain amount of stiffness on their upper arm joints (Furuya et al, 2012).

Research on pianists' muscle activity during various levels of loudness and tempo showed that in regular levels, the triceps significantly reduced their activity and used the help of gravity to control the falling of the arm on the keyboard. When tempo and loudness were increased, though, the triceps failed to use gravity and the arm moved from gravity-driven keystrokes to muscular-driven keystrokes. This resulted in increased muscular activity at the elbow, which caused joint stiffness and, eventually, fatigue (Furuya et al, 2012).

Concerning the elbow, Furuya et al (2012) noted that while muscular activity was increasing, joint velocity was decreasing. Given that mechanical interaction appears between two linked segments, a joint motion initiates from the torque produced by its surrounding muscles and from torque produced at the adjacent joints as well. To execute a planned movement with accuracy, muscular torque has to compensate for these inter-segmental dynamics. When tempo and loudness increase, inter-segmental dynamics increase, too, forcing the muscles to enhance their compensatory work while decreasing joint velocity.

These results suggest that the most physiologically-efficient manner to perform fast tempi in high levels of loudness is to decrease muscular activity and reduce muscle co-activation, in order to avoid joint stiffness and muscle fatigue (Furuya et al, 2012). Again, because pianists achieve this level of muscle control after many years of training, the risk for developing PRMDs is considerably increased during their learning years.

Evolution of the instrument

The piano has undergone radical development during the past three centuries, reaching its current form in late nineteenth century. Pianists tackle more than three hundred years of music on an instrument much younger than a considerable bulk of its repertoire. In fact, an important amount of music played today on the piano was not written for the piano or the modern piano at all.

The modern piano has grown considerably in size, its mechanism is more sensitive and fast in responding, produces more power and volume of sound and possesses a much greater range of dynamics than its predecessors. Moreover, it has a heavier touch weight of 52g, compared to 34g of earlier pianos. These improvements, though, do not change the fact that the core of piano repertoire was composed before mid-nineteenth century. This imposes serious technical difficulties on the pianists, obliging them to adapt music written for an instrument with light mechanism to its much stronger descendant built with different action mechanism and considerably heavier touch weight (Allsop & Ackland, 2010; Kirby, 1994). Furthermore, given the expansion of modern concert halls, pianists are expected to produce a much larger sound than eighteenth and early-nineteenth century composers intended for their music. Unsurprisingly, fatigue and pain are commonly appearing, and more severe cases of PRMDs might develop.

ii) Posture

Even though the risk factors mentioned in previous sections are considered crucial for the appearance and development of PRMDs in pianists, the factor most frequently reported by musicians and researchers as responsible for PRMDs is poor posture (Bruno et al, 2008; Chan and Ackermann, 2004; Gong et al, 2014; Grieco et al, 1989; Ioannou et al, 2015; Kok et al, 2017; Li et al, 2014; Libin, 2016; Mastnak, 2017; McAttemney & Corlett, 1993; Nawrocka et al, 2014; Ostwald et al, 1994; Quarrier, 1993; Rietveld, 2013; Stanhope, 2016; Steinmetz et al, 2010).

The lack of armrests and chairbacks in piano benches obliges pianists to sit without external support of the upper body, a posture which demands efficient control of the trunk and the head for maintaining their body of mass over the base of support (Curtis et al, 2015). Musicians commonly hold non-ideal postures because of the design of the instrument and/or insufficient technique (Chan & Ackermann, 2004; Dommerholt, 2010; Libin, 2016). During long-hour piano practicing or performing in unsupported sitting postures the initial correct posture will inevitably transform to slump, awkward positions (Grieco et al, 1989). These postures, though, require higher levels of muscle activation in order to support the musician (Quarrier, 1993), while, at the same time, muscles have to compensate for reduced balance and control in adjacent muscles and joint torques. Non-ideal postures may increase static loading and stress of the musculoskeletal structures leading to earlier muscular fatigue and excessive muscular tension and creating, eventually, a higher risk of developing PRMDs (Chan & Ackermann, 2014).

When maintaining non-ideal postures for long periods of time the spinal structures are forced to take non-ideal positions and the muscles become overloaded. The addition of dynamic and assymetrical stressors caused by playing the instrument enhances further the effect these postures have on static load (Chan & Ackermann, 2014; Nawrocka et al, 2014). The accumulation of these factors might accelerate degenerative processes in spinal motion segments and contribute to the development of dysfunction and pain. Consequently, sustained poor postures can be considered a potential cause of injury to musculoskeletal structures (Chan & Ackermann, 2014).

Recent research suggests that flexed posture causes appearance of creep in the viscoelastic tissues which affects spinal stability and the reflexive activation of muscles. Because of the appearance of creep, lumbar and thoracic muscles respond in delay to sudden perturbations of the spine deteriorating its stability and possibly exposing it to injuries. In addition, the creep appearing in viscoelastic tissues after 20 minutes of prolonged flexion moment in sitting posture requires more than 30 minutes of rest for complete recovery. Research findings also suggest that five minutes in a slouched posture may alter significantly the sense of lumbar spine reposition in healthy subjects. This affects mechanisms responsible for protecting the spine from excessive loading and injury, thus associating flexed postures with pain and pathology on the spinal regions (Korakakis, 2012).

Poor postures could affect the neuromuscular system, thus leading to inferior performances (Chan & Ackermann, 2014). Youssef et al (2008) showed that the application of static load on flexed lumbar spine causes laxity in the associated viscoelastic tissues and increases significantly the displacement and tension of the neuromuscular neutral zone. As a result, the spinal stability deteriorates during post-loading period (Korakakis, 2012; Youssef et al, 2008). The displacement of the neuromuscular neutral zone takes no less than seven hours to recover, while mechanisms compensating for the increases in displacement tension and the laxity of viscoelastic tissues supporting the stability of the spine start functioning two-to three hours after the static load. For this period of time, first, the body is exposed to injury, and second, the deficiency of viscoelastic tissues and muscles cannot guarantee spinal stability, exposing the spine to injury risks (Youssef et al, 2008).

According to recent research, ergonomic playing postures allow pianists to play more fluently and control their performance more efficiently. Therefore, postural alignment could possibly play a very important role in the development or not of PRMD in pianists (Beacon et al, 2017). As shown in a study on patients with work-related upper extremity pain, including musicians, most subjects showed postural misalignment of shoulders and back. Specifically, the authors noted protracted or rounded shoulders; protruded head and neck; extreme tightness of upper trapezius muscles and active compensatory recruitment of upper trapezius muscles; scapular winging linked with weakness of scapular stabilizers; limitation of shoulder range of motion followed by distortions of the scapulohumeral rhythm and the standard reciprocal muscle action in the upper-back shoulder and arm; and impaired forward flexion, abduction and internal and external rotations of the shoulders. Musicians participating on this research were mostly diagnosed with postural misalignment, thoracic outlet syndrome and medial epicondylitis (Pascarelli & Hsu, 2001).

A posture often adopted by pianists, the antero-position of the head, could cause myalgia of trapezius descendens. If the shoulder blades are not well-stabilized, the pectoralis minor muscle pulls them up and forward, instead of functioning as an accessory breathing muscle; the chest is then rised and the shoulders lifted. This faulty posture, which entraps the brachial plexus nerve, could possibly explain the high frequency of thoracic outlet syndrome in musicians (Rietveld, 2013).

Research conducted by Ioannou et al (2015) revealed that 93% of musicians suffering from PRMDs had dysfunctions of postural stabilization, showing impairments of the lumbopelvic stabilization system and the scapula and upper cross syndrome. The fact that musicians with PRMDs also often report pain on the shoulders and lower back (Steinmetz et al, 2010), makes it essential to examine the connection of the stabilization system to low back pain in musicians .

Body's stabilization system is crucial for the normal function of arms and shoulders. Stabilization of the lumbopelvic region is largely based on deep muscles, which also greatly contribute in the body's equilibrium against gravity and the postural load of limb movements. This stabilization is achieved by the collaborative activity of the transverse abdominal muscle, the deep layer of multifidus muscles, the diaphragm and the pelvic floor muscles. When these muscle groups contract, intraabdominal pressure increases, helping the stabilization of the lumbar spine. Moreover, the contraction of the transverse abdominal and the multifidus muscles causes growing of tension of the thoracolumbar fascia, further strengthening spinal stability. The lumbopelvic stabilization system stabilizes the function of the shoulder and arms via the fascia thoracolumbalis and the latissimus dorsi muscles, which form the fascial system that connects the shoulder girdle with the spine and the pelvic girdle regions (Steinmetz et al, 2010).

It has been observed that patients with low back pain suffer from impaired lumbopelvic stabilization systems. They present delayed contraction patterns in transverse abdominal muscle, a break of the flexion-relaxation phenomenon, and a continual activation of the lumbar extensors in full flexion. Also, there is evidence of atrophy and wasting of segmental multifidus muscles and adipose tissue infiltration. Additionally, impaired function of deep stabilizing muscles triggers an adaptation mechanism which recruits more superficial and global muscles (Steinmetz et al, 2010).

Steinmetz's study showed a high frequency of postural stabilization impairments in musicians with PRMD. 93% of the participants presented dysfunctions in one or more postural stabilization systems; occupational factors specific to musicians possibly contributed to these findings. Pianists maintain static postures for hours, while performing complex, rapid and repetitive precise motor tasks with great precision. Non-ideal postures adopted because of working conditions and/or the specifics of the instrument cause lumbosacral instability. This may lead to unsuitably increased activation of superficial and global muscles, as well as to pain or dysfunction in other areas such as the shoulder, apart from lower back. Indeed, the shoulder is at risk for painful musculoskeletal dysfunction when superficial muscles show hyperactivity. In fact, PRMDs in musicians are located mostly on the spine and the shoulder area (Steinmetz et al, 2010), making the importance of proper body posture more essential for the prevention of PRMDs. However, it is questioned if the majority of musicians are aware of the significance appropriate posture has for their well-being, and if their training touches this subject.

The majority of piano methods for beginners present in their very first pages guidance for the posture of the body on the instrument and the position of the hands on it, either with beautifully drawn pictures or high-quality photos demonstrating a pianist's desired sitting posture (see Appendix). These guidelines, though, do not reappear in next level methods, despite the fact that a pianist commonly needs at least three years of training to leave the stage of "beginner". Moreover, the standard methods of exercises and technique completely neglect the subject of body posture; any instruction offered concerns solely hand and fingers (i.e. C.L. Hanon, O. Beringer, or J. Pischna). As a result, pianists focus on the work of fingers paying little attention to their posture.

The issue of appropriate posture

Pianists naturally assume their habitual sitting posture when sitting on the piano. As recent studies suggest, habitual sitting postures are usually flexed. However, the impact of sustained flexed postures requires a long time of rest for recovery, or it is not reversed (Korakakis, 2012), making it crucial for pianists to avoid these postures. Postures with kyphotic lumbar spine curve were found to require less muscle activity, but they cause greater stress to spinal structures. Postures with flat, short and long lordosis lumbar curves require middle ranges from the lumbar joints. Mid-range, low-load postures do not apply extreme stress to ligaments; on the other side, it has been shown that they are more demanding on the neuromascular control than end-range or high-load tasks. Moreover, a deficit in one aspect of neuromuscular control could possibly be a predictor for consequent development of back pain. In comparison with other sitting postures (long lordosis, short lordosis, slump) flat posture achieved more efficient sagittal and mechanical balance of the spine, applied considerably less stress to articular and ligamentous systems, and demonstrated the least muscle activity. Nevertheless, this posture is not universally accepted as the best sitting posture (Claus, Hides, Moseley, & Hodges, 2009b; Korakakis, Sideris, & Giakas, 2014). Consequently, to avoid PRMDs pianists should adopt the most appropriate sitting posture which, at the moment, has not been definitively defined yet.

An appropriate posture would apply the least possible amount of stress and strain on the body achieving maximal efficiency in the use of it. Postures concerning a specific task require collaboration and interaction between biomechanics and the neuromuscular system. It is stressed again here that a universally acceptable definition of good spinal posture has not been reached yet; currently, the accepted and proposed postures still lack sufficient scientific basis (Claus, Hides, Moseley, & Hodges, 2009a). Optimal sitting posture is often described as a position in which the lumbar spine retains its position in standing; however, recent findings revealed that standing requires less flexion in the lumbar spine than sitting, so standing position of the spine cannot be the rule for sitting (Korakakis, 2012).

In addition, research findings suggest that any changes in the thoracolumbar and lumbar spinal curves affect muscle activity and its magnitude, especially in the deep and superficial areas of lumbar multifidus, the main stabilizing muscle of the spine (Claus et al, 2009b). The result is deterioration of the stabilization system and exposure of the body to injury. Indeed, the high percentage of pianists suffering from back pain, as mentioned in previous sections, seems to prove these findings.

Defining the ideal sitting posture still poses difficulties. In fact, it is questioned whether an ideal sitting posture exists and if it is realistically achievable. Claus et al (2009b) examined if the proposed ideal standing posture, in which lumbar spine is in short lordosis curve, could be kept for one hour in sitting position. The results showed that in order to achieve short lordosis when sitting, facilitation and feedback were needed, and was not possible to sustain the position for the asked amount of time. Korakakis et al (2014), though, showed that postural education is possible and has positive results, which reveals that pianists indeed could learn appropriate sitting postures, provided their training touches the subject of posture.

iii) Early training

Musicians undergo intense, extensive training from an early age in order to acquire the high skills required for their profession (Fry & Rowley, 1989; Gong et al, 2014; Furuya, Tominaga, Miyazaki, & Altenmüller, 2015; Nawrocka et al, 2014). Musical training starts usually at elementary school subjecting the bodies of young students to static and dynamic load bearings, repetitive movements, excessive muscle activation and extreme body postures. Examinations, competitions, pressure, high demands from parents and teachers, long hours of practice at home without supervision consist a young musician's reality almost from the beginning of musical studies. As a result, the still developing body of the child faces a high possibility of damage; indeed, young musicians complain more often about musculoskeletal pain than adult professionals.

Long practicing sessions are common among talented young pianists, but they have negative effects on the young hands. Gong et al (2014) searched the impact of extensive piano practicing in young students (8-12 years old) reporting radial collateral ligament injury in the fifth finger of the right hand. All participants were working on advanced repertoire, despite their young age. The results suggested that the injury was probably caused by extensive stress on the joint imposed by piano playing. The authors concluded that small hands and, consequently, young performers are more subjected to musculoskeletal injuries given that they must abduct the thumb more, predisposing de Quervain disease (Gong et al, 2014). Nevertheless, it seems that personal, parental and teacher expectations rarely consider young pianists' body development (Nawrocka et al, 2014). The choice of repertoire which is challenging and inappropriate for young pianists' body results in overloading of their musculoskeletal system, especially when combined with long practicing sessions (Allsop & Ackland, 2010), leading to early appearance of PRMDs.

iv) Practice habits

Effective use of practicing time is a big challenge for instrumental musicians, especially the young ones. Music students usually attend instrumental lessons once per week and are expected to practice at home without further supervision and counseling for the rest of the week. They are expected to work on their own, and the most dedicated students often engage in practicing sessions that may exceed five hours per day.

Research on practice habits of teenaged music students revealed that they opted for long practicing sessions during which they used inappropriate technique, played with excessive, wasteful muscular effort and tension, and neglected or ignored the importance of rest, despite the fact that lack of rest/sufficient resting time is considered an important risk factor for the appearance of PRMDs (Ackermann et al, 2012; Ericsson, Krampe, & Tesch-Römer, 1993; Fry & Rowley, 1989; Ioannou et al, 2015; Kenny & Ackermann, 2013; Li et al, 2014; McAttamney & Corlett, 1993; Rosenbaum et al, 2012; Zosso & Schoeb, 2012). Several studies have shown that piano students are not aware that several of their practicing habits are actually hazardous for their physical health. These habits, many of which are common among musicians, possibly originate in elementary piano lessons (Allsop & Ackland, 2010).

Traditional music training is based on repetition of the same passage until it reaches a satisfactory level of expertise, a technique called "blocked practice" (Carter & Grahn, 2016). The general attitude is that a considerable amount of practice time will lead to the highest possible performance level (Ericsson et al, 1993). Moreover, intense playing is very common among music students. Young students commonly insist on intensely working on a difficult passage causing more damage by the applied tension than by the duration of practice (Fry & Rowley, 1989). The significantly high percentage of musicians suffering from repetitive strain injury caused mainly by repetition of movements reveals the necessity for change of attitudes and habits in music learning (Carter & Grahn, 2016).

It has been observed that difficult passages do not improve by simple repetition. On the contrary, it has been suggested that inadequate techniques are responsible for insufficient progress and that more complex learning strategies are needed in order to achieve maximal performance. Instead of blocked practice, students should opt for focusing intensely at the music score and trying to find solutions for the technical problems without relying in time-consuming repetitions. This technique is called deliberate practice (Ericsson et al, 1993), summarized as an "activity that requires substantial effort, is not inherently enjoyable, is highly relevant, and will result in maximal improvement in performance. Engagement in such activities can only occur for a limited amount of time per day due to fatigue and burnout consideration" (Horton et al, 2008). This approach is the exact opposite of the long, repetitive practicing sessions young musicians go through every day.

An interesting aspect of practicing a musical instrument is its strong connection with pain. Musicians actually learn to play through pain early in their training and grow up surprisingly tolerant to it (Dommerholt, 2009). Unfortunately, most of the time pain appears after practicing; in this case, the musician has been working over the threshold of pain without realizing it (Rietveld, 2013). Teachers invariably repeat the phrase "no pain, no gain" establishing an attitude of pain acceptance which endures for the rest of the professional life of the young individuals (Ioannou et al, 2015; Quarrier, 1993; Rosenbaum et al, 2012). Research on classical piano students found that 64% of the participants believed that a certain amount of pain is acceptable when working on a difficult section (Bruno et al, 2008). Teenaged musicians habitually practice through pain and often experience pain during resting time, which shows that their musculoskeletal structures have not been allowed enough time for recovery from the high demands of playing (Fry and Rowley, 1989). Furthermore, it has been shown that alterations in muscle recruitment patterns occur in cervical spine in the presence of pain; these alterations have been linked with deviations in normal movement patterns and control of joints (Szeto, Straker, & O'Sullivan, 2005), eventually deteriorating the quality of performance.

Despite severe symptoms of musculoskeletal disorders, performers commonly continue practicing and playing through pain until they can manage it no longer; by that point, though, the harm is often non-reversible (Hagberg et al, 2005; Chan & Ackermann, 2014). Music teachers and professional musicians alike do not consider the appearance of playing-induced pain dangerous or alerting enough for taking take appropriate measures such as reduce practicing hours, consult a health specialist or cease playing for a period of time (Zosso & Schoeb, 2012). Many musicians consider pain a necessary or even desirable aspect of their practicing and believe that its existence is absolutely necessary in achieving high level of performance. Consequently, they ignore pain either consciously or unconsciously (Dommerholt, 2009).

This unusual tolerance of pain could stem by a widespread belief among instrumentalists according to which physical problems and injuries do not concern artists. They either ignore them or neglect them, postponing consultation and therapy. This attitude, though, leads to worsening of the symptoms and could potentially end the musician's career (Hagberg et al, 2005). It should also be kept in mind that in the music world injuries are often thought as a sign of inferior technique and lesser professional abilities, so musicians are very reluctant to reveal them (Chan & Ackermann, 2014; Dommerholt, 2009). Moreover, musicians' attitude towards their job could offer another explanation for the acceptance of pain. In their own words, it is more than a job: their whole life grows around it and they are addicted to long hour practicing sessions and stage performance, giving all their energy and internal power to their occupation. This admirable dedication, however, turns them blind to alerting symptoms including pain, possibly causing PRMDs in the long term (Zosso & Schoeb, 2012).

v) Piano training – Musicians as athletes

The high occurrence of PRMDs among musicians in combination with several hazardous practice habits exercised on a daily basis calls for evaluation of instrumental education. It is questioned if risk factors are addressed, practicing guidelines and learning techniques given, essential information on anatomy and body function offered, demands of the instrument on the body explained, PRMDs mentioned, and prevention and treatment discussed. This section will focus on instrumental education searching its efficiency in preparing aspiring musicians for a life-long career in music.

The high demands the musical profession imposes on performers' health combined with the physical skills and training necessary for elite performance, have recently led many researches to consider performing artists as athletes (Ackerman et al, 2012; Bruno et al, 2008; Chan & Ackermann, 2014; Dick et al, 2013; Mastnak, 2017; Quarrier, 1993; Stanhope, 2016). Both start intense training early in life, practice hard every day, have very little vacation time, compete often and in challenging conditions, face career-threatening injuries, perform through pain, undergo daily routines that include performing, eating and sleeping in unconventional hours. Similarly to sports, where an athlete's body is his/her most important instrument, the body of the musician is the primary and most essential instrument of the performance; consequently, it should be treated accordingly (Dick et al, 2013). In reality, musicians' bodies are rarely prepared and trained to deal with the requirements of their profession. On the contrary, musicians are commonly plagued by poor physical fitness, poor posture and faulty muscle use; unsurprisingly, they often suffer from injuries (Rietveld, 2013).

Despite the athletic demands of their profession, musicians rarely receive or posses the appropriate education and medical awareness to cope with them. They often have insufficient, if any, knowledge on their body and its limits, ignoring the impact cumulative exposures such as prolonged sitting or standing and awkward postures have on their bodies (Chan & Ackermann, 2014; Lai et al, 2015; Stanhope, 2016; Zosso & Schoeb, 2012). Compared to athletes, professional musicians and teachers alike often lack appropriate anatomical knowledge or have a vague understanding of basic body mechanisms (Wood, 2014). Moreover, music training stops upon graduation; after that, there is no supervision and help. Inappropriate techniques and poor practicing habits remain untreated; the accumulation of their negative effects on the body causes, sooner or later, PRMDs (Stanhope, 2016). Appropriate practicing techniques and organization, endurance of the body, nutrition and hydration, significance of rest, injury prevention, proper injury treatment strategies and recovery, are not known to the majority of professional musicians, teachers and students alike, resulting in a high incidence of musculoskeletal injuries among them (Chan & Ackermann, 2014; Dick et al, 2013; Stanhope, 2016). In addition, they are usually not involved in other types of training to support their main musical training, as athletes do. As a result, they suffer from injuries since they do not possess the general and specific physical fitness necessary for the demands of their occupation (Chan & Ackermann, 2014).

vi) Health specialists

A serious problem in the musical world is the lack of health specialists understanding the specific needs of musicians' profession and, equally important, the lack of health insurance (Chan & Ackermann, 2014; Dommerholt, 2009; Wood, 2014). The culture of silence surrounding occupational health issues of musicians complicates their approach. The general viewing of music-making as a non health-threatening activity, even among professional musicians, contributes significantly to this privacy, despite the numerous studies and research findings reporting the opposite. There is lack of emotional and professional support among musicians concerning playing-related injuries; injured musicians are seen as weak, technically insufficient players (Stanhope, 2016; Steinmetz et al, 2015). Ignorance of the risks their occupation imposes on their health allows musician to make judgments easily, forcing their affected colleagues to hide their disorders (Stanhope, 2016).

The fact that PRMDs do not have visible signs as sports injuries do, further burdens their approach. The actual seriousness of the injury is reduced, possibly presenting PRMDs to health specialists and the public as non-serious conditions. The level and quality of health support offered to sports people is not available to musicians. Performers complain about the poor understanding or lack thereof health specialists have of the musical profession; common suggestions given to musicians include “find a real job”, “stop playing altogether”, or “just swap hands” (Stanhope, 2016). Consequently, musicians have a deep suspicion towards health specialists and their recommendations, even in the few occasions they ask consultation (Dommerholt, 2009). It is not surprising, then, that musicians are very reluctant to seek professional help, opting for self-management of PRMD, something they are not qualified to do (Wood, 2014).

vii) Anthropometrics

Pianists and piano teachers have to confront difficulties arising from the relation of their bodies to the instrument. The classical piano is not a flexible construction; on the contrary, its dimensions are fixed. Its height, width, size of keys and resistance of mechanism do not change; there are no smaller, lighter-mechanism instruments addressed to children and short pianists, neither larger, more resisting pianos appropriate for tall, strong pianists. The instrument remains the same; it is the pianist who has to adjust his/her body accordingly in order to perform, with the help of the piano bench which can be adjusted only in terms of height and distance from the instrument. Furthermore, the repertoire and the expectations do not differentiate between boys and girls, men and women; in competitions and auditions men and women compete in the same categories. This, however, is a source of serious problems, mainly for young pianists.

Research on the impact of extensive piano practicing in young students (8-12 years old) reporting radial collateral ligament injury in the fifth finger of the right hand, revealed that all participants were working on advanced repertoire, despite their young age. The results suggested that the injury was probably caused by extensive stress on this joint imposed by piano playing. Consequently, it is possible that small hands are, naturally, more subjected to musculoskeletal injuries given that the pianist must abduct the thumb more predisposing de Quervain disease (Gong et al, 2014). However, it is still common practice to assign advanced repertoire to young pianists, especially the talented ones, regardless of the harm it may cause to their hands.

Beginners, young pianists and even adult pianists with small hands have to often overstretch them to the limits of the hand span, resulting in high occurrence of musculoskeletal disorders in this specific body part (Lai et al, (2015). Pianists with small hands often report injuries in the ulnar digit, because they have to abduct the thumb more and minimize the movement of the fifth finger. The force imposed on the fifth finger when playing specific techniques like octaves or big chords applies a valgus force on the interphalangeal and metacarpophalangeal joints in the fifth finger, which, however, is less abducted than the thumb, resulting in overstretching of the proximal interphalangeal joing. When combined with hypermobility of the joints, which is considered an asset for a pianist, the result is appearance of injuries of the proximal interphalangeal joint (Gong et al, 2014). Ignorance of this anatomical knowledge might easily cause damage a gifted student's or pianist's hand, jeopardizing his/her future in music.

viii) Work environment

Research has shown that in any occupation various human factors and environmental limitations might be connected with the appearance of work-related musculoskeletal disorders (Lai et al, 2015). The professional life of musicians is commonly characterized by irregular weekly schedules and overloaded performance bookings. They are expected to achieve the highest possible accuracy and reach elite level of interpretation, often playing under extreme personal and external pressure. Musicians have to perform regardless injuries, pain, overwhelming pressure and lack of practicing time. Also, it is not uncommon to face inappropriate work environment i.e. inferior quality pianos, lack of space, very high or very low temperatures, insufficient lights, and improper chairs to name a few (Kenny & Ackermann, 2013; Steinmetz et al, 2015; Wood, 2014; Zaza et al, 1998). It is not surprising, then, that they suffer from injuries.

Practically, musicians cannot cease playing; overloaded schedules, financial reasons and/or ignorance of body's recovering mechanisms force them to resume playing without allowing sufficient recovering time for their injuries (Kisner & Colby, 2007; Koutedakis & Sharp, 1999; Rietveld, 2013). Given that the turn-over rate of collagen tissue, of which tendons, ligaments and connective tissues consist of, ranges from 300 to 500 days, the body needs over a year to fully adapt to changes. In reality, musicians rarely can allow themselves this amount of time off playing (Rietveld, 2013; Zaza et al, 1998), subjecting themselves to development of PRMDs.

ix) Psychological factors

Musicians' occupation is often characterized by stressful psychological constraints. Examinations, competitions, pressure, high demands and sometimes unrealistic expectations from teachers and parents fill their training years. Stage anxiety, extreme, stressful performing conditions and inappropriate, competitive working environment are common in their professional life (Chan & Ackermann, 2014; Ioannou et al, 2015; Linton, 2000; Nawrocka et al, 2014; Yoshie, Kudo & Otsuki, 2009; Yoshie, Kudo, Murakoshi, & Ohtsuki, 2009). Unsurprisingly, psychological variables have considerable impact on musicians' body and professional life, with psychological factors frequently reported as a significant cause of pain and PRMDs by musicians (Kenny & Ackermann, 2013; McAttamney & Corlett, 1993; Zaza et al, 1998).

The existence of pain is attributed to many factors and it is difficult to be explained. Research findings suggest that apart from pathological reasons, psychological factors could cause pain. Stress, distress, anxiety, mood and depression are revealed to have a consistent relation with back and neck pain, the body areas most commonly affected in musicians (Linton, 2000). It has been shown that musculoskeletal pain is often accompanied by anxiety and depression. In patients with chronic pain the morbidity of depression is related with more severe pain, disability and low levels of health-related quality of life, results possibly relevant to musicians with non-specific PRMD (Kenny & Ackermann, 2013). In addition, it has been observed that psychological variables are so involved in the transition from acute pain to chronic disability that their effect on back and neck pain is more severe than that of biomechanical or biomedical factors. Self-perceived poor health is associated with chronic pain and disability. Even more, psychological and psychosocial factors may predict the risk for the appearance of long-term pain and disabilities (Ehrman, Gordon, Visich, & Keteyian, 2013; Linton, 2000).

Work-environment situations frequently faced by musicians such as monotonous work, time pressure and mental stress have been linked with the appearance of low back pain. This connection could be explained by the body's reactions to its psychosocial surroundings, considering that psychosocial stress is related to spine loading via a biomechanical path, as research findings suggest. Previous studies on the impact of mental stress on shoulder musculature propose that muscle activity is affected by the psychosocial environment at work and the individual's responses to it (Marras, Davis, Heaney, Maronitis, & Allread, 2000); in musicians, it results in deterioration of performing capacities.

Performance anxiety is perhaps the most significant source of psychological stress for musicians. Even though instrumental musicians appear in front of an audience very often and many have great experience on performing on stage, various levels of stage anxiety are almost always present in every public performance, audition or competition. When playing under stage anxiety, the series of adaptations the body undergoes are considered normal. Nevertheless, their intervention on musicians' control of the performance is eventually a risk factor for PRMDs (Yoshie et al, 2009).

Yoshie et al (2009) examined heart rate, sweat rate, and EMG activity of biceps brachii, upper trapezius, extensor digitorum communis and flexor digitorum superficialis muscles on pianists in relaxed (practice room) and stressful situations (competition). The results showed significant increase in heart rate, sweat rate, and EMG muscle activity during the competition. Increase in stage anxiety was in coincidence with increases in key-stroke force and EMG activity in the upper extremity muscles. Increases in key-force occur countless times during daily practicing sessions raising considerably the activity of the upper muscles. In stressful situations, the muscle activity increases much more initiating a series of consequences that affect severely the performance (Marras et al, 2000; Yoshie et al, 2009).

Specifically, psychological stress affects the coordination patterns of muscle activity in the upper extremity muscles. Under psychological stress, the co-contraction levels of antagonistic muscles increase and the central nervous system enhances joint stiffness in order to retain movement accuracy. The muscles respond to the demands of the central information processing, but they do so at the expense of the physiological efficiency of the body. The results usually include discomfort, fatigue and pain, conditions that have been reported to lead to PRMDs.

The extreme social stressor imposed on the performer by the presence of an audience and/or authoritative judge team triggers activation of the autonomic nervous system, which reaches high levels of autonomic arousal. As mentioned above, the biceps brachii and upper trapezius muscles increase their EMG activity under psychological stress. Previous research has suggested that the trapezius muscle is more related to autonomic arousal compared to other muscles; this muscle's activation might be a compensatory mechanism of the shoulder in order to deal with deteriorated manual capacity in the presence of stress. This adaptation technique, though, fatigues the muscles and leads to less key-stroke force than the performer desires and expects to produce, adding more stress and tension to the playing and resulting, eventually, to PRMDs.

The training of pianists includes strategies of reducing co-contraction of antagonistic muscles, but these techniques are conquered after many years of high-level musical education. Stressful conditions, though, lessen this protective knowledge back to a much earlier stage of piano proficiency in which biomechanical freedom was not yet achieved, resulting in significant impairment of the performance (Yoshie et al, 2009).

Performance anxiety has been shown to enhance negative effects of playing techniques as inappropriate postures, insufficient technique, long hours of practice without rests, forceful playing and intense repetition of difficult passages (Allsop & Ackland, 2010), causing PRMDs. It is important to remind here that musicians prefer to hide their injuries, fearing that the problem with belittle them in the eyes of their colleagues and the audience. More important, acceptance of the problem often has negative impacts on their self-confidence, making them believe that their future as performers has been irreparably ruined. This attitude, though, adds personal anxiety to performance anxiety, increasing the possibilities for the appearance of PRMDs (Steinmetz et al, 2015).

Musicians indeed have to deal with overwhelming psychological stress, but many seem unable to handle it. Ostwald et al suggest that musicians' strenuous training and professional demands, which start early in life, possibly limit their social skills leaving them insufficiently prepared to cope with the psychological strains their profession imposes on them (Ostwald et al, 1994). Furthermore, as mentioned in previous sections, therapists educated in managing both physical and psychological aspects of musicians' PRMDs are still very few, especially when compared to physical therapy specialists available for sports people (Chan & Ackermann, 2014).

x) Genre (Jazz vs Classic)

The majority of research on PRMDs focuses mostly on classical musicians. There is a widespread belief among classical musicians that the improvisatory character of jazz music, along with the freedom and fluidity it allows to the performers, possibly protects them from the stress imposed by the high technical and stylistic standards of classical music. Compared to jazz, classical music is considered to require maximum accuracy in the range of milliseconds, while each performance is scrutinized to the smallest detail by the performers themselves and the audience. This bestows a high level of stress and anxiety on the musicians, which has been shown to cause PRMDs Altenmüller, 2010).

Despite the perceived lack of pressure, jazz musicians face challenges similar to those of classical musicians, as revealed by a large study on tertiary-trained students, teachers and professional jazz pianists in USA and Australia. Specifically, jazz pianists work in a highly competitive environment; young students often participate in competitions and stressful jam sessions with professionals. They are frequently met with inferior quality acoustic pianos, or electric pianos, keyboards and synthesizers which lack the standardized action mechanism supporting the pianist's movements in acoustic pianos. They usually work many hours late in the night, surrounded by amplified instruments producing extremely loud sounds which first, affect their hearing, and second, force them to apply extra pressure on their musculoskeletal system in order to achieve a sound balance with the amplified instruments. Not surprisingly, fatigue appears early on, followed by pain and, eventually, RPMDs (Wood, 2014).

The most affected body areas affected by PRMDs in jazz pianists are the forearm, the neck and the shoulder; hand, triceps and wrist are reported less often, in contrast to classical pianists. This difference could be attributed to style differences; it does not, though, change the fact that jazz pianists are suffering from PRMDs as much as classical pianists. Moreover, they seem to face the same risk factors as their classical counterparts, express the same dissatisfaction with health specialists as classical pianists (Wood, 2014), and are affected by similar implications in their professional and social life.

D. IMPLICATIONS

PRMDs are health problems; the presence of various levels of pain/weakness/strain in one or several body parts obviously cumbers musicians' physical health and well-being, making functioning at work and at home in everyday activities difficult or impossible. Half of PRMD suffering musicians report sleeping disturbances attributed to musculoskeletal complaints. PRMD interfere with musicians' profession, reducing both the quality and the quantity the performance, making musicians to seek professional treatment and/or ask for sick leave. This leads to financial hardship and psychological stress resulting, eventually, in unwelcome changes in social life. They have been career-ending in several occasions, forcing musicians to abandon many years of intense training, practice and professional experience (Kok et al, 2016; Zaza et al, 1998). Moreover, musicians' profession ranks high in occupational stress, which, as in all occupations, is a risk factor for WRMD (Zaza et al, 1998). This way, though, musicians are entrapped in a vicious circle of health, financial and social problems which might last for a long time and even end their career.

E. TREATMENT

Already in 1994 Ostwald underlined the difficulty of approaching musicians with PRMDs, mentioning that it is not feasible for a single person, be it a musician, physicist, coach or surgeon to successfully understand and treat musicians' disabilities (Lederman, 2003; Ostwald et al, 1994). Researchers suggest that treatment programs should be supported and organized by an interdisciplinary team of specialists including health specialists, piano teachers and sports coaches as well (Altenmüller, 2010; Chan & Ackermann, 2014; Bruno et al, 2008; Dick et al, 2013; Mastnak, 2017; Stanhope, 2016). Communication, collaboration and interchange of information between musicians, educators, health specialists and sports trainers could bring the quality of musicians' health support closer to that of sports people (Stanhope, 2016).

Musicians-patients could be a challenge for all sides involved. Performers, when in immense pain due to overplaying and overloaded schedules, usually expect a very quick recovery without allowing time away from the instrument, which is not feasible (Lederman, 2003; Ostwald et al, 1994). They are often afraid or suspicious of surgery and any treatment including the use of needles or electric shocks on their arms and hands, such as EDX techniques (Energy-dispersive X-ray spectroscopy) and routine EMG, techniques commonly recommended for treating their ailments (Lederman, 2003). In case of student patients it is practically difficult to organize and follow a treatment program alongside piano-focusing studies (Ioannou et al, 2015). Teachers' involvement may be needed, if the physician does not have the musical education and ability to suggest instrument-specific changes and adjustments of technique (Lederman, 2003; Ostwald et al, 1994). To summarize, musicians' treatment requires much time, organizing and patience from the physician.

Clinical evaluation of musculoskeletal disorders of musicians should examine several aspects. It should be considered that all incorrect postures cannot be attributed to playing; musicians may have obtained them due to other, non-musical activities. However, in case of already existing postural deficiencies, the playing possibly increases the symptoms, given that the non-ergonomic construction of instruments forces the body to awkward or difficult positions (Dommerholt, 2009; Steinmetz et al, 2010). Consequently, the musician should be examined both without the instrument and while playing it. This, though, poses practical difficulties when pianist patients are involved, because pianos are rarely available in clinics.

Examination of pianists on the piano would allow analysis of their specific ways of playing and detection of possibly hazardous and harmful techniques such as excessive tension and abnormal/inefficient postures (Dick et al, 2013; Lederman, 2003; Ostwald et al, 1994; Rosenbaum et al, 2012; Quarrier, 1993). It could identify work load applied to specific muscle groups and attend factors such as sensation, motor function and perfusion (Rosenbaum et al, 2012). In addition, the pianist's history in performing music and other activities as well should be recorded including practicing habits, technique, method of training, schedule, repertoire, teacher/parent/personal expectations, anxiety, possible perfectionism or extreme perfectionism; this information could help the physician to obtain a holistic picture of the patient and detect possible PRMDs factors (Altenmüller, 2010).

The first and most significant recommendation concerning treatment is rest, the importance of which researchers cannot stress enough (Chan and Ackermann, 2014; Lederman, 2003; Ostwald et al, 1994). Pianists are advised either to reduce the amount of playing or, in severe cases, to completely cease playing for a period of time. Medication includes anti-inflammatory and simple analgesics; more serious conditions require local injections or, if necessary, surgery, which should be followed by rehabilitation programs offering physical and occupational therapy. When resuming playing, warm-up and cooling-down exercises are suggested for protecting the musculoskeletal structures from future injuries (Lederman, 2003; Rosenbaum et al, 2012). However, musicians either cannot afford to rest, or are reluctant to do so, ignoring the most effective method of treatment.

F. PREVENTION

It has been emphatically underlined in recent studies that prevention of pianists' PRMDs depends greatly on education, posture and good physical condition (Ioannou et al, 2015; Nawrocka et al, 2014).

It has been suggested that sufficient knowledge of body anatomy and ergonomics, and biomechanics of piano playing as well would enable pianists to reduce mechanical stress diminishing the possibility for the appearance of PRMDs (Fry & Rowley, 1989; Furuya & Kinoshita, 2008). Specifically, thorough research on the biomechanics of piano playing would attribute greatly on injury prevention by sharing the results for educational purposes and clinical intervention (Lai et al, 2015). Moreover, it would improve the communication between musicians and health specialists, especially if the later were familiar with the specifics of instrumental playing, the physical requirements of the instrument and musicians' terminology (Dick et al, 2013; Lederman, 2003; Dommerholt, 2009, 2010a).

A sufficient knowledge of anatomy and body mechanisms would help musicians to avoid harmful learning techniques and use their practicing time more efficiently. Musicians seem to ignore that long, repetitive practicing sessions may not lead to high level performance (Carter and Grahn, 2016; Ericsson et al, 1993). On the contrary, effectively organized practicing time would limit muscle fatigue, avoiding overloading of musculoskeletal structures. As high-level, well-experienced athletes suggest, efficient exercise requires less time and gives better results (Horton, 2008). It is essential for professional and young musicians alike to be informed of practicing techniques such as interleaved practice, deliberate practice, shadow playing, mental practicing and visualization, which contribute significantly in the learning process without overstressing the body (Chan & Ackermann, 2014; Dommerholt, 2009; Ericsson et al, 1993; Fuji, Kudo, Ohtsuki, & Oda, 2009), eventually limiting the possibility of musculoskeletal disorders and injuries.

Many teachers and performers still promote lengthy practicing sessions as the only path to success. Research findings report that productive, well-focused practice is feasible for a maximum of four hours per day. It has been pointed out that increasing of daily amount of practice should be very gradual, because the body needs sufficient recovery and rest time to avoid physical and mental exhaustion. Similarly to sports, the stress of training should be released before subjecting the body to more intense tasks. If not, physical injury, burnout and reduced improvement appear, followed by lack of motivation and, eventually, stopping of musical activities. Researchers strongly advocate that sufficient rest and, in some cases, complete ceasing of playing, are the most recommended treatment of these issues (Ericcson et al, 1993).

Occupational medicine literature recommends intermitting practicing sessions with short rests (Kisner & Kolby, 2007). Pianists should stop for a minimum of five minutes per every hour of practice to allow musculoskeletal structures time for recovery and repair (Altenmüller, 2010; Chan & Ackermann, 2014; Rosenbaum et al, 2012). Overworked muscles may need up to 48-hour break for recovery (Quarrier, 1993). As mentioned in previous sections, though, most pianists ignore how essential rest is for their recovery.

As suggested by numerous research findings, musculoskeletal disorders mainly originate in the manner the sound is produced by the pianist's body; music education often does not pay enough attention on this manner, even though several researchers underline the importance of proper body posture in preventing painful situations (Ioannou et al, 2015; Kok et al, 2017; Li et al, 2014; Ostwald et al, 1993; Quarrier, 1993; Rietveld, 2013; Stanhope, 2016).

Pianists spend many hours every day playing the piano; however, they are not able to sustain a proper posture for long. Already in 1989 Fry and Rowley proposed that appropriate use of muscle power responsible for supporting the body could help decreasing the percentage of pain-affected musicians. More recent research suggests that musicians should be in good physical condition and participate regularly in exercise programs in order to achieve and sustain elite level performance (Altenmüller, 2010; Bernardi, De Buglio, Trimarchi, Chielli, & Bricollo, 2013; Ioannou et al, 2015; Kenny & Ackermann, 2013).

Nawrocka et al (2014) found a correlation between low levels of activity and the intensity and occurrence of musculoskeletal pain in young music students. This led them to propose that physical activity should be integrated in music education, given the limited time students have for extra-curriculum activities. The combination of poor physical condition with the static load and repetitive motions of piano practice could cause serious damage on the musculoskeletal system of young musicians. This makes the importance of regular exercise even more essential for young musicians (Nawrocka et al, 2014).

For performing musicians, self-wellness is equally important to exercise. The basic musical instrument is, first and foremost, the human body, which should be in the best possible condition, as the musical instrument of a high-level professional musician is expected to be. Musicians' occupation requires considerable amount of energy and strength, but musicians often lack basic knowledge on these subjects. Musicians should be informed about nutrition and hydration (Dick et al, 2013), strengthening exercises including resistance and endurance (Chan & Ackermann, 2014), general fitness and core stability (Rietveld, 2013; Wood, 2014). Since most students and parents are familiar with at least one sport, drawing parallels between music and sport would help the teacher to involve exercise in the daily practice schedule of the student (Stanhope 2016).

The preventative role sports play in the appearance of PRMDs has been advocated by many researchers. It has been proposed that specialized programs should be designed for each pianist individually accordingly to his/her personal body characteristics and needs, such as endurance to playing load and strain, level of fitness, and body awareness (Chan & Ackermann, 2014; Mastnak, 2017; Rietveld, 2013). Grieco et al (1989), supporting the preventive role of physical activity, designed a health education program which includes, apart from education on anatomy and physiology of spine, shoulders, arms and hands, stretching and relaxation exercises for muscle groups most involved and strained in piano playing, noting the importance of distributing these exercises during the day (Grieco et al, 1989). It should be underlined here that not any physical activity can protect the musician from PRMDs; the program should be designed targeting these specific muscle groups supporting the playing, and also strengthening the body in order to cope with the demands of playing (Kenny & Ackermann, 2013).

However, musicians still are not very willing to undergo exercises or be physically active. Despite the considerable strength required to play an instrument and endure long hours of practicing and rehearsing, there is no tradition of regular exercise among musicians (Quarrier, 1993). In contrast, there is a widespread view among musicians that physical exercise and training is hazardous for their ability to play because it will affect negatively tendons, joints, flexibility and sensitivity of touch. Again, education could contribute greatly in changing similar attitudes informing musicians on the significance physical exercise and training have for their professional life and well-being (health) (Mastnak, 2017).

The recent scientific interest in the well-being and specific health needs of performing artists which was initiated by the high percentage of ailing musicians has led to the creation of institutions and education programs dedicated to health and medical problems of performers (Wood, 2014). Musicians currently have access to a growing number of education programs, clinics and organizations which offer training and treatment of PRMDs, both in Europe and North America.

Institutions, Organizations and Clinics

In Europe, health centers are gradually included in several music departments, offering medical help and advice to music students, while post-graduate degrees focusing on musicians' health are created and established in major music departments.

The University College of London offers a postgraduate degree (Masters of Science in Performing Arts Medicine) which trains musicians, physiotherapists and General Practitioners on musculoskeletal injury, disability, pain management, music performance science, assessment and rehabilitation, and performance psychology (Master of Science in Performing Arts Medicine, 2018; Stanhope, 2016).

In addition, the Hannover University of Music, Drama and Media encompasses the Institute for Music Physiology and Musicians' Medicine (IMMM), which focuses on music pathophysiology and music physiology of musicians' disorders. The Institute is conducting research on pianists, currently studying focal dystonia, pain syndromes, and neuroplacticity (Institute for Music Physiology and Musician's Medicine, 2018).

North America shows a strong interest in artists' health, having several organizations dedicated to performers' well-being. *Athletes and the Arts* is an initiative promoting the collaboration between sports and performing arts, based on the view of the musician as an athlete. This initiative consists of music departments, music-associated organizations, the American College of Sports Medicine, the American Osteopathic Academy of Sports Medicine, the Association for Applied Sport Psychology, and the

National Athletic Trainers Association (American College of Sports Medicine (ACSM), 2018; American Osteopathic Society for Sports Medicine, 2018; American Society for Sports Medicine (ASSM), 2018; Athletes and the Arts, 2018; Dick et al, 2013).

Performing Arts Medicine Association (PAMA) was established in USA in 1989 and specializes on performer's health issues. It aims to educate health specialists on the anatomical, physiological and psychological loads and injuries imposed on performers by their profession. Furthermore, the association is dedicated on educating musicians on basic anatomy, body awareness, injury risk factors and injury preventing (Dommerholt, 2009; Rosenbaum et al, 2012; Performing Arts Medicine Association, 2018).

The National Association of Schools of Music (NASM), which includes 644 schools, is the organization responsible for the national standards in music disciplines in USA. In collaboration with PAMA, NASM developed research studies on musicians' health, aiming to help health specialists and musicians to better understand, treat and prevent musicians' ailments (National Association of Schools of Music, 2018). The results of this collaboration, presented in the 2011 NASM *Handbook of a Health and Safety Standard,* declare that

"Students enrolled in music unit programs and faculty and staff with employment status in the music unit must be provided basic information about the maintenance of health and safety within the contexts of practice, performance, teaching, and listening. General topics include, but are not limited to, basic information regarding the maintenance of hearing, vocal, and musculoskeletal health and injury prevention…" (Dick et al, 2013, p. 402).

Currently, research on musicians' health issues is growing, clinics dedicated to musicians' treatment appear in more countries and cities, and programs of prevention and re-training are established in institutions and organizations. However, as Blanco-Pineiro et al (2017) observed, these programs have not been evaluated yet. There is huge variety on working protocols, professional musicians are rarely involved as researchers, and elite, world-famous musicians do not participate in any study, because of practical difficulties, which means that the very best performing musicians are not included in the research process. It is also underlined that, while the impact of poor body posture on the health of the musician has been studied, the impact of this posture on the quality of the performance has not been researched yet. Even though it is practically complicated to evaluate the effect of posture on the quality of the performance (Blanco-Pineiro et al, 2017), it seems that a relationship between them exists and should be addressed.

Despite the growing interest and research studies in biomechanics of music performance, the available scientific knowledge has not been widely incorporated in instrumental education yet. Furthermore, currently there are no optimal ways of applying biomechanical information derived from sports in piano playing, which is an activity encompassing several different styles and techniques (Chan & Ackermann, 2014). Consequently, pianists are still deprived of valuable scientific information concerning essential aspects of their profession, eventually exposing themselves to PRMDs.

CHAPTER 2: EXPERIMENT

It has been mentioned in previous sections that poor body posture is considered the most dangerous risk factor for the development of PRMDs in pianists. However, the main bulk of the available literature on pianists' health has rarely touched this subject, focusing primarily on hand and fingers (Furuya & Kinoshita, 2008; Furuya et al, 2012; Furuya et al, 2015; Gong et al, 2014; Lai et al, 2015; Li et al, 2014; Li-Lin, 2013; Minetti et al, 2007; Rosenbaum et al, 2012; Rosety-Rodriguez et al, 2003; Winges & Furuya, 2015). Moreover, to our knowledge research on pianists' upper body posture relying on optical motion capture systems allowing for the highest accuracy has not been conducted yet (Hadjakos, 2012).

Our research focused on the upper body posture of young pianists relying on the high-accuracy VICON motion capture system, aiming to examine the importance of appropriate upper body posture in preventing the appearance of PRMDs in pianists and allowing maximum efficiency of their upper limbs, eventually optimizing their performance. The performance of two teams, advanced and beginner piano students, was compared searching for differences in spinal angles and hand movements. The hypothesis was that advanced students would show significant differences in all posture variables due to their training.

Method

i) Subjects

Thirteen piano students participated in the research, six boys and seven girls (mean age 14,5 years; mean height 167,14 cm; mean weight 60,68 kg), all of them reportedly without any musculoskeletal disorders. Seven of them were beginners (1,5 to 2 years of piano training) and played the piano as second instrument; six were advanced (at least seven years of piano training) and played the piano as principal instrument. They were recruited through posters and announcements in Public Music Schools and Music Conservatories of Trikala and Larissa. All of them participated after obtaining written informed consent from their guardians, and the experiment was approved by the ethics committee of the University of Thessaly.

ii) Equipment

The participants were tested at the Biomechanics Lab of the School of Physical Education and Sports, University of Thessaly, using a 10-camera Vicon Nexus 2 system, sampling at 100Hz.

A digital piano was chosen (DP-26 Thomann digital piano), instead of an acoustical upright or grand piano, so that the body of the instrument would not block the view of the cameras. The piano was supported by a Millenium KS-1010 black double-braced economy keyboard stand; the keys were placed at 73 cm from the ground, in the same height as in a grand piano. A Thomann KB-15BM adjustable piano bench was provided, and a SEIKO Digital Metronome DM-20 was used for securing a steady tempo.

iii) Procedure

All participants wore sports attire. During the experiment, boys had the upper body uncovered, while girls wore a sports bra; a swim cap was also provided for the placement of head markers. Using double-sided adhesive tape, 27 reflective markers were placed and secured at the most prominent anatomical landmarks of the pelvis, spine, trunk, arms, hands and head, as shown in the Plag-In Gait model. Four additional markers were placed on the piano bench. Specifically, the markers were placed as follows (Fig. 1-4):

Head:

Left front head: positioned over the left temple

Right front head: positioned over the right temple

Left back head: placed roughly in a horizontal plane of the front head markers

Right back head: placed roughly in a horizontal plane of the front head markers

Pelvis:

Left anterior superior iliac spine

Right anterior superior iliac spine

Left posterior superior iliac spine

Right posterior superior iliac spine

Trunk:

7th cervical vertebra

10th thoracic vertebra

Clavicle: jugular notch where the clavicles meet the sternum

Sternum: Xiphoid process of the sternum

Right back: placed on the middle of the right scapula

Arms:

Left shoulder: on the acromio-clavicular joint

Left upper arm: placed on the upper arm between the elbow and shoulder markers

Left elbow: placed on lateral epicondyle approximating elbow joint axis

Left forearm: placed on the lower arm between the wrist and elbow markers

Left wrist 1: left wrist bar thumb side

Left wrist 2: left wrist 5th finger side

Left finger: placed on the dorsum of the hand just below the head of the third metacarpal

Right shoulder: on the acromio-clavicular joint

Right upper arm: placed on the upper arm between the elbow and shoulder markers

Right elbow: placed on lateral epicondyle approximating elbow joint axis

Right forearm: placed on the lower arm between the wrist and elbow markers

Right wrist 1: right wrist bar thumb side

Right wrist 2: right wrist 5th finger side

Right finger: placed on the dorsum of the hand just below the head of the third metacarpal

Fig.1 Front side

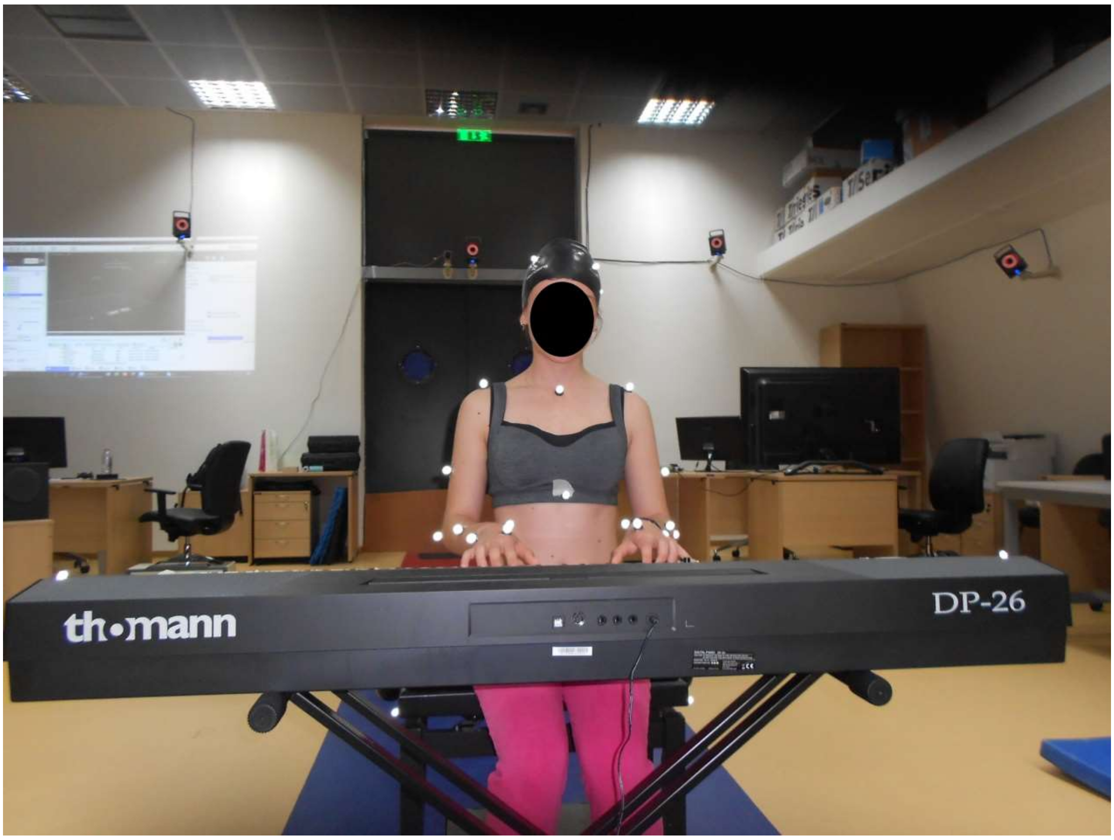


Fig.2 Back side

Fig. 3 Right side

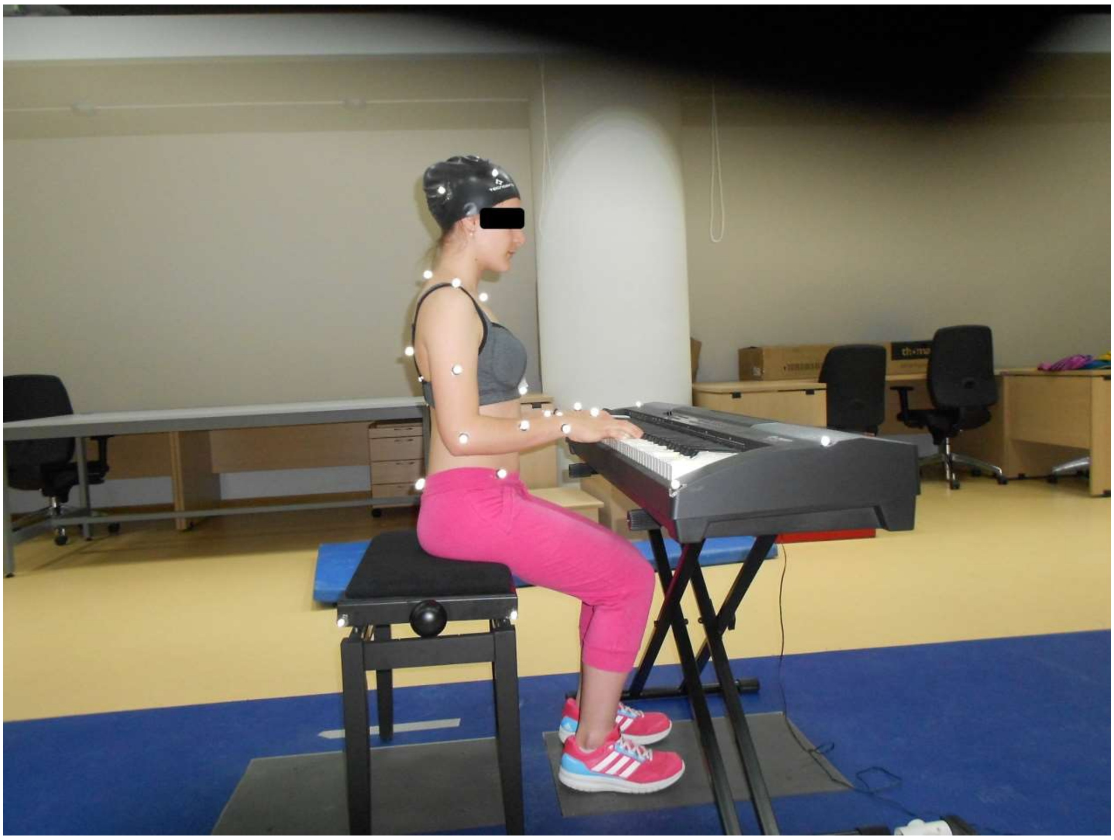
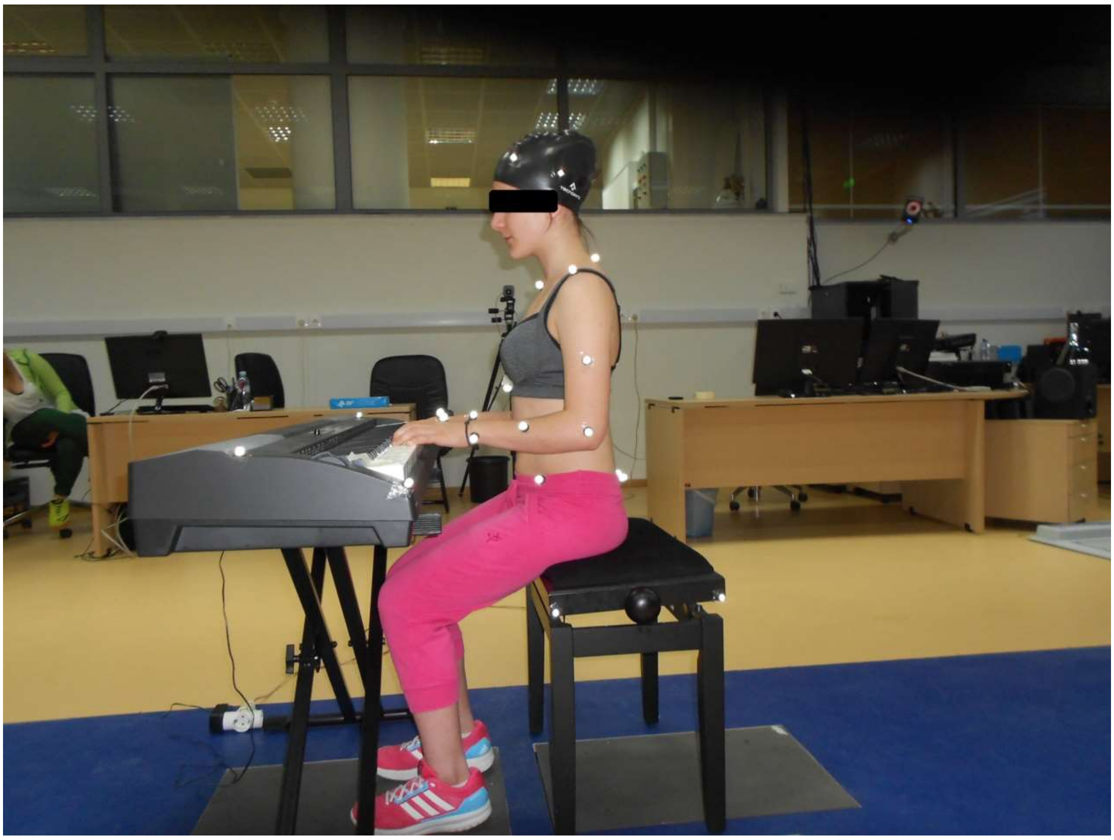


Fig. 4 Left side



All participants had practiced beforehand and were prepared to perform two scales, G-major and E-major, to be played with both hands, in five octaves ascending and descending, in medium dynamic level (*mf*), and in time value of eight-notes (♪). After placing the markers, the participant was informed about the measurement process. Apart from mentioning the possibility of adjusting the height of the piano bench and its proximity to the keyboard, no other instruction was given on how to sit on the instrument or how to play the scales; each volunteer played in his/her own personal way. Each scale was played twice, in tempi (speed) attainable by all subjects: first in a slow tempo (♩=80), and secondly in a faster tempo (♩=130). The digital metronome was giving the tempo non-stop during the performance. Before the measurement, each subject had the opportunity to play the scales few times, to feel comfortable with the instrument and the chosen tempi. The whole process lasted approximately 30 minutes for each participant.

The choice of scales instead of any piece of music was based on three facts. First, they can be played quite easily by advanced students and beginners as well. In piano playing, scales are not very complicated, have been taught since the very first piano lessons, and also reappear steadily during the first nine years of systematic piano training in the Greek music education. Second, G-major is considered an easy scale and E-major a slightly more advanced one, offering the opportunity to examine the behavior of our teams in two levels of difficulty. Third, these scales provide very good examples of placement and sway of the hand on the keyboard and sway of the body, due to the number and position of black keys included in them. Specifically, G-major includes only one black key, as shown in fig. 5, while E-major includes four black keys, as shown in Fig. 6.

Fig. 5 G-major

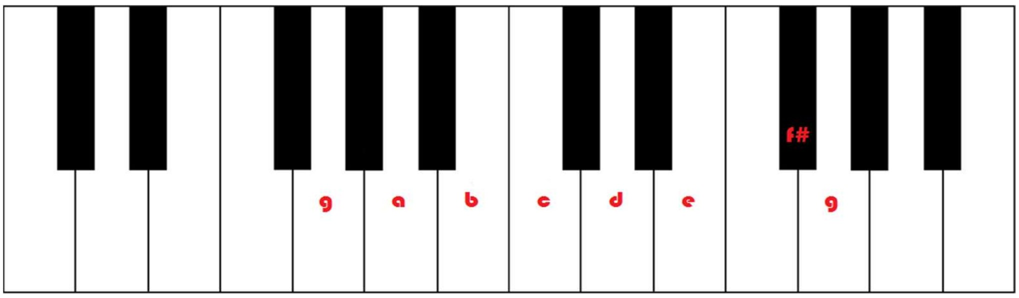
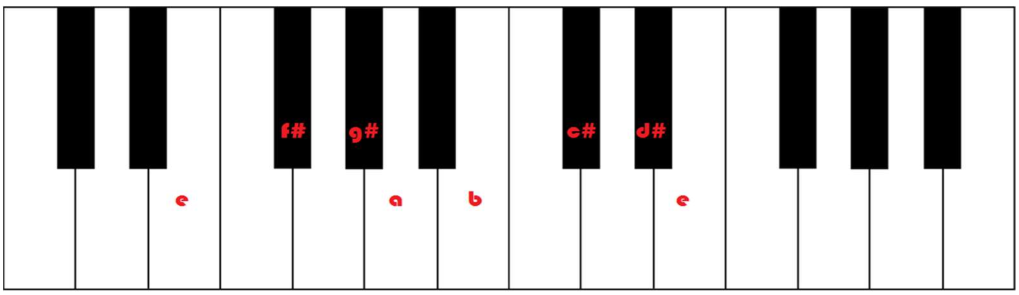


Fig. 6 E-major



The black keys of the piano, as in all keyboard instruments, are positioned higher than the white keys and at the mid of the keyboard. In G-major, the hypothesis was that the advanced students would place their hands towards the mid of the white keys at the beginning of the scale and keep them there for the whole performance, with a small amount of sway during their playing (Fig. 7). As for the beginners, the hypothesis was that they would start by placing their hands at the edge of the keys, moving them towards the mid of the keys only for reaching the black key (Fig. 8), then returning their hands back to their initial position, with a larger amount of sway in comparison to advanced students.

Fig.7 G-major: right hand positions (advanced students)

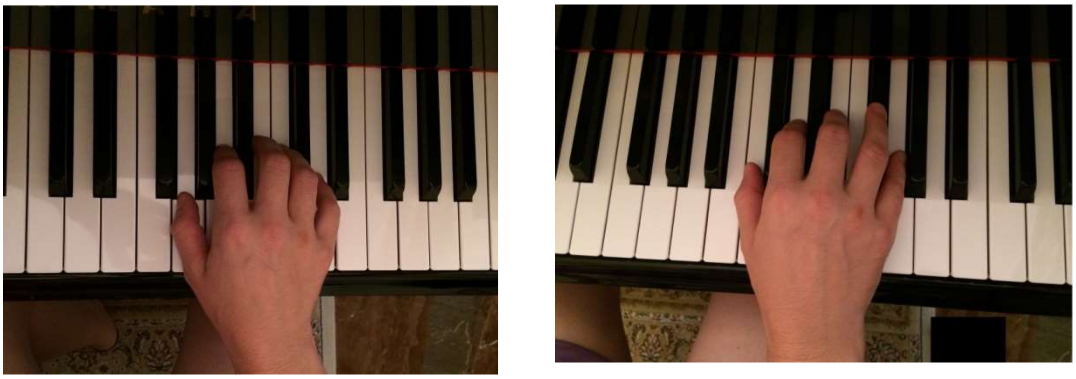
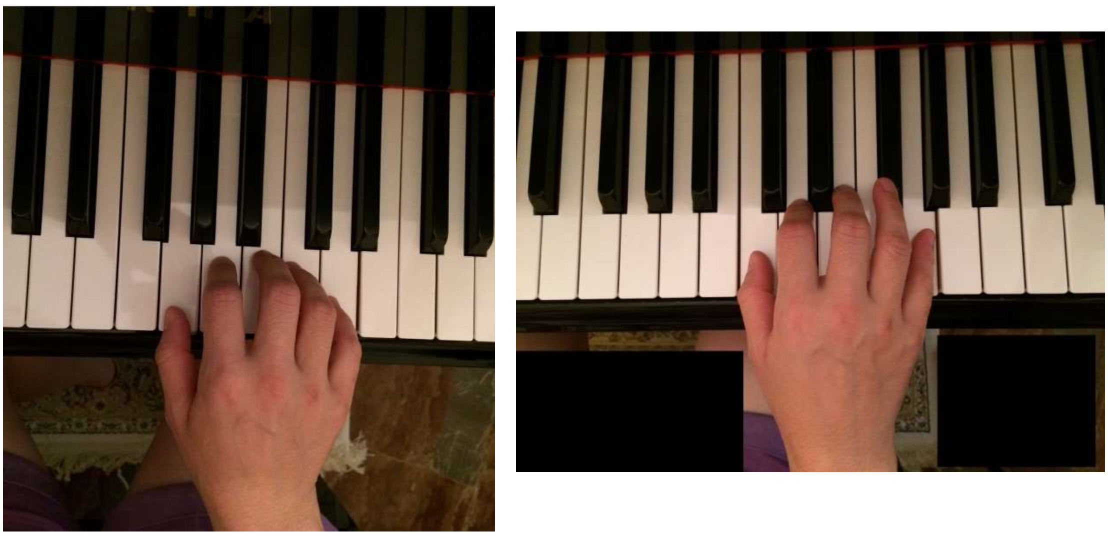
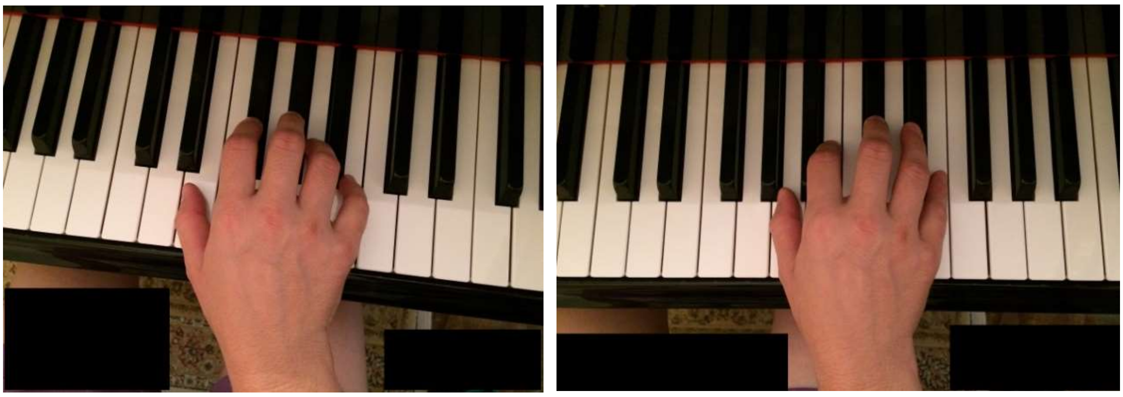


Fig. 8 G-major: right hand positions (beginners)



In E-major, which includes four black keys, it was presumed that the advanced students would place their hands towards the mid of the keys as in G-major, keeping them approximately at the same position during the playing (Fig. 9). Again, a smaller amount of sway was expected. For the beginners, on the other side, it was supposed that they would position their hands at the edge of the keys as in G-major, exhibiting a larger amount of hand sway on the keyboard when reaching for the black keys, in comparison to advanced students.

Fig. 9 E-major: right hand position (advanced)



A major point of observation was the impact the performance of two different scales in two different tempi each would have on the spinal angles and the overall upper body posture of participants. It was presumed that advanced students would show upright spinal angles and less sway of the hands and body, in comparison to beginners. Furthermore, it was hypothesized that larger sway of hands would affect spinal angles during the performance.

iv) Posture variables

The global coordinate system used in the experiment was designed using the upper case letters XYZ. The Y-axis is nominally directed anteriorly, the Z-axis is directly superiorly, and the X-axis is perpendicular to the other two axes.

Left and right hand measurement points were defined by the markers placed on the dorsum below the head of the third metacarpal, and the C7 by the marker placed on the 7th cervical vertebra. For the spinal angle, an extra virtual marker was created between the two posterior superior iliac spine markers, defined at the virtual vector midpoint between them. The spinal angle was then defined by this pelvic virtual marker and the markers at T10 and C7 spinous processes (10th thoracic to 7th cervical vertebra). The boundary between lumbar and thoracic region was set on the 10th thoracic vertebra based on variation in facet joint orientation, as well as on the fact that facet joint orientation and spinal curves in standing are able to transition as proximally as T10 (Claus et al, 2009a, b; Korakakis et al, 2014).

The variables focused on in the experiment were the 7th cervical vertebra (standard deviation), the movement of mid-finger on axes Y and Z consecutively in both hands (standard deviation), the overall movement of mid-finger on axes XYZ in both hands (standard deviation), the spinal angles at the start point, maximum right point and ending point of the performance.

CHAPTER 3: STATISTICS – RESULTS

A. STATISTICS

The statistical analysis was conducted using SPSS 18.0 for Windows. Non-parametric statistics were used to analyze the data because of the small sample size. Specifically, data were analyzed with the Mann-Whitney test to statistically compare the piano performance between the two groups. Wilcoxon signed-rank tests were used to assess within-group differences. For the parameters which showed statistically significant differences effect size calculations were performed to demonstrate the magnitude of the difference between the two groups (Table 4).

B. RESULTS

Table 1 presents the parameters which showed statistically significant differences between the two groups. Specifically, significant differences were noted in six parameters: 7th cervical vertebrae on the Y axis (C7), mid-finger movement of left hand on the Y axis (LF Y), mid-finger movement of right hand on the Y axis (RF Y), spine angle on the start of the performance (SAS), overall movement of mid-finger of left hand on the three axes (LH XYZ), and overall movement of mid-finger of right hand on the three axes (RH XYZ). Effect size calculations showed that the difference in these parameters between the two groups was very significant (Table 4).

Table 1: Parameters

	C7	LF Y	RF Y	SAS	LHF XYZ	RHF XYZ
G slow	-	-	-	-	-	-
G fast	√	√	√	√	√	√
E slow	-	√	√	√	-	-
E fast	-	√	√	√	√	-

The statistical analysis showed that there were no significant differences between the two groups in G-major slow. G-major fast showed differences in all six parameters (C7, LFY, RFY, SAS, LH XYZ, RH XYZ), the only scale to do so. In E-major slow differences were observed in three parameters (LFY, RFY, SAS). In E-major fast differences occurred in four parameters (LFY, RFY, SAS, LH XYZ). Differences were found in parameters LFY, RFY, and SAS in all scales except for G-major slow.

C7 showed statistically significant difference only in G-major fast, meaning that in the other scales both teams swayed their torso back and forth in quite similar manner. The group means revealed that, with the exception of G-major slow, advanced students were quite consistent in the movement of C7, while beginners showed greater variance (Table 2).

Table 2: C7Y group means

	C7Y	
	Beg.	Adv.
G slow	11,83	12,21
G fast	13,85	10,62
E slow	9,57	10,91
E fast	11,41	9,91

Concerning spinal angles, differences in SAS (spine angle at the start of the performance) between the two groups were noted in all scales, with the exception of G-major slow. However, no statistically significant differences were observed in SARmax and SAE (spine angle at the maximum right point of the performance, and at the ending point of the performance respectively), meaning that advanced students placed their spine in an upright position at the start of the performance, but continued in a more slouched position, similarly to beginners.

Table 3 presents the group means of spine angles in SAS, SARmax and SAE. Both teams reached their most upright spinal postures in G-major slow. For beginners, the highest group means were at 160,02 degrees in SAS, 159,83 in SARmax, and 160,14 in SAE. For advanced students, the highest group means were at 164,35 degrees in SAS, 159,83 in SARmax and 164,58 in SAE. The highest group mean for beginners was 160,14 degrees and for advanced 164,58 degrees, which gives a difference of 4,44 degrees.

Table 3 SAS, SARmax, and SAE angles group means (degrees)

	SAS		SARmax		SAE	
	Beg.	Adv.	Beg.	Adv.	Beg.	Adv.
G slow	160,02	164,35	159,83	163,35	160,14	164,58
G fast	158,14	162,89	157,72	161,37	157,46	163,07
E slow	156,63	162,6	158,6	162,3	157,65	162,74
E fast	156,17	162,89	158,76	163,31	157,46	163,75

Significant differences in mid-finger movement on the Y axis occurred for both hands in all scales between the two groups with the exception of G major slow, revealing that the beginners swayed their hands inside-out the keys much more than the advanced students. Yet, differences in the overall movement of the hands (XYZ) were observed only in the fast scales, specifically in G-major fast in both hands and in E-major fast in left-hand only, where advanced students achieved more economical movements. Concerning hand movement on the Z axis, no significant differences were noted in both groups, even though beginners were expected to raise their hand more when reaching for the black notes.

Table 4: Effect size calculation

SCALES	**EFFECT SIZE (BIAS CORRECTED)**	
G	1B	**0,71**
	2B	**1,80**
	3B	**1,20**
	4B	**-1,03**
	11B	**0,95**
	12B	**0,99**
E	2A	**2,15**
	3A	**1,39**
	4A	**-1,07**
	2B	**2,53**
	3B	**1,65**
	4B	**-1,23**
	11B	**0,90**

CHAPTER 4: DISCUSSION – LIMITATIONS - CONCLUSION

A. DISCUSSION

We expected significant differences in all parameters between the two groups but the results gave a different picture, despite the considerable advantage in training advanced students had on beginners.

Both versions of G-major scale provided surprising results. There were no differences in the slow version, while the fast version showed differences in all parameters.

The absence of differences in G-major slow could possibly be explained by the easiness of the scale. Indeed, G-major is considered one of the easiest scales to play and is taught in the first piano lessons. Pianists continue working on it for as long as they play the piano, adding gradually the more complicated major and minor scales. The team of beginners had at least more than one year of experience playing this scale, so possibly they were able to perform it as well as advanced students, at least in the slow tempo.

Nevertheless, advanced students were expected to prove their higher level of expertise no matter the easiness of the scale, which did not happen despite the slow tempo. Moreover, this is the only scale in which they showed a larger sway of C7 in comparison to beginners. It is possible that the easiness of the scale combined with habit (piano students consider the practicing of scales an uninspiring, boring daily exercise) perhaps caused loosening of control and focus, resulting in a careless performance. It could reveal, though, that advanced students were not taught to apply their best skill and ability to any given piece of music, regardless of the level of difficulty.

G-major fast, however, provided differences in six parameters. Advanced students apparently relied on technical skills they acquired during many years of training; they showed economy in their movements limiting the sway of their head and torso; they started the performance exhibiting more upright spinal angle than beginners; they placed their hands towards the mid of the keys for the entire performance enabling the fingers to reach the black key without unnecessary swaying of the hand; the overall movements of each hand were small and smooth, avoiding sways and jumps over the keyboard. In other words, their body worked less in comparison to beginners in the fast scale.

Beginners, though, did not cope sufficiently with the faster tempo. They showed large sways of hands and torso, as well as larger overall movements of hands, and started the performance positioning their spine in a more slouched posture than advanced students. To play the fast scale was a more laborious task for them than advanced students, revealing that their piano skills could not protect them from unnecessary motions on the instrument.

The E-major scale is technically more demanding than G-major, but still accessible to beginners. It is introduced to students some time after G-major not because of its technical difficulty but because the order of learning scales on the piano commonly follows the order they are taught in music theory. The four black keys included in E-major make it seem complicated both in writing and on the keyboard, while practically it is only slightly more challenging that G-major. Similarly to G-major, beginner participants had at least one year of experience on this scale.

Both versions of E-major showed differences between the two teams. In E-major slow differences were found in three parameters (LFY, RFY, SAS) and in E-major fast in four (LFY, RFY, SAS, LF XYZ). Beginners showed a larger sway of the hand inside-out the keyboard which could be explained by the hand position they opted for. They started both versions positioning their hand at the edge of the keys. Considering the pattern of white and black keys in E-major (white-two black-two white-two black-white) and the difference in height and distance between white and black keys, the fingers and hands of beginners had to move constantly in this scale.

Advance students, though, placed their hand at the mid of the white keys, reaching easily the black keys and interchanging between white and black keys without unnecessary jumps and sway of fingers and hand. In the fast version they showed more economical overall movement of the left hand in comparison to beginners. Given that the training of the left hand in piano playing is a difficult task and takes a considerable amount of time, the improved technique they presented could be likely attributed to their advanced training and experience in piano playing. Differences were expected on the overall movement of the right hand, too. Surprisingly, it did not happen despite the six-to seven years of training advanced students had on beginners. It could be possible that, similarly to G-major slow, advanced students considered that this scale does not pose any challenges anymore and were not interested in giving their best when performing it.

The most intriguing results, though, concern spinal postures. As expected, advanced students performed holding their upper body in a more upright spinal posture than beginners in all scales with the exception of G-major slow, as group means show (Table 3). Interestingly, in each scale statistically significant differences in spinal angles were noted only in the start of the performance (SAS). No significant differences were found in SARmax (end of the ascending line of the scale) and SAE (end of the scale, where the descending line returns to the starting point). The most upright spinal angle achieved by advanced students was 164,58 degrees, marked in G-major slow, the easiest scale played on the experiment. This spinal angle, however, is rather slump, which reveals that not even advanced students presented a proper upright posture. Moreover, a comparison of the highest spinal angle group means of the two teams (advanced students: 164,58; beginners: 160,14) gave a difference of 4,44 degrees. Again, considering the additional six to seven years of piano training advanced students had, this result is alarmingly low.

The fact that no statistically significant differences in spinal angles were found in SARmax and SAE, with the exception of G-major slow where no differences were found between the two teams, raises questions concerning both teams. Either advanced students fell back on a slump posture during the performance or beginners gradually improved theirs, with group means suggesting the former (Table 3). Throughout their training, advanced students probably received comments and corrections on their posture at the beginning of each performance; the results reveal that they quite possibly did not receive similar comments concerning their overall posture changes during the whole performance. Most likely, paying attention to posture and striving to achieve an appropriate one was not an essential part of their training.

Furthermore, the absence of statistically significance differences in spinal angles during the performance could reveal that even advanced students were not able, or were not instructed, or even lacked the necessary muscle strength to perform sustaining a proper upright posture for approximately 30 seconds, the duration of each slow scale. The results suggest that beginners placed themselves on the instrument adopting their habitual sitting posture, while advanced students positioned their spine in more upright angles than beginners, falling back to their habitual sitting posture soon after. Given the serious impact changes on the thoracolumbar and lumbar spinal curves have on the main stabilizing muscles of the spine, and considering that musical works appropriate for the level of advanced students commonly range from five to fifteen minutes of playing, it would be interesting to examine the effect these pieces have on students' spinal angles and musculoskeletal system.

Another observation is the absence of differences in C7 in E-major, and in SARmax and SAE spinal angles in all scales (with the exception of G-major slow), while there are significant differences in finger and hand movements in the same scales. It shows that the fingers and, consequently, hands and arms of advanced students functioned more ergonomically than those of beginners without, however, receiving any support from the trunk, which remained in a rather slump position. This playing technique, though, has been shown to tire the hand initiating the development of PRMDs in young pianists. A possible explanation would suggest that the training of the participants focused mainly on improving finger and hand movements ignoring or neglecting the whole body, most importantly its posture which is reportedly a significant factor in the appearance of musculoskeletal disorders and injuries.

These results, no matter how worrying, might not be considered surprising when connected with mainstream piano training. As mentioned in previous sections, appropriate or optimal posture is mentioned in passing in piano methods, and neglected in standard publications of exercises and technique. In addition, performing musicians are suspicious towards physical exercise and training, depriving their body from the strength necessary for sustaining proper upper-body posture. Under these circumstances, the appearance of slump spinal angles in both teams should rather be expected instead of surprising. Not surprising, though, would be the appearance of PRMDs in the near future of these young pianists.

As noted in previous sections, any changes in the thoracolumbar and lumbar spinal curves have a negative impact on the stabilizing system of the spine exposing the body to injury. The sustaining of a posture for a given length of time requires considerable strength which the participants of the experiment obviously lacked, making themselves vulnerable to PRMDs, since inappropriate spinal postures have been proven to be a major factor in the appearance of PRMDs in performing musicians of all ages, especially young students. Considering the above, the fact that the world of performing musicians has not taken drastic steps yet towards improving body postures is rather curious.

Despite the growing number of institutes and health centers dedicated to musicians' medical aid and well-being, the high percentages of musicians suffering from PRMDs reveal that these organizations have not made a positive difference yet. Information on the impact appropriate posture and good physical condition have on musicians' health and career has neither entered mainstream instrumental education nor reached the greater music public yet. This possibly explains why beginners showed similar spinal angles and body postures to students with up to eight years of piano training.

The great importance appropriate posture has on pianists' health and optimal performance is repeatedly stressed in recent studies and research findings. It is also underlined that to achieve and sustain appropriate posture the performer should be in good physical condition, which is obtained through sports training and exercise. Nevertheless, collaboration between the areas of music performance and physical education/sports science is very limited, if non-existent, at the present. In fact, music education could learn from the world of sports not only how to incorporate training programs specially designed for instrumentalist musicians, but also how to promote a healthy lifestyle among performing musicians and, equally important, how to reach younger populations.

B. LIMITATIONS

The results of the present study should be considered in relation with several limitations. First, the number of participants was small, while a greater number would increase significantly the power of the results. Second, the use of an acoustic piano instead of a digital would offer real performing conditions to participants. Third, the choice of a piece of music instead of scales, which often induce boredom and lack of attention to students, would possibly encourage them to sustain their focus and control over their playing during the whole performance. In addition to that, a piano piece including different playing techniques such as chords, octaves and arpeggios instead of scales, which consist of succession of notes, would allow detailed observation of more changes in the upper-body posture of pianists. Fourth, the participants were teenaged music students, with the most advanced of them having no more than eight hears of piano playing; research on more experienced pianists, ideally university students specializing in piano performance, would give more solid information on upper-body posture and the impact piano training and long-term playing has on it.

C. CONCLUSION

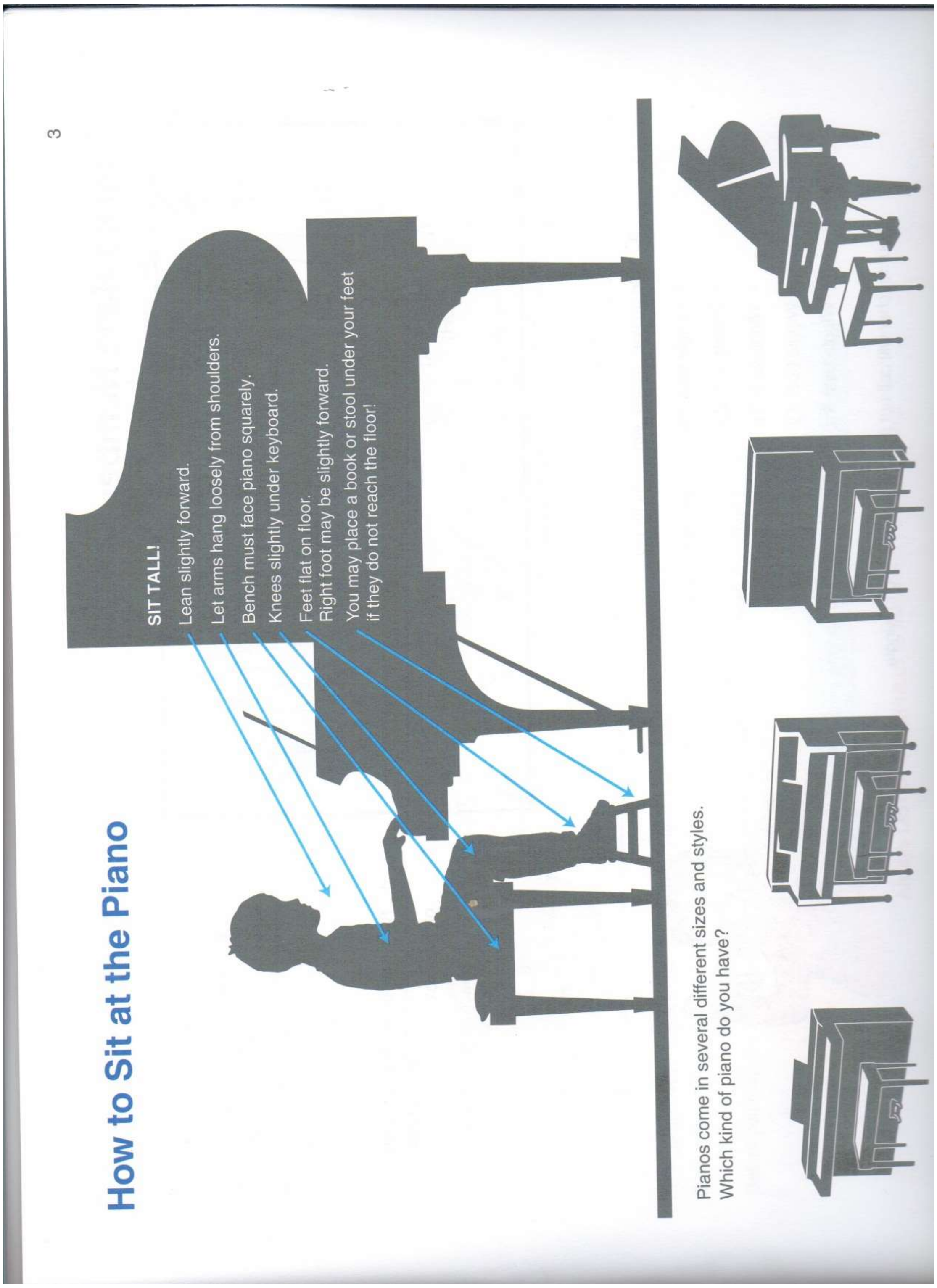
The comparison between beginners and advanced piano students showed that both teams did not opt for upright spinal angles when playing the piano; instead, their spinal angles showed slump postures, making them vulnerable to injuries. Advanced students showed slightly more upright spinal angles than beginners but still slump postures, despite their advanced training. Statistically significant differences in spinal angles were found between the two teams at the beginning of each scale, not at the subsequent stages of the performance, which shows that advanced students did not sustain their initial posture for the duration of the performance, exposing themselves to injuries even when playing non-demanding, well-learnt scales.

The significant differences in finger movements between the two teams reveal that their training was centered more on the areas of hand and fingers than in posture, even though posture is reported as a major factor for the appearance of PRMDs in pianists, an instrumental group with high percentages of these disorders. The results of the experiment suggest that piano training should focus more intensely on proper upper body posture in order to prevent PRMDs, pursuing collaboration with sports sciences, an area which would provide valuable information and experience in the direction of well-being and strengthening of the body.

Despite the proven significance of proper posture in the well-being of pianists, research on this field is still limited in comparison to studies focusing on pianists' hands and fingers. It is important to mention here that there is no universally-accepted definition of the ideal sitting-posture yet, a fact that makes the need for further research on pianists' posture necessary for the prevention and treatment of PRMDs. The high frequency these disorders among pianists, especially young students, stresses the need for thorough exploration of this subject and improvement of both prevention and treatment strategies.

Appendix
Upper-body posture instructions in piano methods for beginners

1. Alfred's Piano Basics. Lesson Book: Level 1A



2. Nancy and Randall Faber: My First Piano Adventure for the Young Beginner. Lesson Book A Pre-Reading (p. 1)

Nancy and Randall Faber: My First Piano Adventure for the Young Beginner. Lesson Book A Pre-Reading (p. 2)

3. Charles Hervé and Jacqueline Pouillard: Méthode de piano: débutants (p. 1)

ΠΩΣ ΚΑΘΟΜΑΣΤΕ ΣΤΟ ΠΙΑΝΟ

Για να υπάρχει σταθερότητα στο κλαβιέ, θα πρέπει ο μαθητής να κάθεται σωστά. Γι' αυτό και είναι πολύ σημαντική η εκλογή του καθίσματος. Εμείς συνιστούμε το παραλληλόγραμμο ή τετράγωνο «σκαμπό» που ρυθμίζεται στο ύψος. Αντίθετα δεν συνιστούμε το στρογγυλό περιστρεφόμενο.

Εικ. 1 Πόδια στο έδαφος

Εικ. 2 Πόδια σταυρωμένα

Ο μαθητής πρέπει, μόλις το ύψος του το επιτρέπει, να βάζει τα πόδια στο πάτωμα.
Για τους πιο μικρούς μπορούμε να βάλουμε ένα σκαμνάκι κάτω από τα πόδια τους ή, πιο απλά, να τους [illegible] τα σταυρώσουν.

Charles Hervé and Jacqueline Pouillard: Méthode de piano: débutants (p. 2)

ΘΕΣΗ ΤΟΥ ΣΩΜΑΤΟΣ

Ο αγκώνας είναι εκείνο που καθορίζει το ύψος του σκαμπό και την απόστασή του σε σχέση με το πιάνο:

ύψος = **αγκώνας στο ίδιο επίπεδο με το πληκτρολόγιο**
απόσταση =**αγκώνας ελαφρώς πιο μπροστά από το σώμα.**

– Καθόμαστε πάντοτε στο μέσον του κλαβιέ, απέναντι από τα πεντάλ.
– **Ακουμπάμε τα πόδια στο έδαφος** (για τα μικρά παιδιά: σταυρώνουμε τα πόδια [εικ. 2] ή τα βάζουμε πάνω σ' ένα σκαμνάκι).

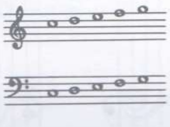
Το ρυθμιζόμενο σκαμπό – παραλληλόγραμμο ή τετράγωνο – εγγυάται την καλύτερη στάση του σώματος.
Το στρογγυλό «περιστρεφόμενο» σκαμπό δεν συνιστάται επειδή δεν εξασφαλίζει καμία σταθερότητα απέναντι στο κλαβιέ.
Απαραίτητη προϋπόθεση για να παίξουμε σωστά πιάνο είναι να κρατάμε το σώμα μας χαλαρό.
Η αναπνοή και το σύνολο «δάχτυλα, καρπός, αντιβράχιο, αγκώνας, βραχίονας, ώμος» πρέπει να είναι ελεύθερα.
Για να γίνει αισθητή η χαλαρότητα του βραχίονα:
– βαδίστε με τα χέρια κρεμασμένα ελεύθερα,
– σηκώστε ένα χέρι και αφήστε το να πέσει φυσικά, παρασυρρόμενο από το βάρος του.

ΘΕΣΗ ΤΟΥ ΧΕΡΙΟΥ

– Τοποθετήστε το χέρι πάνω στα πλήκτρα στην προέκταση του αντιβραχίου:
  - τον αντίχειρα στην αρχή των άσπρων πλήκτρων.
  - τα υπόλοιπα δάχτυλα λίγο στρογγυλεμένα και μπροστά από τα μαύρα πλήκτρα.
  - το χέρι ελαφρά κυρτωμένο.
    (προσέξτε την ισορροπία μεταξύ 1ου και 5ου δακτύλου).

– Κρατήστε το χέρι και τον καρπό εύκαμπτα και χαλαρά.

Θέση στην οποία μπορείτε να δουλέψετε



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