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The effect of strategies to prevent and manage musicians' musculoskeletal symptoms: a systematic review

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The effect of strategies to prevent and manage musicians' musculoskeletal symptoms: a systematic review

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ABSTRACT
The objective of this systematic review was to determine the safety and effectiveness of any public health intervention designed to prevent and/or manage musculoskeletal symptoms (MSSs) in any type of musician. A total of 14 studies were included. Studies investigated exercise and/or education programs, and changes to equipment, with a range of musicians. There was some evidence to suggest that smaller piano keyboards, and exercise programs may be effective. Studies suggesting a benefit of exercise programs typically had lower level designs and higher risk of methodological bias, compared with those that reported no benefit. Future research should use more robust methods to reduce bias and come to definitive conclusions regarding the safety and effectiveness of interventions prior to implementation, to reduce the burden of MSSs for musicians.

Keywords: management; prevention; musculoskeletal; pain; musician; systematic review

INTRODUCTION
Musculoskeletal conditions are the leading cause of years lived with disability,[1] and are an occupational health and safety priority area.[2] Musculoskeletal symptoms (MSSs) are common among musicians,[3-5] and may considerably impact their lives.[6-8] Furthermore, most workers' compensation claims for musicians are for musculoskeletal disorders, which also account for the majority of claim costs.[9] Safe and effective strategies to reduce the prevalence and impact of musicians' MSSs are therefore warranted.

Rationale

Prevention of musicians' MSSs gained attention as early as the 1990's, with concerns raised regarding the implementation of musicians' MSS prevention strategies, until the effectiveness and potential harms were established.[10] Potential harms are not limited to the appreciable risks of exercise programs, but also other interventions where the harms may be more subtle. For instance, focusing musicians' attention towards their MSSs in an education session may

ultimately lead to the progression of minor MSSs to disability[10], and it has recently been suggested some advice provided to musicians may be harmful.[11] Public health interventions have potential harms, including stigmatization[12, 13] and victim blaming.[12] Zaza[10] recommended against the implementation of any intervention to manage musicians' MSSs before the benefit and safety was confirmed; this approach is consistent with the principles of beneficence and non-maleficence, integral to the work of health professionals[14-16] including during health promotion activities.[17] Despite concerns regarding the effectiveness and safety of interventions to manage musicians' MSSs, a range of programs have been introduced into universities.[18-20] Indeed, in the Unites States of America health promotion programs are mandatory in tertiary music courses.[21] Implementation without evaluation has the potential to harm, and to waste limited public health funds; with health budget blowouts being a primary concern for every government, there is growing impetus to address these concerns before implementing interventions.

Objective

The objective of this systematic review was to investigate the safety and effectiveness of any type of public health intervention to prevent/manage musicians' MSSs and their consequences (e.g. impaired playing ability). We did not restrict our review to any particular type of musician, although some studies may focus on a sub-group of musicians (e.g. university music students, woodwind musicians). Through an analysis of the evidence regarding the interventions to prevent/manage musicians' MSSs, recommendations aimed at researchers and the organizations that train, employ and support musicians can be developed to reduce the burden of musicians' MSSs.

MATERIALS AND METHODS

Protocol registration

The review protocol[22] was registered with PROSPERO (CRD42018103744).

Eligibility criteria

Studies were eligible for inclusion where the population of interest was any type of musician, the intervention was any type of public health intervention (e.g. non-clinical), and the outcome was any type of MSS outcome (including consequences). The comparison intervention was not defined. We were interested in studies that investigated MSS prevention at all three levels (i.e. primary, secondary, and tertiary) and/or a change in MSS outcomes. Studies had to be published in full, in English language, in a peer-reviewed journal, as per Ulrich's Periodicals Database.[23] Most studies of musicians' MSS outcomes are published in English language. Two recent systematic reviews[3, 24] included studies written in any language, yet all included studies were published in English. Furthermore, broader evidence suggests that review findings do not change whether or not non-English language studies are included.[25-28] We therefore chose to only include studies published in English language in our review. Narrative reviews (i.e. reviews not compliant with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses[29] systematic review definition) were not eligible for inclusion.

Information sources

Seven databases (Ovid Medline (1946-present), Embase (1947-present), EbscoHost Health Source: Nursing and Academic Edition (1952-present), EbscoHost Cumulative Index to Nursing and Allied Health Literature (1981-present), EbscoHost Music Index (1970-present), Web of

Science Core Collection (1900-present), and Cochrane Library (1992-present)) were searched in June 2018 (see Appendix 1).

The titles of studies published in *Medical Problems of Performing Artists* were also screened for potentially relevant studies, as the majority of studies of musicians' MSSs are published in *Medical Problems of Performing Artists.*[30] The 12 studies investigating the public health management of MSSs identified in a recent systematic mapping review[30] were also included.

The reference and citation lists (Google Scholar and Web of Science Core Collection) of included studies, as well as any relevant excluded reviews and excluded studies reporting on health programs more broadly, were screened for inclusion, using the aforementioned criteria. We continued screening reference and citation lists until no further relevant studies were identified.

Search

The search strategy (reported in Appendix 1) was based on previous systematic searches of similar topics.[30, 31] No date limits were applied. Searches were limited to English language (where permitted).

Study selection

Identified studies were exported into Endnote X8. Duplicates were manually removed, before the titles and abstracts were screened for inclusion using the aforementioned eligibility criteria. The full texts of remaining studies were then obtained, and screened against the same criteria. The same criteria were applied to the potentially relevant studies from screening *Medical Problems of Performing Artists* and the citation and reference lists of relevant studies. Screening was conducted by one reviewer, with a second reviewer verifying any uncertainties.

Data collection process

Data were manually extracted by two reviewers, from the included studies into a purpose-built Excel spreadsheet.

Data items

Spreadsheet headings were year (of publication and the study), country, design, population, sample size, intervention description, whether the study focused on prevention (e.g. all were asymptomatic at baseline) and management (e.g. all were symptomatic at baseline), MSS outcomes and tools used for data collection, reasons for withdrawing from the study or non-compliance, adverse events/ safety concerns, and key findings regarding MSS outcomes.

Risk of bias in included studies

Studies were allocated by two reviewers to the National Health and Medical Research Council (NHMRC)[32] Hierarchy of Evidence. Assessment of potential methodological bias was conducted by two reviewers using the Physiotherapy Evidence Database (PEDro) scale,[33] which is a valid[34, 35] and reliable[34-36] tool for assessing methodological bias. Rasch analysis has been used to demonstrate that the PEDro scale is appropriate as a summed score.[35] Disagreements between the two reviewers were referred to a third reviewer. Potential biases across the studies were reported descriptively.

Summary measures

All outcomes were reported, irrespective of the type of outcome reported.

Synthesis of results

Given the heterogeneity of studies identified in a recent systematic mapping review,[30] findings were reported and synthesized descriptively.

RESULTS

Study selection

A total of 14 studies were included in the review (see Figure 1 for details). Two of the studies were obtained through screening the reference and citation lists of the included studies, and broadly relevant, but excluded studies.[10, 18-20, 31, 37-47]

Study characteristics

Of the 14 included studies, 11 investigated exercise programs (including a combined exercise/education program), one an education program and two equipment changes. The majority (57.14%) of included studies were from the United States of America, while three were from Australia, and one each from Spain, Denmark and the Netherlands. The earliest study[48] was conducted in 1989-1990.

Populations and sample sizes

Professional musicians were investigated in eight (57.14%) studies, university students in four and adolescents in two (Table 1). Total sample sizes ranged from 14-351 musicians, and 7-177 for the intervention/control groups (Appendix 2). Studies were not clearly categorized as prevention or management, with each study including both asymptomatic and symptomatic participants.

Interventions

A range of exercise programs was~~were~~ investigated in 11 studies. These studies ~~investigated~~examined the effect of a fitness program,[49] general muscle exercises,[50-52] strength training[48, 49, 53], endurance training,[53] trunk endurance exercises,[54] Pilates,[54] yoga,[55-57] and performing stretches during rehearsals[58]~~, including yoga, Pilates, stretching and resistance training~~ (see Table 1 and Appendix 2 for more detailed information). Brandfonbrener's[48] intervention also included a short education component delivered to both exercise groups (strength and training, and flexibility exercises), and compared with a control group (no intervention). Khalsa et al.'s[55-57] three studies focused on yoga interventions, with elements of yoga lifestyle (e.g. meditation, counselling) also included. An education program was investigated in one study, that covered theory, personalized instruction, and practical sessions (warm ups, soft tissue mobilization techniques, ice massage, and stretching),[59] improved footwear,[60] and the use of smaller piano keyboards[61] ~~were~~ was also ~~investigated~~ examined (Table 1, with more specific information reported in Appendix 2).

Outcomes investigated and methods of data collection

Reported outcomes were MSS prevalence and incidence, playing time prior to experiencing MSS, MSS intensity and frequency, and degree and frequency of impairment to musical activity from MSSs (Table 2). de Greef et al.[52] referred to playing-related musculoskeletal disorders, citing Zaza et al.,[62] but did not report the definition used, and it is unclear whether the outcome related to prevalence, intensity or frequency, or some other outcome. There was inconsistency in the specific outcomes and data collection methods used, including differences in the MSS quality, recall periods and ratings, with every study having a unique

outcome measure (Table 2). None of the studies reported investigateding the impact of the interventions on MSSs in specific body regions.

Timing of data collection

Data were collected before and after the intervention in 10 studies.[48-51, 53-57, 59] Kava et al.[54] and Ackermann et al.[53] also collected data six weeks before the intervention, and de Greef et al.[52] took baseline measures two weeks prior to the intervention. Longer term follow-up measures were also taken at three months,[52] six months,[51] and 10 months[56] post-intervention, while Brandfonbrener[48] collected data six months into the intervention, at the point the intervention cross-over point. Grier et al.'s[60] outcome was injury incidence and data were collected during the 12 months prior to improved footwear being provided, and the first 12 months of using the improved footwear. Two studies[58, 61] had interventions directly related to playing, with data collection occurring before and after playing tasks.

Statistical methods used

Of the studies that collected data with visual analogue scales (VAS), seven[49, 50, 53, 54, 56, 57, 61] used parametric statistics, Khalsa and Cope[57] reporting that where the data were not normally distributed, non-parametric statistics were used. Khalsa et al.[55] did not report the analysis in sufficient detail to determine whether parametric or non-parametric statistics were used. Kava et al.[54] used a series of rating scales of varying lengths and used parametric statistics. Parametric statistics were used in the studies that collected ordinal data.[51, 58] The scale type and statistics used could not be determined in one study.[52]. Three studies[48, 59, 60] had dichotomous outcomes; only Grier et al.[60] reported the statistical methods used, in that case McNemar's test (see Appendix 2).

Risk of bias within studies

Study designs were randomized controlled trials (RCTs; Level II, n=5), comparative studies with concurrent controls (Level III_2, n=7), and case series with pre-test/post-test (Level IV, n=2). The PEDro scores ranged from 0-5 (Table 1).

Synthesis of results

Exercise programs

Of the 11 exercise studies (including the combined exercise/education program), six reported at least one significant result in favor of exercise. Results were positive for stretches during rehearsals, mixed for strength/ endurance programs, trunk endurance/Pilates mat training, general muscle training, and yoga program, and consistently ineffective for strength training, endurance training, general fitness training, a yoga lifestyle program, and yoga only/yoga lifestyle programs (Table 3). Reported benefits of exercise programs included lower MSS prevalence, ratings of muscle fatigue, discomfort, pain intensity and frequency, performance-related musculoskeletal disorder severity and frequency, and playing time until pain is experienced. Compliance was only reported in two studies,[49, 50] both reporting less than 50% compliance (see Supplementary Material 2).

The appraisal scores for the six studies that had at least one significant finding suggesting the effectiveness of the program ranged from 0-4 (mean 1.50±1.52, median 1.5, interquartile range 0-2), while those with no significant findings ranged 1-5 (mean 3.00±1.22, median 3, interquartile range 2-3). There is an indication that studies with significant findings were therefore at higher risk of methodological bias that those that did not.

Only three studies reported whether there were adverse events. Those that did report adverse events reported aggravation of knee osteoarthritis in one participant[50] and a chronic hip condition in another.[51] Although not necessarily 'adverse events', Nygaard Andersen et al.[49] reported that 18% of participants indicated that the intervention had a negative impact.

Other interventions

The education program resulted in a significant decrease in the number of reported injuries in the intervention group, with no change in the control group.[59] There was no comparison made between the groups. Compliance and whether there any adverse events were not reported.

There was no significant change in injury incidence with improved footwear for military band musicians.[60] Grier et al.[60] did not report whether there were any adverse events, nor participant compliance; however compliance is anticipated to have been high as the footwear formed part of the military uniform.

Using smaller piano keyboards (174 cm), in comparison with full-sized keyboards (188 cm), resulted in significantly lower pain ratings during and after playing, and lower tension ratings while playing.[61] The difference between pre- and post-performance pain ratings was significantly greater when playing the smaller keyboard, in comparison with full size.[61] The analyses were also stratified by hand span (using a mean cut-point) for pain and tension while playing, revealing that there was no significant difference in either measure for those with larger hands, between the two keyboards.[61] For pianists with smaller left hand spans, there was a significant difference in both pain and tension while playing (in favour of the smaller keyboard), while for those with smaller right hands this was only the case for pain while playing. Yoshimura and Chesky[61] did not report whether there were any adverse events.

DISCUSSION

Our review is the first systematic review to consider the effectiveness and safety of public health interventions to prevent/manage musicians' MSSs, and is important to ensure that resources are not being wasted on ineffective strategies, and that these strategies are not harmful. We identified 14 studies that investigated exercise and/or education programs, and equipment changes. Evidence supporting the implementation of each intervention was limited, and is discussed in turn below.

Summary of evidence

Exercise programs

While there is evidence of the effectiveness of exercise in the prevention/management of MSSs in other populations,[63-66] the evidence for musicians was mixed. At least one significant beneficial effect was reported in six of the 11 studies; however, these studies tended to have higher risk of methodological bias. Furthermore, where study findings indicated a significant positive effect of the exercise intervention, the clinical significance of the findings was not discussed. The minimal clinically important difference (MCID) for musicians' pain ratings do not appear to have been established, and there is little consistency for the MCID in other populations.[67] Future research should therefore be directed towards investigating the MCID for musicians' pain ratings, so the benefit of interventions aimed at reducing MSSs can be rigorously investigated.

Owing to the low-level, inconsistent evidence regarding the effectiveness of exercise programs, as well as the lack of evidence regarding the safety of such programs, we cannot recommend their implementation without further investigation. Future research into exercise programs needs to first consider safety, then effectiveness. A more consistent approach to data collection is recommended, as previously outlined,[68] as this would allow meta-analyses to compare the different types of exercises, their dosage and duration, thereby providing stronger recommendations. More robust study designs are also required, with consideration of methodological bias. Further, reasons for non-compliance should be established so that these barriers can be overcome.

Education program

There is evidence to support education as a strategy to prevent/manage MSSs in other populations,[69, 70] however the evidence is insufficient for musicians, despite the implementation of health promotion programs across all university music programs in the United States of America.[21] Martín López and Farías Martínez[59] provide some evidence of a significant decrease in the percentage of students with MSSs perceived to be caused by playing their instrument, with no such decrease in the control group. The groups were, however, not statistically compared. Nevertheless, we identified a range of potential sources of methodological bias in this study; hence, better designed studies are still required to confirm findings. One of the key issues was the definition of the MSS outcome of interest, "physical problems perceived to be caused by playing their instrument".[59] While this outcome may be useful for some research questions and indeed interventions, given the education program may have included education regarding the non-playing risk factors for MSSs, it may be the students' perception of the cause of their MSSs that has changed, rather than the presence of MSSs *per se*. Another issue with the outcome was the lack of a recall period being reported. It was unclear whether data were collected regarding adverse events.

There is insufficient evidence to recommend the implementation of education programs for the prevention/management of musicians' MSSs, and no evidence regarding their potential harm. Studies into education programs for this purpose should however continue. Recent evidence suggests that tertiary music students want to learn more about musicians' MSSs,[71, 72] with most wanting this education delivered in practical formats, including instrument-specific workshops, and few interested in online delivery.[71] Previous research on musicians has also suggested that online health education programs have been ineffective in changing behaviour,[40] and have poor compliance.[73] Face-to-face programs developed with input directly from musicians themselves may be more successful. The potential harm of education programs must be considered.

Equipment changes

Two studies investigated equipment changes to prevent/manage musicians' MSSs. Yoshimura and Chesky[61] identified some benefits of using a 174 cm keyboard compared with the 188 cm, particularly for those with smaller hands. The study had a high level of potential methodological bias, and was conducted over a short period. A longer-term study comparing MSS outcomes for different keyboard sizes is indicated, and should consider the potential harm of the intervention, which may include the disruption to proprioception, whereby pianists may have difficulty in swapping between keyboards of different sizes.

For military band musicians, Grier et al.[60] investigated the change in injury incidence after new shoes were introduced. The new shoes addressed issues identified with the former footwear; however, there was no change in the injury incidence. Given the study was a pre-post study with a high risk of methodological bias, future studies might investigate different footwear with more robust study designs.

Limitations

The exclusion of non-English language studies may have resulted in some relevant studies being missed from the present review. To determine how many potentially relevant studies may have been missed we repeated our database search limiting results to non-English language studies. None of these non-English language studies met the eligibility criteria in the title/abstract searching; hence our study findings would have not changed had non-English language studies been included in the initial search.

The broad nature of this review in terms of the musicians, the interventions and MSS outcomes made it difficult to compare and synthesise the findings of the studies. Indeed, if there had been more homogeneity a meta-analysis could have been conducted which would have strengthened the findings of our review. Furthermore, the generalisability of the findings from one sub-group of musicians to another cannot be assumed;[30, 74] this is particularly true of interventions regarding instrument- or setting-specific interventions (e.g. the use of different chairs will only be relevant for musicians who sit, and Yoshimura and Chesky's[61] findings are only relevant to piano players). The review was intended to be broad as we were aware of the relatively few relevant studies on the topic,[30] and we encourage researchers to consider how their studies fit within the existing evidence base, particularly in terms of the MSS outcomes investigated.[68]

Future directions

~~A range of other public health interventions may be appropriate in the prevention/management of musicians' MSS, including Alexander technique, equipment changes, such as the use of ergonomic chairs[75] and different forms of instrument supports (e.g. harnesses instead of neck straps for reed players),[76] screening programs,[38] and onsite clinics.[39, 45] Importantly, given musicians often work in a self-employed or freelance capacity,[77] strategies that are implemented beyond specific organisations should also be explored.~~

To better target future interventions, we must also determine which sub-groups of musicians (e.g. genre, instrument, sex) have the highest risk of MSS outcomes. There is some evidence to suggest that string musicians and females may have a higher prevalence of MSS outcomes, however this is not conclusive.[24] There has been insufficient research conducted into non-classical musicians to compare their risk of MSS outcomes with classical musicians; something which must be addressed if we are to reduce the burden of musicians' MSSs.[30, 74] It will also be important to consider the potential risk factors for the priority sub-groups of musicians, potentially refocusing research towards these groups. However, stratified analysis of large, broad studies of musicians (including for instance musicians of different genres and career stages), would not only allow for investigation of priority groups, but would also begin to inform the generalisability of the research findings, for the purposes of making

~~[illegible]~~ prevention/management of musicians' MSS, including Alexander technique, equipment changes (~~,~~ such as the use of ergonomic chairs[77]), ~~and~~ different forms of instrument supports (e.g. harnesses instead of neck straps for reed players),[78] screening programs,[38] and onsite clinics.[39, 45] ~~Importantly, given musicians often work in a self-employed or freelance capacity,[77] strategies that are implemented beyond specific organisations should also be explored.~~ Furthermore,

In addition to the abovementioned examples, it has recently been argued that advice around sitting up straight is not evidence-based, and may in fact be harmful advice for some people, leading to hypervigilance, anxiety and a sense of failure.[85] Nevertheless, musicians must often adopt a straight back for aesthetics while performing, and/or to aid in breathing while singing or playing a wind instrument. Interventions under these circumstances should, therefore, focus on developing relaxed, but nevertheless upright, postures.[85]

Another important consideration for the implementation of public health interventions for musicians, is that musicians often work in a self-employed or freelance capacity,[87] hence strategies need to be considered that reach these musicians. These interventions may be delivered through organisations that support musicians (e.g. musicians' associations and unions). Furthermore, this challenge highlights the important role that music educators and educational organisations play in developing musicians with the skills and behaviours to prevent and manage their MSSs.

Conclusions

This was the first systematic review to consider the safety and effectiveness of public health interventions to prevent/manage musicians' MSSs. Strategies are required to address the high burden of musicians' MSSs. It is vital that the interventions have been found to be safe and effective prior to implementation, to ensure that resources are not being wasted on ineffective strategies, and are redirected towards strategies that will maximize health gain. While we identified 14 studies of exercise programs, education programs, and equipment changes, we are unable to recommend the implementation of any of these strategies, without first establishing the safety and effectiveness thereof, using robust methods. Other potential strategies to consider may emerge once we have a stronger understanding of the risk factors for musicians' MSSs.

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DECLARATION OF INTEREST

None declared

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APPENDIX 1: SEARCH TERMS

Table A1: Search terms

	Musician terms (title or keyword)	Musculoskeletal terms (title or keyword)	Intervention terms (title, keyword or abstract)
Search terms	musician* OR "music-related" OR "music related" OR conservatory OR conservatories OR conservatorium* OR conservatoire* OR woodwind* OR flute OR flutes OR flautist* OR flutist* OR clarinet* OR sax OR saxes OR saxophon* OR *bassoon* OR oboe* OR oboist* OR "double reed*" OR "Double-reed*" OR trumpet* OR trombon* OR tuba OR tubas OR tubist* OR bugle* OR cornet* OR euphonium* OR violin* OR violinist* OR viola OR violas OR violist* OR *cello OR *cellos OR *cellist* OR guitar* OR fiddle* OR banjo* OR baritone* OR piano* OR pianist* OR timpan* OR hornist* OR bassist* OR bagpipe* OR drummer* OR percussionist* OR harpist* OR harp OR harps OR harpsichord* OR organist* OR "church organ*" OR "pipe organ*" OR keyboardist* OR instrumentalist* OR vocalist* OR sing OR singer* OR singing OR choir* OR orchestra OR orchestras OR "playing-related" OR "performance-related" OR "playing related" OR "performance related" OR musical* OR (music near/3 (major* OR stud* OR teach* OR tuition OR training OR educat* OR school* OR perform* OR rehear* OR play* OR practi* OR concert* OR band* OR ensemble* or instrument*)) OR ((*wind* OR *reed* OR brass OR string* OR horn* OR bass* OR recorder* OR pipe OR pipes OR piper OR pipers OR drum* OR percussion* OR organ OR organs OR keyboard* OR vocal* OR voice) near/3 (major* OR stud* OR teach* OR tuition OR training OR educat* OR school* OR perform* OR rehear* OR play* OR practi* OR concert* OR band* OR ensemble* OR instrument* OR music* OR corp OR corps)) OR "instrumental music*" OR ((band* OR ensemble*) near/3 (music* OR stage OR big OR folk OR country OR brass OR wind OR string OR percussion OR jazz OR baroque OR Dixieland OR traditional OR Irish OR march* OR military OR army OR defence OR navy OR force OR member*)) OR "marching art*" OR "performing art*" OR (conductor* near/3 (music* OR band* OR orchestra* OR ensemble*)) OR "musical director*" OR "drum major*" OR opera OR operas OR operatic	Medical* OR health* OR *musculo* OR *skeletal* OR muscle* OR joint* OR arthr* OR tendon* OR tendin* OR ligament* OR strain* OR sprain* OR injur* OR fracture* OR pain* OR *ache OR aching OR weakness OR tingl* OR pins OR needles OR numb* OR *mobilit* OR *flexib* OR stiff* OR motion OR tight* OR swell* OR *edema OR *ordinat* OR disorder* OR condition* OR symptom* OR "soft tissue*" OR dysfunction* OR nerve* OR neuro* OR orthop*	Manag* OR prevent* OR reduc* prophyl* OR protect* OR exercis* OR stretch* OR yoga OR equip* OR ergonom* OR control* OR educat* OR train* OR break* OR effectiv* OR effica*
MeSH^		Musculoskeletal diseases OR pain OR "wounds and injuries"	
Emtree^	Musician	Musculoskeletal disease OR pain OR injury	
CINAHL subject heading^		Musculoskeletal diseases OR pain OR "wounds and injuries"	"Preventive trials"
Health Source subject headings^	Musicians	Musculoskeletal system – diseases OR pain or "wounds & injuries"	

near/3 means 3 words between, ^ all terms were exploded where this was available

APPENDIX 2: STUDY DETAILS

Table A2: Population and sample characteristics, intervention, outcomes and timing of data collection of included studies

Study details[a]	Population, inclusion/ exclusion criteria & sample size	Summary of the intervention(s)	Outcome(s) & data collection timing
Exercise programs			
Nygaard Andersen et al.[49] Year(s) NR (published 2017) Denmark RCT (Level II) PEDro:5	Professional symphony orchestra musicians Inclusion: had to be employed by the orchestra Exclusion: "any serious physical conditions or illness that could interfere with participation" 27 recruited, 23 participated: 12 strength group, 11 in the general fitness group (reported elsewhere as 12)	Both groups: 20 minute supervised exercise programs, 3x/ week for 9 weeks. If unable to attend, participants were asked to do the exercises at home. High intensity specific strength training: focusing on shoulder and neck muscles, with individualized training load High intensity general fitness training: Bicycle ergometer	Pain intensity in the last 7 days Pre-intervention, post-intervention
Chan et al.[50] 2012 Australia Case series with pre-test/ post-test (Level IV) PEDro : 1	Musicians from premier symphony orchestra Excluded if they had their injury covered by workers' compensation, or if the intervention conflicted with advice from a medical practitioner 144 musicians recruited, 71 completed the questionnaires, 50 included (excluded those who did not meet minimum compliance)	DVD exercise program over 12 weeks Participants had to complete at least 2x 40 minute sessions/ week 10 minutes warm ups, 5 minutes exercises, 25 minutes gentle stretching/ cool downs	Frequency and severity of performance-related musculoskeletal disorders (PRMD) in the last 7 days PRMD: "any pain, weakness, numbness, tingling or other physical symptoms that interfere with your ability to play your instrument at the level to which you are accustomed during the last week' excluding everyday mild, transient aches or pains" (modified from Zaza et al. [62]) Pre- and post-intervention
Chan et al.[51] 2010-2012 Australia Comparative study with concurrent controls[c] (Level III_2) PEDro : 2	Professional orchestral musicians Excluded if they had their injury covered by workers' compensation, or if the intervention conflicted with advice from a medical practitioner Exercise group: 30 participants Control group: 23 participants	Intervention group: 16 x 35 minute exercise sessions, held over 9-12 weeks (average 10 weeks) Duration and timing established in collaboration with orchestral management Exercises targeted the neck, shoulders, spine, abdomen and hips Progressive approach used Control group: no intervention	Frequency and severity of performance-related musculoskeletal disorder (PRMD) over the last 7 days PRMD: "any pain, weakness, numbness, tingling, other physical symptoms that interfere with your ability to play your instrument at the level to which you are accustomed; exclude any mild transient aches or pains that may simply be a representation of the common everyday symptoms" (quoted as Zaza et al. [62] although it is a modification) Pre-intervention, post-intervention and 6-months post-intervention
Khalsa et al.[55] 2007-2008 USA Comparative study with concurrent controls (Level III_2) PEDro: 4	Adolescent musicians at a 6 week residential summer program Yoga group: 84 participants Control group: 51 participants	Yoga program modified for adolescents (e.g. using English words, yoga games, partnered yoga, playing pop music) 1 hour yoga class (3 times a week) including breath work, yoga poses (focusing on shoulders, wrists, spine and hips), supine rest, and meditation Control: no intervention	PRMD frequency and severity PRMD not defined Pre-intervention, post-intervention

(continued)

Study details[a]	Population, inclusion/ exclusion criteria & sample size	Summary of the intervention(s)	Outcome(s) & data collection timing
Cooper et al.[58] Year(s) NR (published 2012) Country NR: (authors from USA) Comparative study with concurrent controls (Level III_2) PEDro: 0	Junior high school / high school orchestral string students 126 recruited, but only 100 completed the four sessions. After excluding those with missing data: Stretches group: 57 Control group; 43	Intervention group: During orchestra rehearsals stretches of the hands, arms and shoulder were performed every 10 minutes 4 rehearsals were conducted over 2 weeks Control: Rehearse as usual	Level of discomfort (across 5 body regions) Prior to and immediately after each rehearsals
Kava et al.[54] Year(s) NR (published 2010) Country NR: (authors from USA) Comparative study with concurrent controls[d] (Level III_2) PEDro: 2	University instrumental music students Excluded those with a ""diagnosed medical condition such as cervical disc diseases with pain radiating into the upper extremity, neurological symptoms, upper extremity tendonitis, upper extremity nerve entrapment, any condition exacerbated with exercise, or any condition in which exercise was contraindicated" 14 participants: 7 Pilates mat exercise program, 7 conventional trunk endurance exercise program	Participants did 1 hr exercise sessions, 2x/ week for 6 weeks Pilates mat exercise program Conventional trunk endurance exercise program	Playing time until muscle fatigue felt Playing time until pain felt Playing time until muscle tension felt Intensity of pain while playing Frequency of pain while playing Initial test followed by 6 weeks of no intervention, pre-test, post-test
Khalsa et al.[56] 2006 USA Comparative study with concurrent controls[b] (Level III_2) PEDro : 2	Professional musicians attending a summer fellowship program (8 weeks) Yoga lifestyles: 15 participants Yoga only: 15 participants Control: 15 participants	Yoga lifestyle and yoga only groups attended at least 3 meditation or yoga sessions per week for 2 months. Yoga lifestyle also had a 2-day intensive retreat (2 yoga sessions, discussions regarding yoga, meditation, breath control and conscious eating). 2 weeks into the intervention problem solving discussions (45-60 minutes) followed by yoga (60 minutes) started. This group also had a 60-minute private session re yoga postures, breath control and meditation. The yoga only group could also attend a private session but this was optional. Yoga classes were offered at gentle, moderate and vigorous intensities Control: no intervention, but could have a free massage after the study finished	Performance-related musculoskeletal disorder (PRMD) severity and frequency PRMD not defined Baselines, 6 weeks after the program started, and 10 months later (a year after the start)

(continued)

Study details[a]	Population, inclusion/ exclusion criteria & sample size	Summary of the intervention(s)	Outcome(s) & data collection timing
Khalsa & Cope[57] Year(s) NR (published 2006) Country: USA Comparative study with concurrent controls (Level III_2) PEDro: 3	Professional musicians attending a summer fellowship program (8 weeks) Yoga group: 10 participants Control group 10 participants 10 participants (8 completed questionnaires)	Yoga intervention: 1 day intensive orientation (goals/ intentions of program, 2 yoga sessions, discussion regarding yoga, and a meditation introduction session) Over 8 weeks participants could yoga sessions (offered morning and afternoon 7 days a week), at gentle, moderate or vigorous levels (self-selected). 1x per week an evening session was conducted (90 minutes intensive yoga, 2 hours of discussion/ problem solving/ group interaction regarding yoga, meditation, psychological issues related to music and their musical professional career progression) Optional 30 minute early morning meditation offered 5 days a week Meals within the yoga centre All day retreat at the end (overnight stay, yoga class, group meal and social activities) Control: 2 free meals at the yoga centre during the course	PRMD frequency and severity Pre-post
de Greef et al.[52] Year(s): NR (published 2003) Country: Netherlands RCT (Level II) PEDro:5	Professional symphony orchestral musicians with playing-related musculoskeletal disorders, as per Zaza et al.'s [62] definition Exercise group: 25 participants Control group: 28 participants	Exercise program: 45 minute exercise sessions (warm up, general exercises, specialised exercises, cooling down and counselling (how to train and work at home for concert preparation) 15 weeks 10-12 musicians trained at once Control: no intervention	Playing-related musculoskeletal disorders (PRMD) 2 weeks before intervention, post (15 weeks later), about 3 months after completion (30 weeks)

(continued)

Study details[a]	Population, inclusion/ exclusion criteria & sample size	Summary of the intervention(s)	Outcome(s) & data collection timing
Ackermann et al.[53] Year(s): NR (published 2002) Country: Australia RCT[d] (Level II) PEDro: 2	University undergraduate music majors 19 musicians (reported elsewhere as 18)	Both groups did 45 minute exercises classes, twice a week, involving 5 minute warm up, exercises, 5 minutes cool downs. 6 weeks. Exercises were the same for each group Endurance group did 25-30 rep max Strength group did 6-8 rep max	Performance-related musculoskeletal disorders (PRMD) intensity or frequency PRMD: "any pain, weakness, numbness, tingling or any other symptoms that interfere with your ability to play your instrument at the level you are accustomed to. This definition does not include transient aches or pains" (quoted as Zaza and Farewell [88] but appears to be a modification) 6 weeks before the intervention, pre-intervention, post-intervention Note: pain and PRMD appear to be used interchangeably
Brandfonbrener[48] 1989-1990 USA Comparative study wtih concurrent controls (Level III_2) PEDro: 0	Professional symphony orchestral Exercise group: 177 participants Control group: 138 participants	Two intervention groups: strengthening and flexibility. Intervention groups crossed over at 6 months Musicians were taught the exercises and instructed to do them for about 15 minutes a day. Supervised practice. Warm ups and cool-downs were demonstrated and a handout provided – advised to do 5 minutes before and after playing. Control: no intervention	Musculoskeletal symptoms during the study period. It is unclear what period the baseline data refers to. Before intervention, 6 months in (cross-over time), and end of the intervention
Education			
Martín López & Farías Martínez[59] Year(s) NR (published 2013) Spain RCT (Level II) PEDro: 1	University music students Experimental group: 90 participants Control group: 90 assigned, by 59 completed data collection and were included in the analysis	Education sessions were part of a university credit course, conducted over 1 year Involved theory sessions, practical sessions (warm ups, soft tissue mobilisation techniques, ice massage and stretching), as well as personalised instruction Control: no intervention	Whether they had experienced physical problems caused by playing Note: injury, discomfort and physical problems caused by playing were used interchangeably Baseline, mid-point (6 months), post-intervention (12-months)

(continued)

Study details[a]	Population, inclusion/ exclusion criteria & sample size	Summary of the intervention(s)	Outcome(s) & data collection timing
Equipment			
Grier et al.[60] 2006-2008 USA Case series with pre-test/ post-test (Level IV) PEDro: 1	Military band musicians 112 participants	New dress shoes with improvements, including improved cushioning, rubber midsole in the men's shoes (women's shoes did not have a midsole), 1.3cm heel, and improved breathability through vent holes Musicians wore these shoes for approximately 40% of their band activities	Injury index from clinical visits (Installation injury index, modified installation injury index, training related injury index, comprehensive injury index, overuse injury index) The 12 months prior to the new shoes being introduced was compared with the first 12 months of using the new shoes
Yoshimura & Chesky[61] Year(s) NR (published 2009) USA Randomized cross-over trial (Level II) PEDro: 3	University piano majors 35 participants	Two piano keyboards were used one full size and one 15/16 size. Participants practiced assigned repertoire for 2 weeks and were given 45 minutes access to a 15/16 piano. Over two consecutive days pianists played the assigned repertoire on the two piano sizes (1 per day)	Level of pain before and after playing, and level of pain, and tension during playing session Before and after the data collection playing session

Notes: studies are reported in order of the year of publication

[a]Study details: reference, year (s) of the study, country in which the study was conducted, study design (NHMRC Level of Evidence), PEDro score

[b]Intended as an RCT, however insufficient number of volunteers; hence the two intervention groups were randomised, but 14 of the 15 controls were recruited later (non-randomised)

[c]without concurrent controls

[d]compared the two intervention groups at the end of the intervention, as well as with a non-intervention period prior (6 weeks) prior to the intervention

Table A3: Outcome measures, statistical tests used, compliance, adverse events/ safety and findings of included studies

Reference	Outcome measures	Statistical tests used	Compliance	Adverse events/ safety	Findings
Exercise programs					
Nygaard Andersen et al.[49]	Pain intensity during the last 7 days Responses given on a 100 mm VAS from 0 "no pain" to 100 "worst imaginable pain" [89, 90]	Within group: Paired sample t-tests Comparison between groups: Mixed design ANOVA	Mean adherence: 43% (additional 10% if exercising at home was counted) General fitness training adherence: 57% Strength training adherence: 31% Lack of time was reported as the main reason for non-adherence	Safety was not reported specifically. 18% of participants reported a negative impact of the intervention (2/7 from the strength training group and 1/10 from the general fitness group).	No significant difference in the change scores in pain intensity ratings ratings (pre-post) between groups (p=0.29) No significant difference pre-post pain intensity ratings for the fitness group (p=0.09) The difference pre-post pain intensity ratings (26.3±22.5 to 11.4±15.2) for the strength group was reportedly significant (p=0.05)
Chan et al.[50]	PRMD frequency in the last 7 days reported on an 11-point VAS from 0 "never" to 10 "constantly" PRMD severity in the last 7 days reported on an 11-point VAS from 0 "nil" to 10 "worst imaginable" [91]	Two tailed paired sample t-test	41% compliance (excluding those who withdrew due to major injury or illness or unexpected family circumstances) Mean exercise sessions per week 2.1±0.44 (range 2-4)	One had an aggravation of a severe knee osteoarthritis No negative impact on performance was reported	Significant change($p<0.01$) in PRMD frequency (3.3±2.9 to 2.1±2.1) and severity (2.9±2.4 to 1.9±1.9)
Chan et al.[51]	PRMD frequency in the last 7 days was reported on an 11-point ordinal scale from 0 "never" to 10 "constantly" PRMD severity in the last 7 days was reported on an 11-point ordinal scale from 0 "nil" to 10 "worst imaginable" [91]	Multivariate linear regression	Did not report the percentage Stated attendance issues and withdrawal from the program were mainly due to unexpected commitments, injury or major illness unrelated to the intervention. One withdrew due to the exercises aggravating an existing condition	One had an aggravation of a chronic hip condition	At baseline the exercise group had significantly higher PRMD frequency and severity Significant reduction in PRMD frequency and severity post-intervention, and was maintained at the 6-month follow up (Frequency: T0 4.4±3.1, T1 2.8±2.4, T2 2.6±2.5; Severity: T0 4.4±2.9, T1 2.9±2.5, T2 2.6±2.3) PRMD frequency and severity was not significantly different from the control at the 6-month follow-up

(continued)

Reference	Outcome measures	Statistical tests used	Compliance	Adverse events/ safety	Findings
Khalsa et al.[55]	Used the Performance-related musculoskeletal disorder questionnaire [92] PRMD frequency reported on a 100mm VAS from 0 “never” to 100 ‘constantly” PRMD severity reported on a 100mm VAS from 0 “none” to 100 “maximally severe”	Multiple regression	Participants attended 17 classes on average over the 6 weeks	Not reported	No significant difference between groups for PRMD frequency No significance difference for the yoga group for PRMD frequency pre-post For the 2007 cohort, there was no significant difference between groups for PRMD severity For the 2008 cohort, there was a significant difference between groups for PRMD severity (yoga group lower, accounting for the baseline scores; -1.50±1.79) No significance difference for the yoga group for PRMD severity pre-post
Cooper et al.[58]	Perception of discomfort survey (developed for the project) Level of discomfort was reported on Likert scales (1 “no discomfort”, 2 “slight discomfort”, 3 “moderate discomfort”, 4 “high discomfort”, 5 “extreme discomfort” for the hands, wrists, arms, shoulders and neck	Two-way MANOVA	Not reported	Not reported	Significant effect of group (p=0.0001). For the treatment group, discomfort levels were higher before rehearsal (mean 1.70) than after (mean 1.35). For the control group, discomfort levels were lower before rehearsal (mean 1.43) than after (mean 1.62). Significant disordinal interaction (instrument x group, p=0.03). For upper strings: treatment group discomfort scores were higher before rehearsal (mean 1.47) than after (mean 1.22), but for the control group the opposite occurred (mean before 1.43, mean after 1.75). For lower strings: treatment group had higher discomfort levels before treatment (mean 1.92) than after (mean 1.49), and the opposite occurred for the control group (mean before 1.43, mean after 1.48)

(continued)

Reference	Outcome measures	Statistical tests used	Compliance	Adverse events/ safety	Findings
Kava et al.[54]	Questionnaire developed for the project (in their Supplementary Material) Time playing until muscle fatigue, pain and muscle tension were reported along a line with times marked for 0, 30 minutes, 1 hour, 1.5 hours, 2 hours, 2.5 hours, 3 hours Pain intensity: "The intensity of pain that I experience while playing my instrument is" with responses given on a 10 cm VAS from "very low" to "very high" Pain frequency: "the frequency of pain that I experience while playing my instrument is" with responses given on a line with markings 0 "never", 25 "rarely", 50 "sometimes", 75 "often", 100 "every time I play" Lines for each type of response were different lengths	t-tests and analysis of variance	84% attendance for Pilates 95% attendance for endurance Main reasons for not attending were illness or school required rehearsal or performance	Not reported	From the initial to pre-test (non-intervention period) there was a statistically significant difference in pain intensity only. From pre-test to post-test (groups combined) there were significant changes in the playing time until pain and muscle fatigue were felt, pain intensity and pain frequency No significant differences between groups at post-test between groups (did not report whether they were the same at other time periods) Note: The scores themselves were not reported

(continued)

Reference	Outcome measures	Statistical tests used	Compliance	Adverse events/ safety	Findings
Khalsa et al.[56]	Questionnaire slightly modified from Ackermann, Adams and Marshall [53]. PRMD frequency responses given on a 10cm VAS from 0 "never" to 10 "constantly" PRMD severity responses given on a 10 cm VAS from 0 "none" to 100 "maximally severe"	Yoga groups were combined for analysis Two-tailed t-tests	All completed all measures Attendance was "excellent" at the beginning but "decreased at the end" Those in the yoga lifestyle group tended to attend yoga classes, those in the yoga group tended to attend meditation. 13 of 15 in the yoga lifestyle group did the private yoga session 9 of the 15 in the yoga only group did the private yoga session At long-term follow up 73% in the yoga lifestyle, 60% in the yoga only and 53% in the control groups did the final questionnaires)	Not reported	Reported that there were no differences at the end of the study in the discussion, and no change in PRMD in the abstract, but no further information was reported.
Khalsa & Cope[57]	Questionnaire slightly modified from Ackermann (ref 34) PRMD frequency and severity rated on VAS	Two-tailed t-test or Wilcoxon signed rank test or Mann-Whitney rank sum test (if data were not normally distributed)	Attendance was high at the start (4-5 times per week), and later declined (3 times/ week) with an increase closer to the end of the program. 8-9 participants generally attended the evening sessions Approximately half of the participants attended the meditation sessions	Not reported	No significant change in PRMD frequency or severity pre-post in either group, or between groups

(continued)

Reference	Outcome measures	Statistical tests used	Compliance	Adverse events/ safety	Findings
de Greef et al.[52]	World and Health Questionnaire for musicians to collect data regarding playing-related musculoskeletal disorders, using Zaza et al.'s [62] definition	Repeated multivariate analysis	8 dropped out of the experimental group (2 lacked of motivation, 3 due to lack of time, 1 illness, 2 moved away) 3 in the experimental group did not complete the post-test	Not reported	States significant (p=0.05) decrease in the experimental group: T0 98.5±4.3, T1 97.5±4.8, T2 96.8±4.2, d=0.21)
Ackermann et al.[53]	Questionnaire developed for project VAS used for PRMD frequency and intensity ratings	Two-tailed t-tests	94% attendance for strength 85% attendance for endurance Non-attendance due to illness 1 drop out (gave up studies) – excluded from analysis	Not reported	No change during the control period for frequency or intensity (groups appear to have been combined) No significant difference over the test period (groups appear to have been combined) No significant difference between groups at post-intervention
Brandfonbrener[48]	Not reported	Not reported Exercise groups analysed together	Not reported	Not reported	Control and experimental groups had a significant improvement 6 months into the intervention. No change between tests 2 and 3. Note: it is unclear for which outcome The groups were not compared.
Education					
Martín López and Farías Martínez [59]	Questionnaire developed for the project Asked to indicate they symptom description, duration and location of pain (using body diagrams) for current and previous "discomfort"	Not reported	Not reported	Not reported	No significant change in the control group Significant decrease in the experimental group, but it is unclear on which outcome specifically They did not report whether the groups differed at baseline

(continued)

Reference	Outcome measures	Statistical tests used	Compliance	Adverse events/ safety	Findings
Equipment					
Grier et al.[60]	Injury index from clinical visits (Installation injury index, modified installation injury index, training related injury index, comprehensive injury index, overuse injury index)	McNemar test	Not reported	Not reported	No significant difference in any of the injury indices
Yoshimura & Chesky[61]	Questionnaire developed for the project The level of pain before and after the playing task, and during the playing task was measured on a 10 cm VAS The level of tension during the playing task was measured on a 10 cm VAS	Paired t-test Also stratified by hand span, using a mean cut-point for pain and tension while playing	Not reported	Not reported	There were significant differences between the keyboard sizes for: post-performance pain levels (188-mm: 1.98±2.84, 174-mm: 0.95±1.48, p<0.01), pain while playing (188-mm: 2.07±2.74, 174-mm 0.96±1.48, p<0.01), tension while playing (188-mm: 3.17±2.92, 174-mm: 2.20±2.54, p<0.05), and difference score for post-performance minus pre-performance pain (188-mm: 0.71±2.14, 174-mm: -0.13±1.65, p<0.05) For those classified as having larger hand spans (left and right), there was no significant difference in pain or tension while playing between the 188-mm and 174-mm sized keyboards For those classified as having smaller hand spans for the left hand, there were significant differences regarding the keyboard size, for: pain while playing (188-mm: 3.78±3.00, 174-mm: 1.55±1.85, p=0.003), and tension while playing (188-mm: 4.63±3.14, 174-mm: 3.08±2.86, p=0.045) For those classified as having smaller hand spans for the right hand, there was no significant difference regarding tension while playing, however there was a significant difference for the level of pain while playing (188-mm 3.61±3.13, 174-mm: 1.55±1.85, p=0.006)

Notes: studies are reported in order of the year of publication

Table 1: Study characteristics

	Country	Study design (NHMRC level)	PEDro score[a]	Items where criteria were met	Population	Intervention group(s)
Nygaard Andersen et al.[49]	Denmark	RCT (II)	5	1, 2, 3, 9, 10, 11	Professional symphony orchestra musicians	1. Strength training 2. Fitness program
Martín López & Farías Martínez[59]	Spain	RCT (II)	1	2	University music students	1. Education program 2. No intervention
Yoshimura & Chesky[61]	USA	RCT (II)	3[b]	2, 10, 11	University piano students	1. 174cm keyboard[e] 2. 188cm keyboard[e]
de Greef et al.[52]	Netherlands	RCT (II)	5	2, 8, 9, 10, 11	Professional symphony orchestra musicians	1. General muscle exercises
Ackermann et al.[53]	Australia	RCT (II)	2	1, 2, 11	University instrumental music students	1. Strength training[d] 2. Endurance training[d]
Chan et al.[51]	Australia	Comparative study with concurrent controls (III_2)	2	1, 10, 11	Professional symphony orchestra musicians	1. General muscle exercises 2. No intervention
Khalsa et al.[55]	USA	Comparative study with concurrent controls (III_2)	4	4, 8, 10, 11	Adolescent musicians	1. Yoga 2. No intervention
Cooper et al.[58]	USA	Comparative study with concurrent controls [c] (III_2)	0	-	Junior high & high school orchestral string players	1. Stretches during rehearsals 2. No intervention
Kava et al.[54]	USA	Comparative study with concurrent controls (III_2)	2	1, 8, 10	University instrumental music students	1. Trunk endurance exercises[d] 2. Pilates mat exercises[d]

(continued)

	Country	Study design (NHMRC level)	PEDro score[a]	Items where criteria were met	Population	Intervention group(s)
Khalsa et al.[56]	USA	Comparative study with concurrent controls (III_2)	2	4, 8	Professional musicians	1. Yoga[d] 2. Yoga lifestyle[d] 3. No intervention
Khalsa & Cope[57]	USA	Comparative study with concurrent controls (III_2)	3	4, 8, 10	Professional musicians	1. Yoga lifestyle 2. No intervention
Brandfonbrener[48]	USA	NRCT[c] (III_2)	0	-	Professional symphony orchestra musicians	1. Strength training & an education program[d,e] 2. Flexibility exercises & an education program[d,e] 3. No intervention
Grier et al.[60]	USA	Case series with pre-test/ post-test (IV)	1	8	Professional military band musicians	1. Improved footwear
Chan et al.[50]	Australia	Case series with pre-test/ post-test (IV)	1	1, 11	Professional symphony orchestra musicians	1. General muscle exercises (delivered by digital video device)

Notes: Studies are listed in order of publication year. NHMRC: National Health and Medical Research Council. RCT: randomized controlled trial, NRCT: non-randomised controlled trial
[a]The PEDro score does not include Item 1. [b]not applicable for Item 4. [c]grouped in clusters. [d]intervention groups were combined for analysis. [e]cross-over design. See Appendix 2 for further information.

Table 2: Details of data collection regarding musculoskeletal symptoms

Outcome	Time period	Scale type	Anchors	Studies
Prevalence of musculoskeletal symptoms				
Musculoskeletal symptoms	Study period[a]	NA	NA	[48]
Musculoskeletal symptoms perceived to be caused by playing their instrument	NR	NA	NA	[59]
Incidence of musculoskeletal injuries				
International classification of diseases, 9th revision, clinical modification diagnoses: installation injury index, modified installation injury index, training related injury index, comprehensive injury index & overuse injury index	1-year	NA	NA	[60]
Intensity of musculoskeletal symptoms				
Performance-related musculoskeletal disorders[b]	NR	100 mm VAS	0 “none” to 100 “maximally severe”	[55]
	NR	10 cm VAS	0 “none” to 100 “maximally severe”	[56]
	NR	VAS	NR	[57]
Intensity of pain	Last 7-days	100 mm VAS	0 “no pain” to 100 “worst imaginable pain”	[49]
	NR	10 cm VAS	“very low” to “very high”	[54]
	Current[c] While playing[d]	10 cm VAS 10 cm VAS	NR	[61]
Level of discomfort[e]	NR[f]	Likert	1 “no discomfort”, 2 “slight discomfort”, 3 “moderate discomfort”, 4 “high discomfort”, 5 “extreme discomfort”	[58]
Level of tension	While playing[d]	10 cm VAS	NR	[61]

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Outcome	Time period	Scale type	Anchors	Studies
Frequency of musculoskeletal symptoms				
Performance-related musculoskeletal disorders[g]	NR	100 mm VAS	0 “never” to 100 “constantly”	[55]
		10 cm VAS	0 “never” to 10 “constantly”	[56]
		VAS	NR	[57]
Pain frequency	NR	Line with anchors marked	0 “never”, 25 “rarely”, 50 “sometimes”, 75 “often”, 100 “every time I play”	[54]
Severity or intensity of musculoskeletal symptoms which impair musical activity				
Performance-related musculoskeletal disorders[g]	Last 7-days	11-point ordinal	0 “nil” to 10 “worst imaginable”	[51]
		11-point VAS	0 “nil” to 10 “worst imaginable”	[50]
	NR	VAS	NR	[53]
Frequency of musculoskeletal symptoms which impair musical activity				
Frequency of performance-related musculoskeletal disorders[h]	Last 7-days	11-point VAS	0 “never” to 10 “constantly”	[50]
		11-point ordinal	0 “never” to 10 “constantly”	[51]
	NR	VAS	NR	[53]
Time playing until symptoms experienced				
Time playing until pain experienced	NR	VAS-like	0 minutes, 30 minutes, 1 hour, 1.5 hours, 2 hours, 2.5 hours, 3 hours	[54]
Time playing until muscle tension experienced	NR	VAS-like	0 minutes, 30 minutes, 1 hour, 1.5 hours, 2 hours, 2.5 hours, 3 hours	[54]
Time playing until muscle fatigue experienced	NR	VAS-like	0 minutes, 30 minutes, 1 hour, 1.5 hours, 2 hours, 2.5 hours, 3 hours	[54]

Notes: No study of intensity/severity with a recall period other than ‘current’ reported whether ratings referred to at its worst, on average or at its least. NA; Not applicable. NR: Not reported. VAS: Visual analogue scale. [a]Unclear what recall period was used for the baseline data. [b]not defined. [c]before and after the playing task. [d]while playing a set repertoire (45-minutes). [e]ratings were made for the hands, wrists, arms, shoulders and neck regions, with a grand mean of these ratings used for analysis. [f]not clearly reported, however ratings made before and immediately after rehearsals which may indicate that ratings were for ‘current’ discomfort. [g]definition based on Zaza et al.’s,[62] (essentially unable to play at their usual level due to musculoskeletal symptoms) and excluded “mild, transient aches or pains”

Table 3: Summary of effectiveness findings

	Significant findings	Non-significant findings
Strengthen training		No significant difference in change scores (pre-post) for pain intensity, compared with general fitness training[49] No significant difference in pre-post pain intensity scores[49] No significant difference in PRMD frequency and intensity compared with endurance training[53]
Strength or endurance	Significant improvement in the prevalence of musculoskeletal symptoms in the first 6-months for combined exercise groups and no intervention[48]	No significant difference in PRMD frequency or intensity, pre-post[53]
Muscle endurance training		No significant difference in PRMD frequency and intensity compared with strength training[53]
Trunk endurance or Pilates mat training	Significant change in playing time until pain experienced, pre-post[54] Significant change in muscle fatigue, pre-post[54] Significant change in pain intensity, pre-post[54] Significant change in pain frequency, pre-post[54]	No significant difference between the trunk endurance and Pilates mat groups at post-test (not reported for other time points)[54]
General muscle training	Significant decrease in PRMD frequency, pre-post[50, 51] Significant decrease in PRMD severity, pre-post[50, 51]	No significant difference compared with no intervention in PRMD frequency and severity scores at 6-month follow up[51] No significant difference in PRMD compared with no intervention[52] No significant change in PRMD, pre-post[52]
General fitness training		No significant difference in change scores for pain intensity, compared with strength training[49] No significant difference in pre-post pain intensity scores[49]
Yoga	Significant difference in PRMD severity compared with no intervention in one of two cohorts only[55]	No significant difference in PRMD severity compared with no intervention in one of two cohorts only[55] No significant difference in PRMD severity, pre-post[55] No significant difference in PRMD frequency compared with no intervention and pre-post[55]
Yoga lifestyle		No significant difference in PRMD severity or frequency, pre-post[57] No significant difference in PRMD severity or frequency, compared with no intervention[56]
Yoga or yoga lifestyle		No significant difference in PRMD compared with control (unclear whether this was for frequency and/or severity)[56] No change in PRMD (unclear whether this was for frequency and/or severity)[56]
Stretches during rehearsals	Significantly lower discomfort scores compared with control[58] Significant reduction in discomfort scores, pre-post[58]	
Education program	Significant decrease in the number of injuries reported in the intervention group, pre-post[59]	No significant change in the number of injuries reported in the control group, pre-post[59]
Improved footwear		No significant change in injury incidence[60]

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	Significant findings	Non-significant findings
Smaller piano keyboard	Significantly lower ratings of pain during & after playing, & tension while playing, when playing the smaller keyboard compared with the standard size[61] Change in pain rating pre-post (post-performance – pre-performance pain rating) significantly lower when playing the smaller keyboard compared with the standard size[61] Significant difference in ratings of pain and tension while playing for those with smaller left hands, and for ratings of pain for those with smaller right hands[61]	No significant difference in pain and tension while playing for those with larger hands[61] No significant difference in tension while playing for those with smaller right hands[61]

Notes: PRMD: playing- or performance-related musculoskeletal disorders. See Appendix 2 for further details.

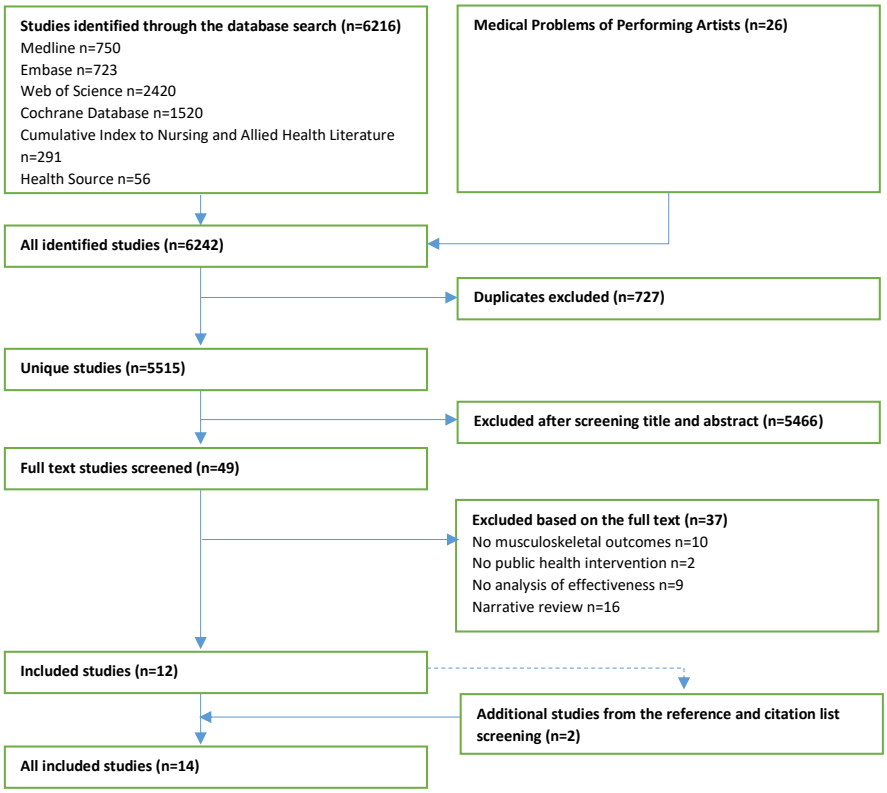

Figure 1: Flowchart of study inclusion/ exclusion

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