Identifying Vocational Deficiencies in Musicians

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A combination of factors exposes musicians to neuro-musculoskeletal disorders, which lead to pain and damage. These involve overuse due to long playing hours, containing repetitive movements under stressful conditions, usually performed in an unnatural posture. Although the evoked disorders are usually non-traumatic, they may often lead to prolonged or even permanent damage. For instance, in upper string players, these include bursitis and tendinopathies of the shoulder muscles, tendonitis of the rotator cuff, injury at the tendon sheaths, medial or lateral epicondylitis (also known as tennis elbow), myofascial pain, and wrist tendonitis (also known as carpal tunnel syndrome, or De Quervein’s syndrome). In cases of intensive performance, a traumatic injury may result, requiring drastic means of intervention such as surgery. It should be pointed out that the upper body and upper extremities are the most commonly affected sites of playing musicians.

vocation-related neuro-musculoskeletal disorders

evaluation of playing-related disorders in professional musicians

temporomandibular joint

diagnostics of muscular disorders

biomechanical aspects of neuro-muscular deficiencies

1. Introduction

Vocation-related deficiencies place a burden on the working individual, society and economy, requiring means to identify, evaluate and alleviate the factors responsible for evoking these deficiencies. Specifically, performing music players are exposed to the hazards of neuro-musculoskeletal injuries due to the high loads their body is subjected to, as well as discomfort and pain. It has been reported that among orchestra musicians, the incidences of pain and/or neuro-musculoskeletal disorders (percentages of tested players in a given group of instruments) are 75% for violin and viola players, 73% for cello, 60% for double-bass, 69% for woodwinds, 39% for brass and 32% for percussion players [1]. Players of the violin and viola are thus specifically recognized as the most susceptible to playing-related musculoskeletal disorders (PRMD) [2][3][4][5][6][7][8].

In these players, the muscles and joints of the upper extremity are the most frequently affected, particularly on the left side, and the side on which the instrument is actually being held [7][9][10][11]. The unusual and non-symmetrical postures involved in generating the motion of the upper limb segments have been reported to enhance the formation of PRMD [12]. The neck, shoulder and temporomandibular joint (TMJ) are particularly prone to damage due to the continued flexion of the head and the shoulder required to grip the instrument in place. The limbs and trunk are subject to relatively high loading forces, repetitive movements, vibrations and fatigue, and the elbow and fingers are common sites of disorders [11][13][14][15]. In addition, upper string musicians perform nearly incessantly during the concert, which makes them even more susceptible to fatigue and injury.

Common neuro-musculoskeletal deficiencies will include temporomandibular deficiencies (TMD), disorders related to the active muscles involved during playing and disorders related to body posture, kinematics and dynamics. The issues discussed include motion detection and analysis, force and impact, multi-parameter detection and multidimensional analysis, as well as semi-quantitative methods using visual assessment, physical examination and questionnaires.

2. Temporomandibular Joint (TMJ) and Temporomandibular Disorders (TMD)

2.1. The Existence of TMD

Disorders of the TMJ pertain to the musculoskeletal system and are associated with complaints in the orofacial region where the muscles of mastication and/or the TMJ are involved [16][17]. The playing of musical instruments has frequently been linked to the presence of TMJ disorders (TMD).

2.1.1. Wind Instruments

Wind-playing musicians may overload the masticatory system due to straining of the masticatory muscles and facial muscles that control the shape of the stress and lips, leading to discomfort and pain [17][18][19][20].

2.1.2. Upper String Instruments

During playing of upper string instruments such as violin or viola, the instrument is supported between the left shoulder and angle of the jaw to fixate the instrument between the inferior border of the mandible and the shoulder (supraclavicular fossa). The myofascial trigger points of the muscles of mastication induce jaw pain [7][21][22][23][24].

Mandibular lateral displacement, consisting of a lateral inclination of the occlusal plane and resulting in differences between the right and left masticatory muscles, gives rise to a marked uneven stress distribution in the mandible [25][26][27].

2.1.3. Lower String Instruments

Temporomandibular disorders, often with chronic low back pain, have also been reported in cello playing, due to the forward head posture, accompanied by a posterior thoracic curve and rounded shoulders [28].

2.2. Methodologies for TMD Identification and Evaluation

2.2.1. Imaging Methods

X-ray methods, including postero-anterior cephalogram, panoramic tomogram and lateral cephalogram have been used to compare between players, and gender- and age-matched controls. Significant morphological differences have been found between violin players and controls [25][26]. In the lateral cephalogram method, several cephalometric parameters are used for comparison [29]. Using these parameters, upper string players are found to have a measurable increase in the facial height compared to the matched controls, especially in the right side of the lower face, and an increase in the anterior inclination of the upper and lower incisors [25]. This can be considered to result from prolonged playing of the violin, involving increased face muscle activity. Thus, compared to controls, the categories of violin and viola players are shown to have a higher prevalence of brachyfacial type individuals, manifested by smaller facial heights and greater lengths of mandibular corpus [25]. This finding has been further confirmed not only for strings, but also for wind instrument players [26].

2.2.2. Inserts and Devices

Occlusal Contact Insert

Intra-oral insert devices, fabricated by computerized three-dimensional methods, are used to correct occlusal contact disorders and restore the occlusal stability of upper string players [30].

Chin Rest and Chin Force

A chin rest [31][32], consisting of a pressure-sensitive pad with shoulder pads as possible mediators [33], is often used in violin playing. Chin rests may also be used for measuring the compressive force on the left mandible by means of a custom-built force sensor fixed between the violin's top plate and a chin cup [34].

Changing the chin rest and changing the shoulder pad, both reported to affect the pressure and force applied over the chin rest during violin performance, are common ways to modify the violin to accommodate the player for effectiveness and comfort. I

Displacement Measurements of the Mandible

Displacement of the mandible accompanied to the exertion of the chin force can be assessed using a digital camera attached to the head of the subject [34].

2.2.3. Finite Element Analysis (FEA) in TMD

Using a three-dimensional finite element model (3D FEM) of the entire body has confirmed the earlier observations [35] that the occlusal plane in patients with mandibular lateral displacement rises in the direction of the mandibular displacement.

A lateral inclination of the occlusal plane has been found to induce cervical spine displacement and to cause the stress distribution in this area to be asymmetrical, thus affecting posture [36][37][38]. The simulation of the inclination of the occlusal plane, namely the effect of its lateral upwards inclination, has been carried out by studying the stress distribution in the mandible in conjunction with cervical spine morphology [27].

With the upward inclination of the occlusal plane towards the mandibular displaced side [35], as well as its lateral inclination [27][36], the FEA model has demonstrated high occlusal stresses on the left side of the mandible, with marked differences in the area corresponding to the left molar root apex.

The above analysis suggests that in players suffering from mandibular lateral displacement, it is necessary to improve maxillo-mandibular antero-posterior imbalance, as well as to correct the right–left skeletal asymmetry [36].

3. Muscle Activity and Disorders

3.1. Why Disorders May Result from Muscle Activity in Musicians

Playing musical instruments involves the activation of numerous muscles at considerable levels of intensities. Muscle activity is usually monitored by means of the electrical signals accompanying its activity, namely the electroyograpm (EMG).

The electromyographic activity of these muscles reveals their relative roles in actuating the shoulder and elbow joints [39][40]. Controlling the bowing motion is carried out by the forearm flexor and extensor muscles [1][4][41].

3.2. Muscle Electrodiagnostic Methods

3.2.1. Measuring Muscle Activity

Most published works make use of surface EMG, while intramuscular electrodes are less common, and these studies mainly deal with the muscles of the upper limbs and trunk [42][43][44]. Quantitative EMG can also be used to study the force intensity in various muscles of playing violinists, including the trapezius, deltoids, biceps and triceps muscles [45][46].

3.2.2. EMG Processing and Reproducibility

The EMG signals of string players are often processed in the time domain, e.g., using the average rectified EMG (AREMG) from different muscles, as detected by surface electrodes [45]. Another method consists of quantifying the EMG amplitude and duration distributions in defined time domains, using the exposure variation analysis (EVA) [47][48][49]. This processing method is based on the simultaneous assessment of amplitude variability, as well as the time period corresponding to the different amplitudes.

Rectified EMG signals are also used to study muscle synchronicity among the proximal/distal musculature of the limb by means of cross-correlation analysis [50][51], or among antagonistic muscles to reveal synchronicity and co-contraction in drum players [52].

The processing of the EMG in the frequency domain is associated with the frequency content of the signal, and specific quantities, such as mean and median frequencies, and is used to express fatigue of the muscle [53][54].

3.2.3. EMG using Wire Electrodes

Monitoring the electric activity of muscles may also be achieved with fine wire electrodes, which are inserted into the muscle of interest. This method is characterized by its high specificity and is therefore expected to produce more accurate activity results, compared to the conventional surface measurements. However, because it is invasive, it may cause discomfort and interfere with normal playing [55].

3.2.4. Additional Electrodiagnostics Techniques

In addition to EMG, more specific electrodiagnostic techniques can be used in performers. These techniques include upper-limb H-reflex reciprocal inhibition [56], somatosensory evoked potential brain mapping techniques, and transcranial magnetic stimulation (TMS) [43][57], and these have been used particularly in studying focal dystonia and cortical excitability/plasticity. Repetitive TMS is being used for the treatment of complex regional pain syndrome (CRPS), a chronic progressive disease characterized by severe pain combined with sensory, autonomic, and motor disturbances [58].

3.2.5. EMG Applications in Performers

(a) Co-Activation of Muscles

Co-activation (or co-contraction) refers to the simultaneous activity of antagonist muscles. The consequence of co-activation is that the same joint torque can be produced in various different ways, depending on the activation level of each of the acting antagonist muscles [59].

In playing upper string instruments, co-activation takes place when the left forearm, the wrist and the finger flexor, as well as extensor muscles, are used to control the fingering movements in the hand. Similarly, in the right forearm both the flexors and extensors are used to control the bow of the instrument [1][4][41][60].

(b) Muscle Imbalance and Asymmetry

To reveal muscle imbalance, the quantitative EMG results of the bilateral trapezius, deltoid, biceps, and triceps muscles are compared between players with performance-related pain in the neck and shoulder region and players without pain [41][45].

(c) Risk Assessment (e.g., Increased Deltoid Activity)

With raising the arm the deltoid also raises the humeral head. To counterweight the subsequent compression of the humeral head against the undersurface of the acromion and reduce the risk of injury of the supraspinatus tendon, simultaneous contractions of the infraspinatus, teres minor and subscapularis rotator cuff muscles occur [61]. An increased deltoid muscle activity will usually evoke a decrease in subacromial space and an increased compression of the humeral head, thus augmenting the hazard of injuring the supraspinatus tendon.

(d) Subacromial Impingement Syndrome (SAIS)

Subacromial impingement syndrome (SAIS), the commonest disorder of the shoulder, is a painful disorder due to loss of subacromial space [62].

(e) Assessment of Shoulder Rest and Backrest Support

EMG of the upper arm muscles of the violin players can also be used to assess the efficacy of a shoulder rest attached to the violin. The EMG signals (rectified EMG) of the left trapezius and right sternocleidomastoid muscles reveal a significant reduction in muscle activity when the shoulder rest is used [63][64]. EMG reduction in these muscles (thus their forces) is associated with their increased lever-arm.

(f) Comparison Between Upper Strings and Cello Playing

Opposed asymmetry differences in the middle and lower trapezius MAI in the upper string and cello groups are also noted between bowing down (from tail to tip) and bowing up (from tip to tail). In upper strings, sliding the bow up requires higher muscle activity (about 50% higher than sliding it down) [39][65]. The reason is that there is a static loading of the left shoulder to support the instrument, and a dynamic, repetitive loading of the right shoulder to facilitate the bowing, the latter being eased by gravity during the bowing down movement [47][46].

(g) Piriformis Muscle Syndrome

A potential syndrome of great discomfort in cellists is piriformis syndrome, associated with the piriformis muscle, which can particularly become tight and cause pain through pinching of the sciatic nerve [28]. Although a monitoring of the surface EMG of the piriformis is possible [66], it might be preferable to make use of fine-wire electrodes, due to the deep location of the muscle [67].

(h) Muscle Fatigue

Through the processing of the EMG signal, information about muscle fatigue can be obtained both in the time domain (e.g., amplitude of the normalized the rectified signal) and/or in the frequency domain (e.g., median frequency) [53][54]. In musicians, EMG analysis has been found to be efficient for detecting muscle fatigue with PRMD players compared to those without PRMD [68].

(i) Efficacy of “Taping” for Muscle Movement Restriction

As above-described, altering the resting position of the scapula due to muscle imbalance can stimulate pain [69]. This pain can be alleviated by taping the scapulae of violinists into a position that prevents excessive elevation and protraction whilst playing. EMG measurements can be used to evaluate the efficacy of taping treatment by recording the activity from the upper trapezii, the scapula retractors and the right sternocleidomastoid muscles.

(j) Biofeedback

The recording of surface EMG is also useful for biofeedback in the treatment of pain problems, and to train players to reduce excessive force, such as that produced in the left hand and wrist of violinists from gripping the neck of the violin too tightly [22].

(k) Assessment of Low Back Pain (LBP)

Using EMG measurements, it has been demonstrated that the presence of low back pain (LBP) can cause a modification of the activation between synergistic muscles of the lumbar back, suggesting that subjects with LBP experience higher fatigability of the erector spinae muscles at the thoracic part than at the lumbar part [70][71][72][73]. The increased fatigability of the thoracic part may be relevant in string players whose upper body is active during playing.

4. Posture and Motion

4.1. Significance of Posture and Movement to Playing Disorders

Information about posture and kinematics can be used for developing efficient and effective strategies to prevent overuse syndrome in violinists, keeping biological loads under physiological limits, focusing on physical economy for minimizing fatigue during training [74][75] and for the assessment of postural flaws [6][69][76][77].

4.2. Measuring Kinematics and Dynamics in Playing

4.2.1 Three-dimensional Motion Analysis

Monitoring the kinematics of the body, violin and bow is accomplished by measuring the time-position of properly attached passive markers using an optoelectronic motion capture system [32].

Specific systems include the MacReflex 3D analysis system [15][78] and the Vicon multiple-camera motion capture system [15][40][79]. The three-dimensional time coordinate data are offline reconstructed using a Butterworth filter [39][80]. Angular information can also be obtained from these photogrammetric data [81]. Dynamic modeling using inverse dynamic analysis is used to estimate internal loads at the joints [79][82].

4.2.2. Electrogoniometers (twin axis) and Potentiometers (single axis)

Bi-axial electrogoniometers are used to measure the range of wrist motion, to identify frequently assumed wrist positions, and to determine the differences between right and left wrist motions among professional violinists [83][84]. Single-axis potentiometers are used to measure finger movement in double bass players [15][85].

4.2.3. Impact Loading

Intensive, stressful activations of the upper limb during playing result in severe loading on the upper limb from each bowing beat, and are related to progressively increasing harm. The small intrinsic hand muscles, which are greatly involved in generating these recurrent abrupt movements, are thus exposed to risk of damage [86][87]. Similar to the muscles, tendons and nerves of the wrist, the forearm, elbow, shoulder, and neck are at great risk, and repetitive strain injury can take place [13].

4.2.4. Accelerometry

The application of accelerometers to measure movement, especially dynamic movement, can provide detailed information about abrupt dynamic loading, including intensity, timing and frequency content [54]. Although the application of accelerometers in assessing musicians' movement has up to this point been limited, the potential of this method is promising [88][89][90].

4.2.5. Other Force Measurements and Dynamometry

Forceplate measurements can be used to monitor the foot–ground reaction forces during playing. For instance, in flute playing, two forceplates, one for each foot, can serve to study the shifting effects from one foot to the other following changes in playing technique [91]. Forceplate measurements, together with kinematic and EMG measurements, may also be incorporated into a multi-segment biomechanical model for studying the biomechanics of violin playing [40].

A custom-designed force transducer has been used to monitor the force exerted on the fingerboard of the instrument by the left finger in playing a musical note at diverse playing tempi or other playing conditions [92][93]. This finger force has been used as the input force in a 3D biomechanical dynamic model for the index finger, to simulate the internal tendon and joint forces of the hand [94][95].

4.3. Combined Measurements

4.3.1. EMG and Kinematics/Dynamics

Combined measurements of kinematics of the bowing arm and of the EMG of the trapezius and serratus muscles are performed to look for differences between violinists with subacromial impingement syndrome (SIS) and uninjured violinists [49][55][82].

4.3.2. EMG and Acoustic Signals (Sound)

The simultaneous recording of muscle activity and its relationship to sound production as captured by its acoustic signals can be used to study a musical performance of violin playing with vibrato [96].

4.4. Multidimensional Signal Analysis (MSA)

Multidimensional signal analysis (MSA) involves the coordination and correlation between data collected through multiple experimental and analytic techniques [31][39][40][65][49][97][78].

4.5. Semi-Quantitative Methods Using Visual Assessment, Physical Examination and Questionnaire

Task-specific measures of PRMD, incorporated into qualitative posture assessment and physical examination, have been used in conjunction with questionnaires [2][7][69][77][98].

5. Summary

This study provides a description of the playing-related motor disorders in performing musicians, and of the methodologies used to identify and evaluate these disorders. Methodologies to diagnose, characterize and evaluate PRMD are clearly of importance for the further improvement of devices and techniques aimed at reducing damage associated with the prolonged playing of music.

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