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A Scoping Review of Exercise Intervention for Playing-Related Musculoskeletal Disorders (PRMDs) among Musicians

Adedayo Tunde Ajidahun
https://orcid.org/0000-0002-5265-4212
University of the Witwatersrand, South Africa
adajidahun@aol.com

Hellen Myezwa
https://orcid.org/0000-0003-4562-6413
University of the Witwatersrand, South Africa

Witness Mudzi
https://orcid.org/0000-0003-4818-5318
University of the Witwatersrand, South Africa

Wendy-Ann Wood
https://orcid.org/0000-0002-7824-3024
University of the Witwatersrand, South Africa

Abstract

Exercise-based programmes have been used successfully in the prevention of musculoskeletal problems in sport and among performing artists. However, the components and the implementation protocol of the exercise programmes vary but the main focus is on managing the presenting symptoms of the musician. The aim of this study was to explore evidence concerning the components of exercise-based programmes in the management of musculoskeletal problems among musicians. A scoping review of peer-reviewed literature from the inception of associated databases up to June 2016 was conducted on exercise-based intervention for musculoskeletal problems among musicians. A total of 176 articles were identified and 12 met the inclusion criteria and were included in the study. The components of the prescribed exercises are focused on strengthening and stabilising the core. They include stretching exercises prior to performance to reduce strain to the musculoskeletal system and proprioceptive motor control exercises. As such, this study highlights the importance of exercise-based interventions in mitigating the severity of musculoskeletal problems.

Keywords: exercise; musician; musculoskeletal disorders; injury

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Background

Over the last three decades, the focus on health problems related to instrument playing has shifted to a more preventative approach (Ackermann, Adams, and Marshall 2002; Brandfonbrener 1997; Chan, Driscoll, and Ackermann 2014). Musculoskeletal problems are the most common playing-related health problems among musicians (Gembris, Heye, and Seifert 2018; Žuškin et al. 2005). A cross sectional study conducted among professional orchestras in the United Kingdom reported a prevalence of musculoskeletal problems in 86 per cent of the instrumental musicians over a period of 12 months (Leaver, Harris, and Palmer 2011). The upper extremities and trunk are usually the most affected areas of injury. The fretting hand in the guitarists (Rigg, Marrinan, and Thomas 2003), the fingers in the pianists (Allsop and Ackland 2010) and the arms and wrists in the bassoonists (Brusky 2010) were the commonly reported area of musculoskeletal problems. The most common diagnoses of playing-related neuro-musculoskeletal problems among musicians are musculo-tendinous overuse injuries, compressive neuropathy and neurological problem of focal dystonia (Hoppmann and Patrone 1989; Larsson et al. 1993; Lederman 2003; Ostwald et al. 1994).

Apart from the musical instrument being a predictor of musculoskeletal injury among musicians (Allsop and Ackland 2010; Brusky 2010; Rigg, Marrinan, and Thomas 2003; Moraes and Antunes 2012), risk factors such as gender, age and practice hours have been associated with musculoskeletal problems (Abreu Ramos and Micheo 2007; Davies and Mangion 2002). In the broad category of instrumental musicians, the female gender has been reported as a risk factor for Playing Related Musculoskeletal Disorders (PRMDs) (Yeung et al. 1999; Zaza 1992; Zaza and Farewell 1997). Musculoskeletal problems in the general population are higher among females than males (Anderson et al. 2001; Brandfonbrener 2002; Ekman et al. 2000). Variation in joint laxity (Brandfonbrener 2002), smaller body frame (Ekman et al. 2000) and hormonal influences (Anderson et al. 2001) have been reported in literature to predispose females to musculoskeletal problems. The female gender is at a higher risk of developing musculoskeletal problems and the increased risk is mostly a genetic variation (Anderson et al. 2001; Brandfonbrener 2002; Ekman et al. 2000).

There is contradictory evidence to suggest that age has a direct influence on the development of PRMDs (Ranelli, Straker, and Smith 2008). Ranelli, Straker, and Smith (2008), in their study with young learners, showed that older musicians will more likely report musculoskeletal problems than young learners. Age is not considered a predictor of PRMDs among instrumental musicians. However, knowledge and understanding of PRMDs increases with age, which is directly associated with an increase in years of experience (Ranelli, Straker, and Smith 2008).

Lack of warm-up exercises prior to playing has been reported to predispose the instrumental musician to PRMDs (Davies and Mangion 2002; De Greef et al. 2003;

Kaufman-Cohen and Ratzon 2011; Yoshimura et al. 2008). Instrumental musicians practise and play for an average of five to nine hours per week (Kaufman-Cohen and Ratzon 2011; Yoshimura et al. 2008; Newmark and Lederman 1987). A significant increase in practice hours increases the development of playing related problems among amateur instrumentalists (Newmark and Lederman 1987). Similarly, Zetterberg et al. (1998) reported that higher practice hours among female music students are associated with pain in the hand. The development of problems such as pain is linked to physiological and anatomical changes that occur due to repetitive strain and overuse (Shan, Visentin, and Schultz 2004).

There are varying degrees of severity which depend on the instrument played, the gender of the player, the years of experience in playing, and time spent playing (Bragge, Bialocerkowski, and McMeeken 2006; Leaver, Harris, and Palmer 2011; Yeung et al. 1999). The demands of playing a musical instrument share similarities with respect to the demands placed on an athlete in terms of the amount of time required for practising and acquiring the skills in question, as well as the demands on the neuro-musculoskeletal system (Dommerholt 2009; McCrary 2016). The demands of playing a musical instrument involve repetition, skill acquisition through long hours of practice and sustained posture positions, all of which predispose the player to injury (Kaufman-Cohen and Ratzon 2011).

Several injury prevention strategies, such as health promotion programmes inclusive of health education and exercise intervention, have been utilised in the management of PRMDs. These strategies have shown positive outcomes in improving the understanding of the predisposing factors and injury management strategies with subsequent behaviour change in the prevention PRMDs (Ackermann et al. 2014; Barton and Feinberg 2008).

Exercise programmes have been used consistently to reduce the incidence of musculoskeletal problems in sport (Gatterer et al. 2012; Longo et al. 2012). Similarly, exercise programmes have been adapted and developed to reduce the incidence of musculoskeletal problems among musicians (Ackermann, Adams, and Marshall 2002; Chan, Driscoll, and Ackermann 2014; Cooper, Hamann, and Frost 2012).

In recent years, exercise-based programmes have been employed to manage musculoskeletal problems associated with the playing of musical instruments (Chan and Ackermann 2014; Chan, Driscoll, and Ackermann 2014). A number of the injury prevention strategies have been established in countries such as Australia, United States of America, and Canada, where health practitioners have been involved in the management of playing-related musculoskeletal problems (Ackermann et al. 2014; Chan, Driscoll, and Ackermann 2014; Zaza 1993).

Devroop (2014) proposed a research model that could be adopted for South African musicians, which included: 1) the establishment of research teams; 2) the determination of prevalence rates of medical problems; 3) the identification of risk factors; and 4)

education. This model comprises exercises adapted to existing injury-prevention strategies to suit the nuanced differences in the South African population (Devroop 2014). Similarly, Rennie-Salonen and de Villiers (2016) also suggested the inclusion of a health promotion programme aimed at preventing injuries in the teaching of music students in South Africa at the undergraduate level.

Practising habits and the demands of performance placed on musicians have been considered to be similar in several respects to those associated with sport (Dommerholt 2009; McCrary 2016). In sport, exercise-based injury prevention is focused mainly on conditioning the athlete to the demands of the profession (Longo et al. 2012; Steffen et al. 2013a). Exercise-based injury prevention programmes include core training, neuromuscular facilitation, and plyometric patterning, with regard to the demands of the sports, as in the case of football (Kilding, Tunstall, and Kuzmic 2008; Steffen et al. 2013a) and basketball (Longo et al. 2012) respectively. Therefore, the inclusion of an exercise-based injury prevention programme as part of the occupational health promotion programme for musicians may reduce the incidence of playing-related musculoskeletal problems.

In recent years, scoping reviews have been used to consider the evidence surrounding such problems, to identify gaps in the research, to map out existing evidence around a topic, and to explore the grey areas to provide answers to pertinent questions (Crooks et al. 2010; Hanass-Hancock et al. 2013; O'Flaherty and Phillips 2015). Scoping reviews, unlike systematic reviews, are not to synthesize results for the overall aim of determining effectiveness to influence policy and systems; they are often used to clarify concepts, identify knowledge gaps or identify characteristics of a related concept (Munn et al. 2018). The overall aim of this study was to evaluate the components, implementation and prescription of exercise programmes used in the management of musculoskeletal problems among musicians. The results from this review could be of assistance in future studies in adapting, developing and implementing a holistic exercise programme to reduce musculoskeletal problems among musicians.

Methodology

The scoping review followed five steps, namely: to identify the research questions and relevant studies; to select material for the study; to chart data; and to summarise and collate the results (Arksey and O'Malley 2005; Levac, Colquhoun, and O'Brien 2010).

Research Question

The research question for this scoping review was based on the exercise prescription guideline of the American College of Sports Medicine (2014), which includes the type of exercise, prescription parameters and implementation strategies. Therefore, the research question for this scoping review is: What are the exercise programmes that have been used to prevent/manage PRMDs in musicians?

The research objectives of this scoping review were as follows:

- To evaluate the content and structure of an exercise-based injury prevention/management programme for the prevention of PRMDs among musicians; and
- To evaluate the implementation strategy of the exercise-based injury prevention/management programme for the prevention of PRMDs among musicians.

Identifying Relevant Studies

The following data bases were searched: Physiotherapy Evidence Database (PEDro); MEDLINE via PubMed; Cumulative Index to Nursing and Allied Health Literature (CINAHL); Cochrane Controlled Trials Register in the Cochrane Library; EBSCO; Sport discus; and SCOPUS.

The following search terms were employed in various combinations based on the Boolean search strategy: “musicians”; “instrumentalists”; “musculoskeletal”; “injury”; “rehabilitation”; “exercise”; and “management”. The combinations used followed the following pattern—“Musician” OR “instrumentalist” AND “injury AND “exercise”; Musician” OR “instrumentalist” AND “injury AND “management”; Musician” OR “instrumentalist” AND “injury” AND “rehabilitation.”

Study Selection

Guidance for the scoping review was structured on the population, phenomena of interest, intervention and outcome (PICO) (Schardt et al. 2007). The eligibility criteria of the studies are outlined in Table 1.

Table 1: Eligibility criteria

Eligibility criteria	Inclusion criteria	Exclusion
Population	All studies were conducted on participants that were performing arts musicians and were 18 years and older. Both male and female participants were included.	Participants who had exercise interventions for systemic diseases or traumatic musculoskeletal problems were not included.
Intervention /Outcome	All literature on reproducible exercise programmes for musculoskeletal injury among musicians, related exercise prescription and the implementation strategy outlined were included in the scoping review.	All other forms of intervention among musicians were excluded from the scoping review.
Study type	Both experimental and epidemiological study designs included randomised controlled trials, non-randomised controlled trials, quasi-experimental studies, before-and-after studies, prospective and retrospective cohort studies, case-control studies, and analytical cross-sectional studies. Descriptive epidemiological study designs including descriptive cross-sectional studies were also considered. Only peer-reviewed studies were included in the scoping review.	

Extraction and Charting of Data

A total of 176 studies were identified from the databases. A review of the abstracts and titles included 41 articles and excluded 135 articles. Nine duplicates and 20 articles that did not meet the inclusion criteria were removed, leaving 12 articles. Twelve articles were included in the scoping review. The flowchart of the study selection process is outlined in Figure 1.

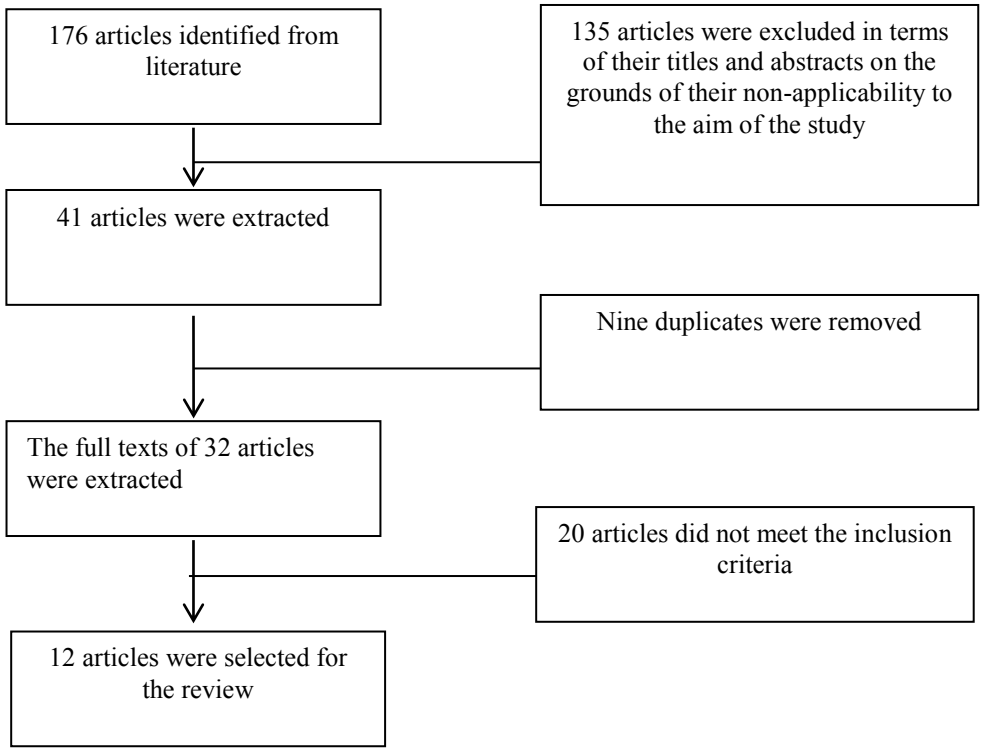

Figure 1: Flowchart of the study selection process

Results

The data extracted from the selected studies included the demographics of the population studied, outcome measures and the methodology, as charted in Table 2. The components, prescription, implementation strategy and the key outcomes of the exercise programme were also extracted, as shown in Table 3. The exercise components, based on the exercise prescription guideline by the American College of Sports Medicine (2014), were charted. This guideline records the type of exercise, its frequency, sets and repetition, and, additionally, the implementation process.

Characteristics of the Included Studies

Table 2 outlines the characteristics of the included studies. The characteristics extracted include the study design, the population and the outcome measures.

Table 2: Characteristics of the incorporated studies

Author	Population
McCrary (2016)	Population: 55 music students and professional orchestra musicians Mean age: 28.2±12.3 years Gender: 15 males and 40 females Outcome: Muscle activity and perceived exertion
Chan, Driscoll, and Ackermann (2014)	Population: 53 professional orchestra musicians Mean age: 44 years Gender: 20 males and 33 females Outcome: PRMDs / perceived exertion
Chan, Driscoll, and Ackermann (2013a)	Population: 144 professional orchestra musicians Mean age: 45±9.3 years Gender: not reported Outcome: Programme uptake and compliance, PRMD and perceived exertion
Chan, Driscoll, and Ackermann (2013b)	Population: Four physiotherapists with over 20 years of experience Outcome: Exercise programme
Ajidahun and Phillips (2013)	Population: Seven professionals with experience in the health of the performing artists Years of experience: 3–12 years Outcome: Warm-up exercise programme
Cooper, Hamann, and Frost (2012)	Population: 126 high school string players Age range: 14–18 years Gender: 35 males and 65 females Outcome: Perceived level of self-discomfort
Lee et al. (2012)	Population: 2 college musicians Gender: 1 male and 1 female Outcome: Playing-related health problems, physical and musical efficacy
Kava et al. (2010)	Population: 14 music students Outcome: Posture, breath control, muscle tension and endurance

De Greef et al. (2003)	Population: 53 professional orchestra musicians Mean age: 46 years Gender: 18 males and 32 females Outcome: Perceived physical competence and PRMDs
Ackermann, Adams, and Marshall (2002)	Population: 19 undergraduate music students Outcome: PRMDs, perceived exertion and muscle strength and endurance
Spahn, Hildebrandt, and Seidenglanz (2001)	Population: 44 music students Age range: 19–35 years Gender: 70% females and 30% males Outcome: PRMDS and anxiety
Brandfonbrener (1997)	Population: 315 professional orchestra musicians (age and gender not reported) Outcome: Musculoskeletal problems

Table 3: Exercise rationale, protocol and key findings

Author	**Aim: To determine/ evaluate the following:**	**Specific exercise and prescription**	**Key findings**
McCrary (2016)	The effects of four different warm-up protocols on muscle activity and exertion during performance	Warm-up protocols: Cardiovascular warm up: Moderate to high-intensity activities for 15 minutes. Core muscle strengthening: Dual-loading gluteal bridges, leg crossovers, opposite arm/extension and dynamic plank (20 RM each). Shoulder strengthening: Shoulder “A,” Shoulder “T” and Shoulder “W” (10 RM each) Musical warm-up group: Playing of graduated scales on the instrument	Perceived exertion: RPE decreased for all warm-up groups and there was no significant difference between the three groups. Muscle activity: Significant pre- and post-test differences in the right upper trapezius in the musical warm-up group and the right lower trapezius in the core muscle warm-up group

Author	Aim: To determine/ evaluate the following:	Specific exercise and prescription	Key findings
Chan et al. (2013a) Chan, Driscoll, and Ackermann (2014)	The effects of a developed exercise programme for the prevention of musculoskeletal injury for the mitigation of musculoskeletal injury and exertion during performance in the case of a professional orchestra	Exercises (the intervention was for a period of 9–12 weeks): Control: Low-load activation of supporting musculature of the local body region, scapular retractor and depressor activation (12 RM, 3 sets). Control, proprioception and balance: Increasing difficulty through unstable and changing positions, alternating arm and leg fall-outs on pool noodle (6 RM, three sets, 30-40 seconds consistent loading). Control, proprioception and resistance: Exercises modified into functional movement patterns with added resistance, deep neck stabiliser activation with cervical rotation and with resistance. Strengthening exercises: Deep neck flexor and extensor, low load activation of the lumbar multifidus, the abdominal muscles, and the gluteal muscle group.	Perceived exertion: There was a significant reduction in RPE at T1 and T2 respectively in the intervention group ($p<0.01$). PRMDs: There was a significant reduction in PRMDs in the exercise group ($p<0.05$) but no statistical significance between the initial evaluation and the group's six-month follow up.
Chan et al. (2013b)	Compliance to the exercise programme developed by Chan et al. (2013b) with the assistance of a digital video disc for home use.	Same as Chan et al. (2013a) and Chan, Driscoll, and Ackermann (2014).	Uptake and compliance: 25% of the participants commenced the programme; 50% of the participants completed the programme. PRMDs: Significant reduction in the frequency and severity of PRMDs was reported post-intervention. Perceived exertion: No significant changes in RPE. There was a moderate effect on the strengthening of the muscles that supported playing, while the least effect was experienced in the ability to cope with stress. Participants reported moderate positive effects on performance.

Author	Aim: To determine/ evaluate the following:	Specific exercise and prescription	Key findings
Cooper, Hamann, and Frost (2012)	Physical intervention of easily-performed stretches during rehearsals to reduce discomfort during performance.	Wrist rotations, shoulder deltoid exercise and forward oppositional finger-wrist press, hand/ finger extensions and fist clench and unclench. Hand wringing, arms – bicep curls and shoulder – deltoid variation (ear to shoulder). Handshakes, arms – triceps extension and fingers clenched and unclenched. All stretches were performed during rehearsals and the prescription was four sets, four times over two weeks.	As opposed to the control group, the intervention group reported significantly lower levels of discomfort (M=1.35) after rehearsals.
Lee et al. (2012)	Yogic breathing exercises, strengthening and flexibility exercises to reduce injury and improve self-efficacy.	Upper chest, middle chest, lower chest and the complete chest. Composite upper extremity stretch, pectoralis stretch. Exercises for cervical retraction, resisted scapular retraction, resisted chest pull, pelvic clock. All exercises were performed daily for a period of 20 minutes over four weeks.	The combined breathing and strengthening exercise showed increased awareness of physical efficacy, comfort of posture, and awareness of tension.
Kava et al. (2010)	Endurance of the scapular and trunk muscles to support the workload of the distal upper extremity.	Biceps curl, reverse fly, lateral raise, triceps extension, shoulder forward flexion, bent over row, back extension, shoulder extension, opposite shoulder and hip extension, sit-ups and push-ups. Prescription: The prescription of each exercise was 15–20 RM. All exercises were performed for a period of 13 weeks.	PRMDs: Increase in trunk endurance reduces fatigue and PRMDs. Breath control: Improved breath control after exercise in both groups

Author	Aim: To determine/ evaluate the following:	Specific exercise and prescription	Key findings
De Greef et al. (2003)	The effect of specific exercises identifying the strong and weak points in playing, the position of the musician at rest and during performance, the coping of the musician with movement patterns and effort, in order to develop a programme focused on all the identified patterns (Groningen programme).	Groningen programme: The programme consisted of the following: Warm-up and cool-down and mobility exercises, strength and endurance exercises, and specialised exercises specific to the demands of the musician. The programme was implemented over a period of 15 weeks. The specific exercises and the prescription parameters were not reported.	Musculoskeletal disorders: Decline in musculoskeletal disorders Physical competence: Increased perceived physical competence. Clinical relevance, moderate effect size (d=0.21).
Ackermann et al. (2002b)	Resistance training would reduce exertion and reduce musculoskeletal injury.	Warm up and cool down (5 minutes). Strength and endurance exercise: Biceps curl, reverse fly, lateral raise, triceps extension, shoulder forward flexion, bent over row, back extension, shoulder extension, opposite shoulder and hip extension, sit ups and push ups. Prescription: Strength (6–8 RM with Swill ball), endurance (25–30 RM). The duration of the exercise programme was 45 minutes and the implementation lasted for 6 weeks.	Perceived exertion: The endurance group had significant drop in RPE ratings. PRMDs: No significant difference in PRMDs after 6 weeks between the two groups.
Spahn et al. (2001)	Education on injury prevention would have a positive effect on psychological and physical health.	Health education Exercise: Posture exercises. Exercises for foot, leg, pelvis, lower back, abdominal muscles and upper extremity. Breathing exercises. The prescription parameters were not reported.	PRMDs: Significant reduction in musculoskeletal injury in the test group. Performance anxiety: Significant reduction in anxiety in both groups.

Author	Aim: To determine/ evaluate the following:	Specific exercise and prescription	Key findings
Brandfonbrener (1997)	Strengthening and flexibility exercise and warm up would reduce musculoskeletal symptoms. Education of the musicians on injury risk factors and importance of the exercise would improve cooperation.	Exercise: Warm up and cool down Strengthening and flexibility exercises. The specific exercises were not reported. The exercises were performed for a period of 15 minutes daily.	PRMDs: No significant difference in the musculoskeletal injury between experimental and the control group.

Exercise Programmes

The primary aim of this study was to explore the content and structure and implementation of an exercise programme adapted and developed for musicians. Warm-up exercises were included as part of the overall exercise intervention in four studies (Ackermann, Adams, and Marshall 2002; Brandfonbrener 1997; Chan, Driscoll, and Ackermann 2014; De Greef et al. 2003). Only two studies reported on the specific warm-up exercises done (Chan, Driscoll, and Ackermann 2014; De Greef et al. 2003). General physical activity was conducted as a warm-up exercise prior to the specific exercises in the Groningen study (De Greef et al. 2003). In their study, Chan, Driscoll, and Ackermann (2014) included breathing exercises, large body movements, trunk rotations and stretching exercises as warm-up exercises. McCrary (2016) evaluated the effects of three different warm-up protocols on perceived efficacy. Rated Perceived Exertion (RPE) was significantly reduced in the entire range of warm-up protocols (core strengthening, cardiovascular training and shoulder strengthening) (McCrary 2016). No significant difference in perceived exertion was observed between the three groups of violinists (McCrary 2016).

The specific exercises in the Groningen programme cannot be assessed, although the types of exercises prescribed included conditioning, strengthening, and mobility, warm-up and cool-down and specialised exercises patterned according to the needs of the different players (De Greef et al. 2003). The Groningen programme reported a decline in musculoskeletal disorders and an increase in perceived physical competence (De Greef et al. 2003). Ackermann, Adams, and Marshall (2002) compared the effects of strength and endurance exercises on musculoskeletal injury among undergraduate music majors. Both of the strength and endurance exercise training programmes showed a significant reduction in perceived exertion but there was no significant difference between the two groups in terms of the frequency and prevalence of musculoskeletal problems after six weeks (Ackermann, Adams, and Marshall 2002).

A comparison of the trunk endurance exercise programme, as well as shoulder strengthening programmes, and Pilates on musical performance and musculoskeletal injuries showed that both groups achieved improved breath control, in addition to increased trunk endurance, thereby bringing about a decline in fatigue and musculoskeletal disorders (Kava et al. 2010). A recent exercise programme developed for musicians by Chan, Driscoll, and Ackermann (2014), irrespective of the instrument played, focused more on improving neuromuscular control and proprioception of the shoulder and scapular region, as well as on strengthening the deep neck flexors and on the training of the core stabilisers (Chan, Driscoll, and Ackermann 2014). The exercise showed a significant reduction in musculoskeletal problems and perceived exertion in the intervention group ($p<0.05$) (Chan, Driscoll, and Ackermann 2014). Lee et al. (2012) incorporated yogic breathing exercises with strengthening and flexibility exercises, and the two groups of musicians showed an increase in physical efficacy and postural awareness.

The repetitive maximum for the core muscle exercises for the management of back pain was reported to be between 10–20 Repetitive Maximum (RM) (Chan, Driscoll, and Ackermann 2014; Kava et al. 2010; McCrary 2016). The stretching exercises conducted during rehearsals were reported to be carried out over four sets at rehearsals (4 times x 2 weeks) (Cooper, Hamann, and Frost 2012). The study by Kava et al. (2010) reported the repetitive maximum for the trunk endurance exercise to be 15–20 RM, whereas Ackermann et al. (2002b) reported the repetitive maximum for endurance and strength training to be 25–30 RM and 6–8 RM respectively. Chan, Driscoll, and Ackermann (2014) used progressive loading depending on the capacity of the musician. A warm-up exercise was scheduled for 5–15 minutes in the Delphi study by Ajidahun and Phillips (2013), while its duration amounted to between five and ten minutes in the studies by Brandfonbrener (1997) and McCrary (2016) respectively.

Discussion

The aim of this scoping review was to evaluate the components, prescription and implementation of exercise programmes used to manage instrument-playing health-related problems among musicians. The literature review established that health problems related to instrument playing are associated with the way in which the musical instrument is actually played (Bragge, Bialocerkowski, and McMeeken 2006; Moraes and Antunes 2012). The focus of injury-prevention programmes among musicians has shifted from primarily improving skills to a more holistic approach of physical conditioning as related to performance (Chan, Driscoll, and Ackermann 2013b; Chan, Driscoll, and Ackermann 2014).

In as much as the methodology of the study is not appropriate to evaluate effectiveness, it is noteworthy to report that exercise-based interventions showed positive outcomes in

the management of musculoskeletal problems among musicians (Ackermann, Adams, and Marshall 2002; Brandfonbrener 1997; Chan, Driscoll, and Ackermann 2013a; Chan, Driscoll, and Ackermann 2014; Cooper, Hamann, and Frost 2012; De Greef et al. 2003; Kava et al. 2010; Lee et al. 2012; McCrary 2016; Spahn, Hildebrandt, and Seidenglanz 2001). Exercise programmes were mainly adapted from physiotherapeutic exercises to suit the target demands of the anatomic structures associated with playing a musical instrument (Ackermann, Adams, and Marshall 2002; Brandfonbrener 1997; Chan, Driscoll, and Ackermann 2013a; Chan, Driscoll, and Ackermann 2014; Cooper, Hamann, and Frost 2012; ; De Greef et al. 2003; Kava et al. 2010; Lee et al. 2012; McCrary 2016; Spahn, Hildebrandt, and Seidenglanz 2001). The components of the exercise programme focused on the anatomic regions that are directly associated with the demands of playing the musical instrument. From the findings of the study, these proved to be mainly the neck, the back and the upper extremities.

Strength Versus Endurance Versus Core Stabilisation Training

The back is an area of the body that is commonly subjected to injury among musicians (Leaver, Harris, and Palmer 2011; Moraes and Antunes 2012). Its integral role in stabilising posture might be a plausible cause (Granata and Wilson 2001; Hammill, Beazell, and Hart 2008). Strength training, endurance training and core stabilisation training, as well as Pilates exercises, were used differently in these studies to either prevent or mitigate injury to the back (Ackermann, Adams, and Marshall 2002; Chan, Driscoll, and Ackermann 2014; Kava et al. 2010; Lee et al. 2012).

The prescribed exercises showed positive outcomes in the reducing the prevalence of musculoskeletal problems regardless of the specific type (strength, endurance and core stabilisation training) (Ackermann, Adams, and Marshall 2002; Chan, Driscoll, and Ackermann 2014; Kava et al. 2010; Lee et al. 2012). Comparisons between strength and endurance training, and between endurance and Pilates training, showed no significant differences, although the various exercise patterns were shown to result in a significant reduction in musculoskeletal injury (Ackermann, Adams, and Marshall 2002; Kava et al. 2010).

Training of the core stabilisers with proprioceptive and neuromuscular control training of the back, neck and shoulder also showed a significant reduction in musculoskeletal injury (Chan, Driscoll, and Ackermann 2014). Strength, endurance, and core stabilisation training showed no significant advantages over the other exercises in mitigating musculoskeletal problems (Kava et al. 2010). Each of the exercises—Pilates, strength training, endurance training and core stabilisation exercises—demonstrated a prophylactic effect in that they all increase the strength and endurance of the global stabilisers and the local stabilisers respectively (Ackermann, Adams, and Marshall 2002; Kava et al. 2010). An improvement in strength and endurance, as well as in training

of the core stabilisers, has been reported to be associated with positive outcomes in rehabilitation and a reduction in the incidence of musculoskeletal injury generally (Abdelraouf and Abdel-aziem 2016).

This implies that in developing an exercise-based injury-prevention programme, any of the three exercises would achieve similar results in preventing musculoskeletal injuries in musicians. However, stabilisation exercises would be more important in preventing low back pain in this population. Hammill, Beazell, and Hart (2008) found that the poor feed-forward activation of the local stabilisers is a risk factor for back pain, while Granata and Wilson (2001) found that the maintenance of spinal stability to reduce the onset of muscle fatigue and injury through overuse can be achieved by training the core stabilisers. Thus, in developing an injury-prevention programme for string instrument players with low load muscle activity, correct training in feed-forward activation and general training in lumbar stabilisation tend to have a prophylactic effect on performance-related back pain.

Proprioception and Neuromuscular Control

In the literature review for this scoping review research study, only one study was found to include neuromuscular control exercises as a component of their exercise programme (Chan, Driscoll, and Ackermann 2013b). Chan, Driscoll, and Ackermann (2013b) reported positive outcomes in their study, which included neuromuscular control, as well as strength and endurance training, in their exercise programme for the management of PRMDs in the members of professional orchestras.

Recent exercise-based injury prevention in sports and rehabilitation programmes have included more proprioceptive and neuromuscular controls in their exercise-based programmes and positive results have been reported in the rehabilitation of musculoskeletal injuries (Schiftan, Ross, and Hahne 2015; Steffen 2013a; Steffen 2013b). The positive outcomes would be due to training in feed-forward activation, which is the basis for training in neuromuscular control (Borghuis, Hof, and Lemmink 2008; Van Vliet and Heneghan 2006).

The neural pathways are trained to anticipate movement for better control of joint movement. It has been suggested that feed-forward activation is important in the prevention and rehabilitation of musculoskeletal injuries (Van Vliet and Heneghan 2006). Neuromuscular control is an important component in the acquisition of skills in string playing (Baader, Kazennikov, and Wiesendanger 2005; Konczak, vander Velden, and Jaeger 2009), and musculoskeletal dysfunction has been associated with altered neuromuscular control (Rathleff et al. 2013; Terada, Pietrosimone, and Gribble 2014). This suggests that a change in neuromuscular control on account of musculoskeletal dysfunction would result in a change in skill control required for an optimal performance.

It would, therefore, be important to include neuromuscular control exercises in an exercise-based injury-prevention programme for string players.

Stretching

In this study, stretching exercises showed positive outcomes in the two intervention studies that use flexibility training as part of their exercise programme (Cooper, Hamann, and Frost 2012; Lee et al. 2012). The role of pre-activity stretching in injury prevention is unclear (Shrier 1999; Small, Mc Naughton, and Matthews 2008; Weldon and Hill 2003). However, muscle stretching has been hypothesised to increase muscle compliance, which results in the extensibility of the muscle that leads to a reduction in muscle force (Witvrouw et al. 2004). In as much as the prophylactic effect of stretching exercises is unclear, the stretching of the shoulder and forearm muscles during breaks during music practice significantly reduces discomfort and perceived exertion among string players (Cooper, Hamann, and Frost 2012). This suggests that in string players, stretching exercises could be effective in reducing perceived exertion and discomfort.

Implementation and Compliance

Chan, Driscoll, and Ackermann (2013a) further evaluated compliance to the exercise programme among professional orchestra members. They reported that in their studies, compliance was poor and that participants with poor compliance reported a higher incidence of musculoskeletal injury. Compliance with an exercise programme in the management of musculoskeletal dysfunction is a challenge in rehabilitation (Bennell, Dobson, and Hinman 2014; Dorflinger, Kerns, and Auerbach 2013). High adherence to exercise programmes shows a reduction in the incidence of musculoskeletal injuries and improvements in outcome measures (Saarni et al. 2009; Steffen 2013a; Steffen 2013b). Thus, adequate communication with the patient about the importance of exercise, objective self-reporting measures, and their role in injury management would improve compliance and subsequently reduce the incidence of musculoskeletal injury, improve function and reduce pain (Bollen et al. 2014; Dorflinger, Kerns, and Auerbach 2013). In implementing an exercise-based injury-prevention programme for musicians, it would be important to consider compliance and adherence to the programme.

Conclusion

The scoping review showed that exercise generally tends to reduce musculoskeletal problems and perceived exertion. The focus of the exercises used in the studies under scrutiny was mainly to strengthen the muscles in the region associated with a high prevalence of musculoskeletal injuries, which include the back, neck and shoulder

regions. The anatomical and physiological demands of performance vary across various instrumentalists and it is important to note that prescribing the same exercise might not necessarily achieve an optimal result. Therefore, future research should develop and implement instrument specific exercise programmes to determine their effectiveness.

Limitations of Study

There is a probability that this review may have excluded some publications, despite the comprehensive and broad search strategy utilised. Another limitation of the scoping review is the lack of quality appraisal of the reviewed articles. Therefore, the result of effectiveness should be interpreted with caution. These limitations are not unusual in a scoping review and are considered as a limitation of the study design in itself (Pham et al. 2014).

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