REVIEW PAPER

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HAVE MUSICIANS' MUSCULOSKELETAL SYMPTOMS BEEN THOROUGHLY ADDRESSED? A SYSTEMATIC MAPPING REVIEW

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Abstract

The authors aimed to characterize the current evidence base regarding musicians' musculoskeletal symptoms (MSS), in order to identify gaps for future research. A systematic search was conducted to identify peer-review studies published in English in 2007–2016 that investigated musicians' MSS. Narrative reviews, case reports, protocols, and questionnaire or program development papers were excluded. Data were synthesized descriptively in order to identify gaps in the current evidence base. Five systematic reviews and 153 primary studies (133 unique) were included in this review. The majority (71%) of studies investigated professional musicians and/or university music students, with orchestral musicians being the most commonly investigated group. The majority of studies investigated the extent of the problem (68%) and/or associated factors (54%). Eight studies compared the prevalence of MSS outcomes with other populations. A range of risk factors were investigated; however, few studies used longitudinal designs. A total of 16 intervention studies were identified (3 clinical, 13 public health), with 12 investigating education or exercise programs. There is a need for research into musicians beyond classical university music students and professional orchestral musicians, and these musical sub-groups should be compared to determine the most at risk groups of musicians. Studies looking at potential risk factors should move towards longitudinal designs so that the temporal relationship of these factors and MSS could be established, where cross-sectional designs have indicated that an association exists. Intervention studies should be based upon the risk factors identified, and extend beyond education and exercise programs. Int J Occup Med Environ Health. 2019;32(3):291–331

Key words:
pain, musculoskeletal pain, literature review, music, musculoskeletal diseases, occupational diseases

INTRODUCTION

Musculoskeletal disorders (MSDs) impact significantly on the general population, and are the leading cause of years lived with disability globally [1]. The prevalence of musculoskeletal symptoms (MSS) is high among workers, with the 12 month prevalence as 92% [2]. However, there are a number of under-investigated groups, including subgroups of the agricultural [3–5], science [6], health [7,8], and catering [9] industries, as well as musicians [10].

Ramazzini was the first to investigate the health issues experienced by musicians, including a chapter on musicians in his *De Morbis Artificum Diatriba,* published in 1700 [11]. Despite the acknowledgement of musicians' health issues over 300 years ago, it was not until the late 1980s, with the initial publication of *Medical Problems of Performing Artists* in 1986 [12], and the inception of the Performing Arts Medicine Association in 1989 [13], that musicians' health became an established field of research and practice.

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Musicians experience a range of health problems, including neurological [14,15], musculoskeletal [16–19], respiratory [20,21], auditory [22,23], dermatological [24–26], and psychological conditions [27], which may be the result of or impair musical activity. Musculoskeletal symptoms are one of the most common health complaints experienced by musicians, with the 12 month prevalence of MSS in professional musicians and university music students reported as 86–89% [19]. Musculoskeletal symptoms may result in a range of participation restrictions and activity limitations [28–30], and in some cases they have led musicians to change their careers [31,32], or to stop playing permanently [33].

The broad nature of MSS, the diversity of musicians as a population, and the wide range of potential risk factors and interventions for musicians' MSS mean that despite the large number of studies conducted into musicians' MSS over the last 30 years, it is likely that there are still under-investigated sub-populations and unanswered research questions. There is little current guidance regarding gaps in the research into musicians' MSS, which may lead to unnecessary replication of studies, or sub-populations of musicians (e.g., opera musicians, military band musicians) remaining under-investigated. The present research, therefore, uses a systematic mapping review approach to provide a comprehensive analysis of the current evidence base.

This systematic mapping review aims to characterize the recent research (published in 2007–2016) regarding musicians' MSS, and to identify gaps in the recent research evidence base. Specifically, the authors were interested in the sub-populations investigated, the types of studies conducted, and the types of outcomes analyzed, as well as the associated factors or mechanisms for MSS, and interventions that had been investigated. In addition, other research topics relating to musicians' MSS were described.

METHODS

A systematic mapping review is an appropriate method for identifying gaps in the literature and may guide decisions regarding future research [34]. Systematic mapping reviews utilize transparent and explicit methods to search for literature, with synthesis typically being tabular and/or graphical [34]. There is no formal quality assessment in these types of reviews, although study designs may be reported [34]. These reviews characterize the literature according to key features, which may include the population, setting and/or theoretical perspective [34].

Database search strategy

Seven databases (Ovid Medline, Ovid Embase, EbscoHost Health Source: Nursing and Academic Edition, EbscoHost Cumulative Index to Nursing and Allied Health Literature, EbscoHost Music Index, Web of Science Core Collection, and Cochrane Library) were searched in January 2017 using search terms relating to musicians and MSS (Table 1). Terms were searched in the title and keyword fields, and subject headings (e.g., MeSH and Emtree) were searched as applicable. In addition to specific MSS terms, broader search terms, e.g., health* and medical*, were also included in order to capture studies that might report MSS specifically within the full text. Where possible searches were limited to the English language, and pubication dates to 2007–2016. The search strategy was developed through a review of previous search strategies regarding musicians' MSS [10,16–19,35,36], scoping searches, and the assistance of an academic librarian. All studies identified in the database searches were exported into EndNote X7.

Manual search of *Medical Problems of Performing Artists*

The titles of articles published in *Medical Problems of Performing Artists* [12] in 2007–2016 were screened, as were the abstracts sections of this journal. Titles were deemed potentially relevant if they mentioned musicians or performing artists, as well as MSS, health or medical conditions. Potentially relevant studies were added to the list of studies identified through the database search.

Table 1. Search terms used in the search for the studies on musicians' musculoskeletal symptoms published in 2007–2016

Search field	Musician terms	Musculoskeletal health terms
Title or keyword	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 and needles" OR numb* OR *mobilit* OR *flexib* OR stiff* OR "range of motion" OR "range-of-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*
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"
Health Source subject headings	Musicians	Musculoskeletal system – diseases OR pain or "wounds & injuries"

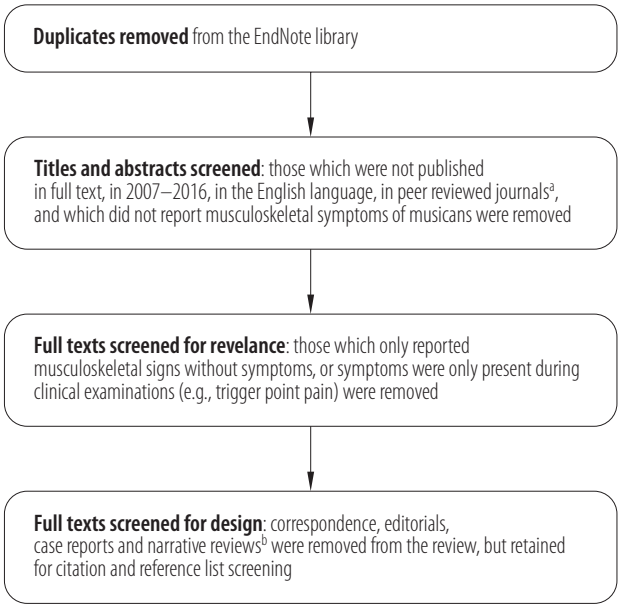
* Truncation.
NEAR/3 – up to 3 words between.
All subject heading terms were explored where available.

Study inclusion/exclusion

The process of study inclusion/exclusion is outlined in Figure 1. Where there was any uncertainty regarding the inclusion or exclusion of studies based on the title and abstract, these were retained. The full texts of the remaining studies were obtained and screened against the same criteria. If there was any uncertainty regarding study inclusion or exclusion, the views of other authors were sought.

Reference and citation list searching

The reference and citation lists of included studies, and the relevant narrative reviews, case reports, editorials and correspondence were screened to identify potentially relevant studies. Citation lists were obtained from Google Scholar and Web of Science (January 2017). Potentially relevant studies were then screened against the inclusion/exclusion criteria. This process continued until no additional studies were identified.



[a] As per Ulrich's Web Serial Analysis System.
[b] Narrative reviews were those which did not meet the Preferred Reporting Items of Systematic Reviews and Meta-Analyses (PRISMA) definition of a systematic review, i.e., they did not have "a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research, and to collect and analyze data from the studies that are included in the review" [37].

Figure 1. Inclusion/exclusion criteria in the study on musicians' musculoskeletal symptoms (MSS)

Data extraction and analysis

Data were extracted manually by the first author, with each article extraction checked independently by another author. Data were extracted into a purpose-built table. Studies were classified as the extent of the problem (e.g., prevalence (this included studies where the prevalence could be calculated, i.e., the number of affected participants, and the sample size was reported), incidence, severity), associated factors and mechanisms (associations had to be reported statistically), interventions, and "other" (for studies that did not fit within the other categories), as based upon van Mechelan et al.'s [37] model of injury prevention research.

Extracted data included:

- the year of data collection and publication,
- the country in which the study was conducted (if this was not reported, the country of ethics approval, funding and/or author affiliations was used),
- the study design,
- the population level:
  - professional ("professional" status was applied only when the study reported the population as being professional),
  - professional and university music students,
  - university music students,
  - adults (all ≥ 18 years, or the mean minus the standard deviation was ≥ 18 years),
  - children (did not meet the adult criteria),
  - mixed (adults and children reported together),
- musical genre (e.g., classical, or jazz),
- ensemble type,
- type of an extent sudy (e.g., prevalence, incidence),
- mechanisms or associated factors,

– interventions,
– MSS outcomes investigated:
  • MSS in general (including specific diagnoses and where "playing-related" was not defined, or inconsistent terminology was used),
  • MSS with perceived risk or aggravating factors,
  • MSS consequences (e.g., time off from playing, treatment).

In keeping with the systematic mapping review design, data were presented in tabular and graphical forms [34], supported with narrative descriptions.

RESULTS

A total of 158 articles were included (Figure 2). Some studies utilized the same datasets as others [27,28,32,38–66], resulting in 138 unique studies.

Systematic reviews

Five systematic reviews were included [10,17–19,35], 4 of which were published in 2015–2016. Professional musicians and university music students [10,19,35], flautists of any age and level [17], and instrumentalists of any age and level [18] were investigated. Three also systematic reviews investigated the extent of the problem; namely, prevalence [17–19] and episodic incidence [17]. Three reported MSS in general, and the consequences of symptoms, with all reporting that the included studies did not define "playing-related" adequately [17–19]. Silva et al. [18] also reported on symptoms caused by playing the piano and preventing piano being played (classified as mixed age and level).

Four systematic reviews investigated factors associated with MSS outcomes in musicians [10,18,19,35]. Two focused on risk factors [10,35], and 2 focused on prevalence, but also investigated the differences in prevalence by gender [18,19], age [19], instrument group [19], and occupational group (e.g., teachers, orchestral) [19]. These systematic reviews investigated professional musicians and university music students [10,19], professional instrumentalists and university instrumental students [35], and instrumentalists of mixed ages/levels [18]. Baadjou et al. [35] excluded musicians in marching bands, and also appeared to have excluded instrumental music teachers; however, the reason for that exclusion was not given. In addition to investigating factors associated with MSS outcomes, Wu [10] also reported the percentage of participants agreeing with the perceived contributing factors; however, it was unclear whether these were specifically for their own symptoms or more general perceptions.

Primary studies

Of the 133 unique primary studies, 68% investigated the extent or severity of MSS, 54% associated factors or mechanisms, 12% interventions, and 32% other topics. There was a steady rise in the number of studies published over the last 10 years, particularly for the extent/severity and associated factors/mechanism studies (Figure 3). Values reported henceforth refer to the number or percentage of unique primary studies.

The majority of primary studies (85%) were from high-income countries (as per the United Nations [67]). This was the case across all types of studies, with 82% of extent/severity studies, 85% of associated factors/mechanisms, 100% of intervention studies, and 80% of other study types coming from high-income countries. Overall, most unique studies were from Europe (38%) or North America (29%), with these continents dominating most study types.

Extent/severity studies

The majority (71%) of studies investigated professional musicians and/or university students, with professional and/or university student orchestral or classical musicians being the most commonly investigated (32%) (Table 2). While the players of a range of non-Western instruments were investigated, those playing Western instruments were most commonly investigated. Regarding specific in-

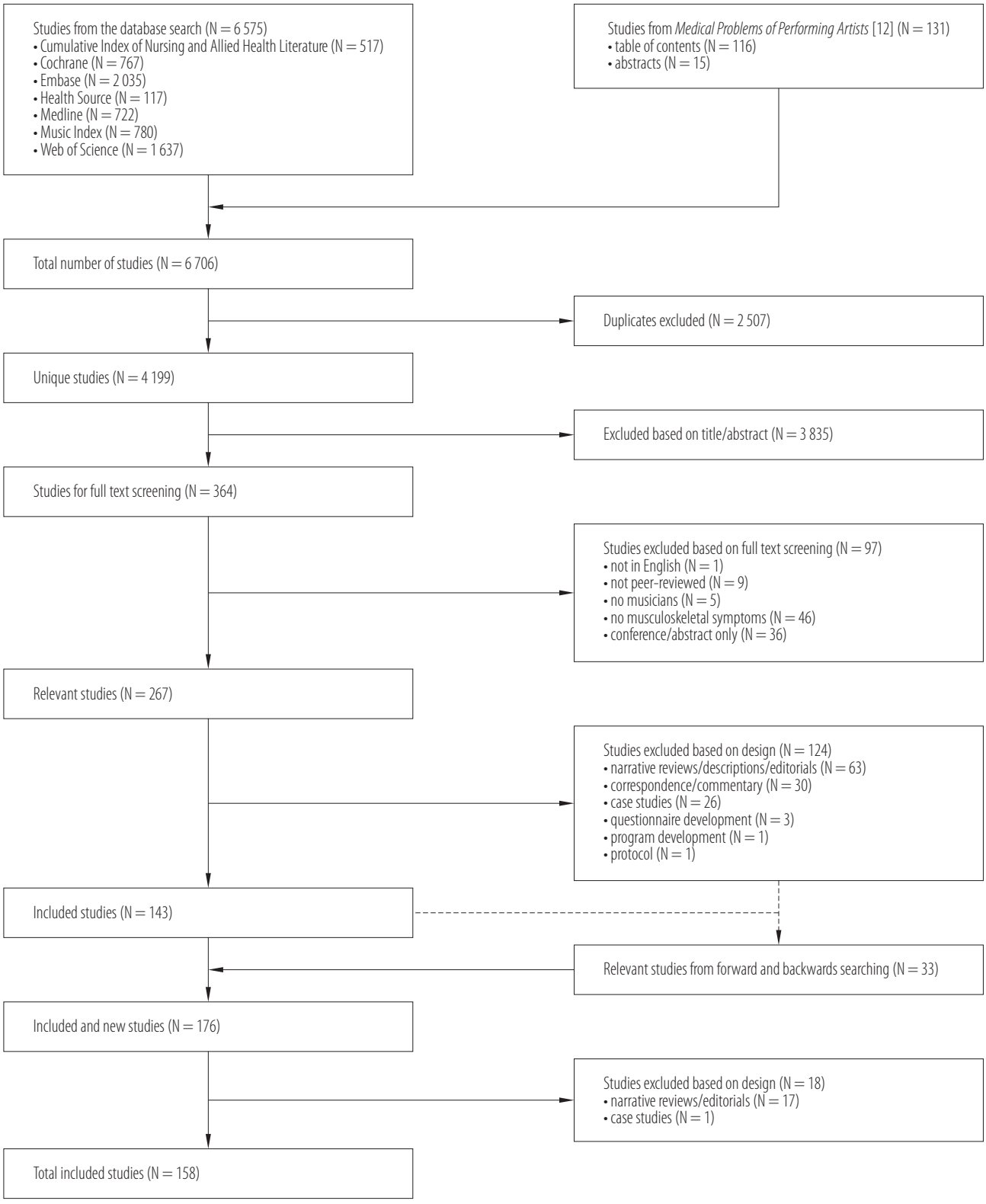
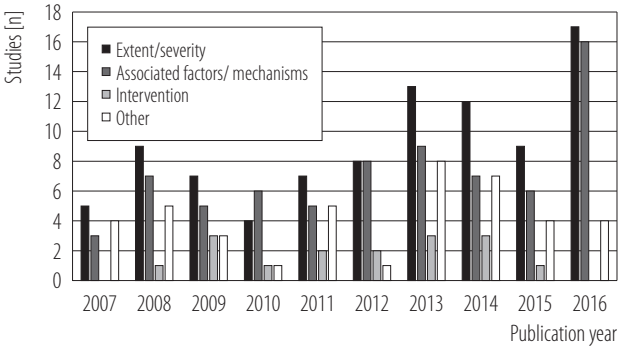


Figure 2. Flowchart of the inclusion/exclusion criteria in the study on musicians' musculoskeletal symptoms

struments, the most commonly investigated were flautists (10%), trombonists (10%), and pianists (14%) (Table 3). When instruments were grouped, they tended to be within traditional instrument groupings (e.g., woodwind, brass, strings, percussion); however, there were some exceptions. Some appeared to be collections of instruments where there were small numbers of participants (e.g., keyboards, or harps in orchestras) [46,54,93], while others grouped instruments according to their biomechanical exposures; namely, symmetrical or asymmetrical playing postures [93]; whether their musical activity (e.g., instrument or singing) was thought by the researchers to place



Where there were duplicate reports of a study, the oldest publication was counted.

Figure 3. Publications on musicians' musculoskeletal symptoms by year of publication

Table 2. Type of musicians in the studies on musicians' musculoskeletal symptoms published in 2007–2016

Musician type	Reference			
	extent/severity	associated factors/ mechanisms	intervention	other
Professional	27–30, 45, 46, 60, 64–66, 68–95	27–30, 45, 46, 60, 64, 65, 71, 74, 76, 79–88, 90–93, 95–97	58, 59, 68, 90, 98–100	29, 30, 32, 51, 52, 61–63, 68, 73, 85, 92, 94, 101–103, 104
orchestral	27–30, 45, 46, 60, 64–66, 68, 71, 72, 74, 76, 78–81, 83, 87, 91, 92, 94, 95	27–30, 45, 46, 60, 64, 65, 71, 74, 76, 79–81, 83, 87, 91, 92, 95	58, 59, 68, 98–100	29, 30, 61–63, 68, 92, 94, 103
classical	45, 78, 80, 86	45, 80, 86, 97		32, 52
symphony or philharmonic	28, 30, 60, 68, 74, 76, 79, 81, 94, 95	28, 30, 60, 74, 76, 79, 81, 95	68, 100	30, 68, 94
state or opera	27	27		
symphony or opera	29	29		29
symphony or pit	65, 66	65		
stage and pit	64			
stage	64			
pit	64			
military band	84, 85, 89, 90	84, 85, 90	90	85
blues	90			
ceremonial	90			
chorus	90			
concert	90			
Cuban band	73			73
opera singers				104
classical choristers	75			

Table 2. Type of musicians in the studies on musicians' musculoskeletal symptoms published in 2007–2016 – cont.

Musician type	Reference			
	extent/severity	associated factors/ mechanisms	intervention	other
Professional – cont.				
teachers	69, 82, 93	82, 93		102
jazz				102
Professional or university students	91, 105–109	91, 106–108, 110, 111	112, 113	105, 114
University students	53–55, 91, 102, 115–139	53, 54, 91, 115, 116, 119, 122, 125–127, 129–131, 133–142	143–148	55, 102, 121, 124, 125, 128, 129, 136, 137, 139, 149–152
orchestral	116	116		
symphony orchestra	134	134		
marching band	117, 130, 132	130		
classical	53–55, 127, 128, 136	53, 54, 136		55, 128, 136, 150
jazz	102, 118			102
rhythmic	127			
musical theatre	139	139		139
Adults	49, 50, 54, 77, 153–161	49, 50, 153–157, 159–160, 162–164		56, 57, 158, 166–169
orchestral	153	153		
band	158			158
drum and bugle corp	159	159		
Korean traditional	49, 50	49, 50		
Irish traditional				56, 57
Children	40–44, 47, 48, 136, 170–177	40–44, 47, 48, 136, 170, 172–174, 178	179, 180	136, 177
orchestral	172	172	179, 180	
classical	136	136		136
marching band	174	174		
Mixed	38, 39, 69, 136, 181–185	38, 69, 136, 182, 183		39, 136, 183, 184, 186
classical	136	136		136

This classification refers to the target population that was not necessarily the same as those from whom data were collected (e.g., Rickert et al. [61–63,151], Ackermann and Driscoll [175], Ajidahun and Phillips [186], and McKechnie and Jacobs [177]).

them at increased risk of orofacial pain [74], and whether the arms were elevated ≥ 40° for playing [83,182]. Regarding the latter, Nyman et al. [83] further divided groups by playing time, resulting in 4 groupings that included "traditional groupings" of violin and viola, as well as cello and double bass.

In addition to instrumentalists, drum majors [132], composers [125], vocalists [73,75,77,125,127,135,139], and vo-

Table 3. Instruments and instrument groups investigated

Instrument type	Reference			
	extent/severity	associated factors/ mechanisms	interven-tion	other
Wind	47, 79, 84, 93, 116, 127, 170	79, 84, 116		
symmetrical wind				166
woodwind	30, 41, 44–46, 54, 60, 65, 66, 76, 86, 119, 122, 125, 128–131, 135, 138, 158	122, 130		68, 114, 128
non-reed/aerophone	129, 170	170		
flute	41, 44, 46, 77, 84, 87, 121, 132, 183, 184	183		121, 183, 184
piccolo	132			
reed	170	170		
oboe	41, 44, 46, 84			
clarinet	41, 44, 46, 84, 132			
bassoon	38, 39, 41, 44, 46, 66, 84	38		39
saxophone	41, 44, 84, 132			
brass	30, 41, 44–46, 54, 60, 65, 66, 71, 76, 85, 86, 119, 122, 125, 129–131, 135, 138, 158	71, 85, 122, 130	146	68, 85, 114
high brass/small mouthpiece	85, 170	170		
trumpet	41, 44, 46, 71, 73, 84, 132			
French horn	41, 44, 46, 71, 84			
tenor	132			
baritone	41, 44, 132			
mellophone	132			
low brass/large mouthpiece	85, 170	170		
trombone	41, 44, 46, 65, 71, 73, 84, 87, 132, 155	155		
euphonium	41, 44, 84			
tuba/sousaphone	132			
tuba	41, 44, 46, 71, 84			
Non-wind	170			
keyboards	47, 125, 129, 135, 154			166
piano/keyboard	131			
piano/organ	46			114
piano	41, 44, 69, 70, 73, 82, 102, 105, 127, 136–138, 177, 185	69, 82, 96, 136, 137, 164	144	101, 102, 105, 136, 137, 149, 150, 177
organ	70			
accordion	73, 171			
strings	47, 76, 119, 122, 127, 129, 131, 135, 138, 154, 172, 173, 176	79, 110, 122, 171, 173	180	114

Table 3. Instruments and instrument groups investigated – cont.

Instrument type	Reference			
	extent/severity	associated factors/ mechanisms	interven-tion	other
Non-wind – cont.				
strings – cont.				
bowed strings	54, 93, 125, 157	157		
upper strings	30, 41, 44–46, 60, 65, 66, 79, 83, 86, 124, 172	162, 163		68, 124, 166, 168
violin	41, 44–46, 87, 92, 108, 120	79, 92, 108, 111, 140, 178		92, 149
viola	41, 44–46, 87, 185			
lower strings	30, 41, 44–46, 60, 65, 66, 79, 83, 86, 172			68, 166
cello	41, 44, 46, 65, 87, 91, 185	91		61-63, 149, 151
double bass	41, 44, 46, 106	106		
ajaeng	49, 50	49, 50		
haegeum	49, 50	49, 50		
plucked strings	54, 125, 129			
harp	46, 66			114
tres	73			
laúd	73			
guitar/gambus	131			
guitar	41, 44, 46, 73, 156	156		114
bass guitar	106, 115	115		
gayageum	49, 50	49, 50		
geomungo	49, 50	49, 50		
bassists[a]	73, 106	106		
percussion	30, 41, 44–46, 65, 66, 73, 86, 107, 119, 122, 125, 127, 129–131, 135, 138, 158, 160	107, 122, 130, 160		114
membranophone percussion	160			
snare drum	132			
bass drum	132			
tabla	88	88		
keyboard percussion	160			
auxiliary/other percussion	160			
cymbals	132			
santur	154			
Mixed groupings				
percussion/harp/keyboard	60			68
harp/piano/organ/guitar	46			

Table 3. Instruments and instrument groups investigated – cont.

Instrument type	Reference			
	extent/severity	associated factors/ mechanisms	interven-tion	other
Mixed groupings – cont.				
piano/guitar/percussion	93			
percussion/keyboard	54			
clarinet/oboe/bassoon/ trumpet/recorder/keyboard/ piano/percussion	93			
violin/cello/double bass/ trombone/flute/guitar	93			
bassoon/clarinet/French horn/ oboe/tuba	83			
flute/trumpet/trombone	83			
viola/violin/daegeum/flute/ trombone/trumpet/harp/ percussion	182			
cello/double bass/clarinet/ saxophone/bassoon/oboe/ horn/tuba/piano	182			
violin/viola/vocal/trombone/ tuba/clarinet/saxophone	74			

Mehrparvar et al. [154] also included 3 other instruments in a graph regarding prevalence, but these were not labeled. Some studies had "others" groups where the instruments were not specified. These have not been included here.
[a] The item "Bassists" refers to double bassists and bass guitarists, and therefore crosses the bowed and plucked string categories.

cal or eurhythmics teachers [93] were also investigated. In most cases, the musicians themselves were asked about the presence of symptoms; however, Ackermann and Driscoll [175] surveyed parents of child instrumentalists only, while McKechnie and Jacobs [177] surveyed child pianists, their parents and piano teachers.

Eight unique studies compared the prevalence of MSS and/or the consequences experienced by musicians with other groups, comparing especially the following: children playing the accordion with non-musical children [171], adult musicians with the general population [161], university music students with university medical [53–55] or health students [123], choristers with the general population [75], professional orchestral musicians with the general working population [28], professional pianists and organists with those without increased foot activity [70], and university orchestral students with those who had not played any music for at least the past year [116]. Kok et al. [54,55] also compared the medical students who did and did not play a musical instrument. Overall, the comparison between musicians and non-musicians remains under-investigated.

Most primary extent studies investigated prevalence of MSS outcomes, with only 5 studies reporting the incidence [68,89,90,117,174]. These, however, appeared to investigate episodic incidence, rather than true incidence. Four of these studies [89,90,117,174] investigated marching or military band musicians, while the remaining one [68] investigated professional orchestral musicians.

Data were collected by asking for daily injury reports [117], or using data from onsite or military clinics [68,89,90,174]. It should be noted that there were a number of other studies indicating that they were reporting incidence, whereas their methods and results indicated that they were actually reporting prevalence [66,69,80,84,121,170].

The particular outcomes investigated in the studies focusing on the extent of MSS were predominantly symptoms in general (87%) [28–30,38,40–50,53–55,60,64–66,69–88, 91–95,102,105–109,115–126,129–131,133–135,138,139, 154–161,170–173,176,177,181–183,185]. Of the studies investigating the extent of MSS, 19% reported the perceived risk or aggravating factors for symptoms, with the most common factor type relating to musical activity (Table 4), and 58% investigated consequences, with musical consequences being the most commonly reported category (Table 5).

Associated factors

Similar to the extent/severity studies, most of the studies (69%) of associated factors/mechanisms focused on professional and/or university musicians, with orchestral and classical musicians (30%) being the focus where the genre or ensemble was reported (Table 2). A smaller range of instruments were investigated when compared with the extent/severity studies (Table 3), with piano (8%) and violin (8%) being the most commonly investigated groups. One study investigated vocalists [139]. Additionally, Zamorano et al. [97] conducted a study exploring the relationship between pain and tactile thresholds, and pressure and thermal pain sensitivity in 3 groups, i.e., musicians with no pain, musicians with chronic low back pain, and non-musicians with chronic low back pain.

Of the 74 unique primary studies investigating MSS associated factors or mechanisms, most were cross-sectional studies. Exceptions were a prospective cohort study comparing MSS before and after an orchestra camp [153], and another that investigated the reported injuries and illnesses during a band camp [174]. There were also 12 case-control studies [96,97,110,111,115,140, 141,162–165,178]. Of these case-control studies, 3 included a playing-task [111,115,178], 1 resisted finger extension/flexion [165], and another emotionally and physically stressful tasks [110]. Kuppens et al. [110] used a randomized cross-over design regarding the order of emotionally or physically stressful tasks, while Woldendorp et al. [115] compared pain intensity before and after a playing task, as well as muscle activity before, during and after a playing task.

Studies of risk factors for MSS outcomes most commonly investigated activities and behaviors, particularly musical factors (72%), while personal factors (65%), such as age and gender, were also commonly investigated. Only 1 study investigated the relationship between the equipment used, in this case footwear, and MSS outcomes (Table 6). Some 22 studies also investigated the association between different MSS outcomes.

Similar to the extent/severity studies, the majority (86%) of the studies of risk factors reported general symptom outcomes [27,28,30,38,40–50,53,54,60,64,65,69,71,74,76, 79–88,91–93,95–97,106–108,110,111,115,116,119,122,125, 126,129–131,133–135,138–142,154–156,160–164,170,172, 173,178,182,183]. Two studies of instrumental musicians used perceived risk/aggravating factors as the outcomes, these being playing [64] and band [90]. Musculoskeletal symptoms consequences were the investigated outcome in 41% of the risk factor studies; however, the range of consequences was less diverse than in the extent/severity studies (Table 5).

Intervention studies

Professional and university musicians were again the most commonly investigated populations (88%), with only 2 studies investigating children [179,180] (Table 2). Orchestral musicians were again the most frequently investigated type of musicians (44%) (Table 2). Unlike the

Table 4. Perceived risk or aggravating factors

Factor	Reference
Music-related	
Playing	64, 68, 73, 102, 124, 175
military band	90
marching band	132
Work	66
long sessions of playing	29, 66, 121, 127
extensive practicing	129
change in practice routine	137
sudden increase or decrease in playing hours	29
sudden increase in playing time	121
increase in playing time	30
sudden increase in playing[a]	66, 127
insufficient warm-up	29, 66, 121
insufficient rest breaks	121, 129
too few breaks when playing	29, 94
technique flaws	29, 66, 121
inappropriate technique and/or abnormal body posture	129
increased difficulty	30
particular repertoire or a difficult piece	29
repertoire scheduling	66
playing when physically exhausted	29
carrying an instrument or other equipment	29
variation in the functioning of and/or malfunction of the instrument	29
instrument set up	66, 121, 127
conductor approach	66
touring/travelling	66, 121
continuing to play with symptoms	94
performing the same movement repetitively	94
Dance-related	
dance partner	139
difficult choreography or movement pattern	139
too many repetitions/rehearsals	139
Environmental	
inadequate chairs	29, 30, 121
cramped playing conditions	29
practice/rehearsal venue	85
climatic conditions	139

Table 4. Perceived risk or aggravating factors – cont.

Factor	Reference
Environmental – cont.	
temperature	29
lighting	29
dance floor	139
changing dance floors	139
dance floor too slippery or too sticky	139
Psychosocial	
emotional problems	30
stress and/or anxiety	29
mental stress	139
stress	66, 127
performance anxiety	66, 121
depression	29
feelings of inadequacy	29
job dissatisfaction	29
time pressure/practicing with a deadline	29
own performance aspiration	139
pressure by the school	139
pressure by the teachers	139
parents' expectations	139
lack of support from the manager/conductor	29
lack of social support	29
other psychological causes	139
Physical condition	
physiological strains	121
lack of endurance or strength	29
poor physical condition	121
poor flexibility	66, 121
poor fitness	66, 139
excess muscle tension	29, 66, 127
poor posture	29, 30, 66, 121, 127
fatigue	139
physical fatigue	139
muscle fatigue	66
general overload situation	139

Table 4. Perceived risk or aggravating factors – cont.

Factor	Reference
Other	
lack of understanding of physical strain	121
lack of basic knowledge of anatomy/physiology	129
loss of concentration	139
insufficient rest	66, 127
poor injury management	66
inadequate nutrition	139
bad drinking habits	139
another student	139
ignoring warning signals	139

Chimenti et al. [29] also grouped their factors as playing-related, musculoskeletal, work environment-related and psychosocial.
[a] Unclear which parameter (e.g., time, intensity) is increased.

Table 5. Consequences of the musculoskeletal symptoms investigated, by study type

Musculoskeletal symptoms consequences	Reference		
	extent/severity	associated factors/ mechanisms	intervention
Seeking advice/treatment/informing others			
professional care	29, 39, 134		
hospitalization	119		
military or onsite clinic	68, 89, 90		90
doctor/physiotherapist/chiropractor or similar professional	119		
medical/health professionals	28, 38, 43, 53, 102, 126, 174, 183	28, 38, 43, 174	
medical practitioner	30, 38, 39, 69, 94, 124, 129, 139, 183, 184	38	
specialist	28, 53, 74, 139	74	
surgeons	102		
orthopedist	92, 124		
physician	85		
general practitioners	28, 53, 102, 124		
physiotherapists	28, 30, 39, 53, 69, 94, 102, 121, 128, 129, 183		
physiotherapist/occupational therapist	92		
occupational therapy	30		
occupational therapists/acupuncturists	102		
acupuncturist	39		

Table 5. Consequences of the musculoskeletal symptoms investigated, by study type – cont.

Musculoskeletal symptoms consequences	Reference		
	extent/severity	associated factors/ mechanisms	intervention
Seeking advice/treatment/informing others – cont.			
massage therapists	39, 121, 183		
chiropractors	28, 30, 39, 69, 102, 121, 128, 183		
osteopath	39, 121, 128		
psychologists or counselors	102		
alternative medicine	30, 53, 94		
Alexander practitioner	30, 39, 94, 121, 128		
Feldenkrais practitioner	30, 39, 128		
Bowen therapy	128		
yoga teacher	39, 121, 128		
Pilates instructor	39, 128		
school administration	139		
teachers	69, 139		
instrumental tutors	39, 129		
other tutors	129		
superiors	85		
colleagues	85, 129		
friends	129, 139		
the Internet	129		
attempted to conceal the problem	85		
Treatments			
self-treatment	38	38	
general body training	128		
exercises/stretching	129		
stretching	39, 121, 128		
exercise or posture program	94		
exercise	39, 121		
muscle resistance exercises	128		
braces/splints/orthoses	94		
brace	39		
hand splint	129		
bandages	129		
heat	39, 121, 128		

Table 5. Consequences of the musculoskeletal symptoms investigated, by study type – cont.

Musculoskeletal symptoms consequences	Reference		
	extent/severity	associated factors/ mechanisms	intervention
Treatments – cont.			
ice	39, 121, 128		
taking medication	43, 94, 119, 128, 129, 139, 183	43	
anti-inflammatory medication	39, 115, 121, 183		
cortisone injection	128		
pain killers	28, 39, 115, 121, 131, 183	28	
gel/cream	129		
rest	39, 121, 129		
relaxation techniques	128		
warm up	128		
massage	128		
surgery	94		
diagnostic imaging	94		
Impact on work or study			
time off from work/studies	28, 64, 66, 85, 95, 119, 139	28	
missed opportunities for work/study	128		
change in jobs/duties	119		
prevented from doing normal work	119		
hindered ability to perform their work	106		
workers' compensation claim	29	29	
Impact on the quality of musical activity			
impaired playing ability/interferes with playing	27, 28, 30, 38–44, 64, 66, 73, 76, 82, 86, 119, 125, 127, 128, 130, 136, 137, 153, 172, 176	27, 28, 38, 40–44, 64, 82, 86, 127, 130, 136, 137, 153, 165, 172	99, 100
difficulty using the usual technique	119, 176		
difficulty playing as well as they wanted to	119, 176		
difficulty playing the usual amount of time	119, 176		
distracted while playing	131, 183		
affects the high range	71, 85	71, 85	
affects the low range	71, 85	71	
playing flexibility	71	71	
affects transition from the low to the high range	71, 85	71	
affects transition from the high to the low range	71, 85	71	

Table 5. Consequences of the musculoskeletal symptoms investigated, by study type – cont.

Musculoskeletal symptoms consequences	Reference		
	extent/severity	associated factors/ mechanisms	intervention
Impact on the quality of musical activity – cont.			
affects moving in both directions	71	71	
affects the ability to hold long notes ("shaking")	71, 85	71	
affects tone quality	71, 85	71	
affects the beginning of notes (attack "blockage")	71, 85	71	
affects accuracy ("cracked" notes)	71, 85	71	
breaking off held notes	71, 85	71	
affects attack in tongued passages	71, 85	71	
affects coordination	71, 85	71	
affects the marching technique	130	130	
Changes made to musical activity			
technique change	94		
regular practice breaks	128		
stopped playing with discomfort/increase in discomfort	128, 129		
changed postural playing position	69, 105		
increased playing time	39		
warm up	128		
reduced playing time	39, 94, 121, 128, 131, 183, 184		
affected playing time	30		
stopped playing/time off from playing[a]	69, 82, 94, 102, 128, 130, 137, 154, 183	82, 130	
cannot play	30, 155	155	112
paused from practicing	28	28	
paused from rehearsals	28	28	
omitted playing at concerts	28	28	
missed playing commitments	128		
missed rehearsals/services	29, 159		
missed competitions	159		
stopped marching participation	130	130	
absence from orchestra	30		
cannot give classes	30		
missed a scheduled practice/performance	132		
music disability scales	133, 153, 157	133, 141, 153, 157, 159, 162	

Table 5. Consequences of the musculoskeletal symptoms investigated, by study type – cont.

Musculoskeletal symptoms consequences	Reference		
	extent/severity	associated factors/ mechanisms	intervention
Impact on life outside of work, study and music			
functional limitations/impact on life/daily activities	53, 55, 90, 127, 130	80, 90, 130	
impaired level of function with activities of daily living at home	28	28	
impact on function of leisure time activities	28	28	
impact on sleep	28, 124	28	
emotional impact	55		
financial problems	128		
social isolation	128		
opening a tight or new jar	138		
recreational activities in which external force impact the upper extremity	138		
general disability scale[b]	86, 119, 133, 138, 157	80, 86, 97, 119, 133, 138, 141, 157, 162	113

One study referred to time off, but did not specify whether this concerned the time off from playing, work or study [131].
In some cases (e.g., [127,128] certain consequences were combined, e.g., the impact on playing and financial problems, and Artigues-Cano et al. [184]), the prevalence of those who had injuries related to flute playing or who sought medical advice for their pain was reported.
[a] Based on the report of how many musicians continued to play with symptoms or a worsening of symptoms in 3 studies [39,102,137].
[b] The scale used by Berque et al. [86] incorporated musical and general disability items.

Table 6. Summary of the factors associated with musculoskeletal symptom outcomes

Factor	Reference
Personal (non-modifiable)	
gender/sex	27, 28, 30, 38, 40–47, 49, 50, 53, 69, 71, 74, 76, 79, 80, 82, 84, 86, 90, 91, 93, 95, 97, 106–108, 116, 119, 127, 129, 131, 134–139, 141, 142, 154, 155, 157, 162, 170, 172, 173, 182, 183
age	27, 30, 40–46, 49, 50, 69, 71, 74, 76, 79, 82, 84, 86, 90, 95, 97, 106–108, 119, 129, 134, 136, 137, 141, 142, 154, 157, 162, 172, 182
hand dominance	82, 97, 154
race	82, 90
Physical	
non musical	
general health	106
physical health	133
medical history	80

Table 6. Summary of the factors associated with musculoskeletal symptom outcomes – cont.

Factor	Reference
Physical – cont.	
non musical – cont.	
other health conditions	82, 174
body mass index	49, 50, 80, 82, 90, 119, 133, 141, 154, 162, 170, 172
height	49, 50, 82
weight	49, 50, 82
other anthropometric factors	69, 82, 96, 136, 155, 164, 172
trigger point/pressure pain threshold	27, 60, 65, 91, 96, 97, 110, 163
tactile thresholds	97
hypermobility	60, 82, 172
range of motion	60, 82, 178
rotation speed	82
muscle resistance/strength tests	60, 82
craniocervical flexion test	162
nerve root/peripheral nerve tests	60
motor performance tests	163
kinesthetic awareness	141
fine motor dexterity	141
sensorimotor incongruence coordination	140
myoelectric activity	178
palpation soreness/pain	60
push-ups	90
sit-ups	90
2 mile run	90
cortisol levels	81
intracellular pH	165
phosphocreatine levels	165
inorganic phosphate levels	165
Pi/PCr ratio	165
fatigue	82
musical	
chin rest sore	82
weight of the instrument	80
self-reported muscle tension when playing	137
seat height when playing	137
self-reported playing posture	69, 116, 137, 154

Table 6. Summary of the factors associated with musculoskeletal symptom outcomes – cont.

Factor	Reference
Physical – cont.	
musical – cont.	
maximum interval on the piano	82
incorrect embouchure	116
strong resistance	116
pressure from mouthpiece	116
loss of lip	82
loss of seal	82
standing time	90
marching time	90
range of neck motion while playing	178
playing-related perceived exertion	111
muscle activity before, while and/or after playing	111, 115
Psychosocial/organizational	
non-musical	
marital status	82, 90
number of children	82
part-time employment	139
employment duration	154
perceived job security	95
perceived physical environment	80
work psychosocial factors	80
support at work	95
control at work	95
career satisfaction	107, 134
goals achievement	107
mental health	119, 133, 162
stress	79, 160, 173
psychological disturbance/distress	92, 106
somatizing tendency	95
mood	95
depression	27, 65, 82, 97, 142
anxiety	27, 82, 97, 142
pain-related anxiety	134
personality type	159
self-esteem	27

Table 6. Summary of the factors associated with musculoskeletal symptom outcomes – cont.

Factor	Reference
Psychosocial/organizational – cont.	
non-musical – cont.	
generalized self-efficacy	27
neuroticism	27
locus of control	27
positive affect	134
negative affect	134
financial situation	139
musical	
enjoyment of music/playing	40, 173
information from the teacher on reducing playing-related musculoskeletal disorder risk	137
age when deciding to become a professional musician	71
acceptability of the "no pain, no gain" attitude	136
medicine taken for performance anxiety	40
performance anxiety/stage fright	27, 40, 45, 46, 65, 82, 95, 108, 134, 135, 172
playing-related stress	137
Activities/behaviors	
non-musical	
current healthy behaviors	125
smoking	49, 50, 80, 95, 106
diet	107
drinking	49, 50
household chores	80
hobbies	49, 50, 80
stretching	50
stretching/warming up	49
prevention exercises	107
physical activity/exercise	42, 47–50, 76, 79, 80, 82, 90, 106, 107, 119, 131, 133–136, 154, 173, 183
relaxation techniques	107
sleep	79, 82, 173
travel	82
hand-related activities	82
computer use	42, 106
television/video	42
writing	42

Table 6. Summary of the factors associated with musculoskeletal symptom outcomes – cont.

Factor	Reference
Activities/behaviors – cont.	
non-musical – cont.	
electronic games	42
intensive hand activities	42
oral parafunction	182
night bruxism	79
day bruxism	79
physical activities in a typical work day	95
musical	
instrument	41, 44, 65, 87, 106, 157, 173
instrument group	27, 28, 30, 44–47, 54, 74, 76, 79, 80, 83, 85, 86, 93, 95, 129, 134, 135, 138, 142, 154, 170, 172, 182
number of instruments played	41, 44
whether the piano was their main instrument	69
playing other instruments (≥ 5 h/week)	106
chin rest type	108
age of starting music	71, 82, 97, 107, 136
years of playing	40, 44, 47, 48, 69, 74, 82, 85, 86, 92, 97, 108, 116, 119, 134–137, 157, 162, 170, 173, 182
years in the profession	45, 49, 50, 71, 80, 84, 86
years of university study/ensemble experience	71, 85, 134
education level	53, 69, 90, 137, 139, 173
which university/academy they attended	54, 127
professional vs. university	91
teachers vs. performers vs. players	69
professionals vs. non-professionals	69
music major vs. non-major	130
active duty vs. air national guard	85
main musical activity (e.g., orchestral)	107
orchestra type (pit vs. stage vs. pit/stage)	64
military performance group	90
playing genre	106, 127, 137
repertoire difficulty	40
playing in additional ensembles	173
changes to embouchure technique	71
changes to breathing technique	71
type of playing technique	69, 106

Table 6. Summary of the factors associated with musculoskeletal symptom outcomes – cont.

Factor	Reference
Activities/behaviors – cont.	
musical – cont.	
general workload per week	71
duration and/or frequency of musical activity	40, 41, 44, 47, 48, 69, 71, 74, 76, 80, 82, 83, 85, 86, 93, 96, 97, 106–108, 116, 119, 127, 129, 134, 136, 137, 154, 156, 157, 162, 1709, 172, 173, 182
set amount of musical activity	85
changes in the amount of playing time	40, 153, 172
warm ups	40, 71, 80, 82, 122, 137, 173
cool downs	40
breaks	40, 69, 80, 82, 136, 137
stop practice with playing fatigue	82
stop practice with mental fatigue	82
public concerts	82, 107
resting time before a concert	107
day of a band camp	174
upper limb physical requirements	80
Equipment	
musical	
shoe	
heel fit	90
width	90
toe room	90
cushioning	90
breathability	90
durability	90
feet	
too hot in warm weather	90
to cold in cold weather	90
orthotics	90
frequency of replacing shoes	90
Association between musculoskeletal symptom outcomes	29, 42, 44, 46, 71, 74, 76, 82, 86, 88, 96, 106, 126, 129, 133, 134, 138, 141, 155, 157, 162, 172, 174

other study types, few were specific to an instrument or instrument group, with 1 investigating brass instrumentalists [146], and another one pianists [144] (Table 3).

Only 16 unique intervention studies were identified. The study designs included randomized controlled trials [58,59,113,143], a randomized cross-over study [144],

non-randomized prospective concurrent comparative studies [98,99,148,179,180], and case series/pre-post studies [68,90,100,112,145–147,149]. While Kava et al.'s [148] and Lee et al.'s [145] were intended as non-randomized prospective concurrent comparative studies, and a randomized controlled trial, respectively, the analyses reflect pre-post designs.

Three clinical studies included only symptomatic participants using radial shockwave therapy of trigger points [113], oral splints [112], or Tunia exercises [58,59]. The remaining 13 studies focused on public health interventions that included exercise programs (yoga lifestyle [98], yoga [98,179], stretches during rehearsals [180], breathing exercises [145], trunk and upper extremity endurance exercises [148], Pilates [148], and general muscle exercises [99,100,145]), education programs [143,146,147], and equipment changes (ergonomically modified piano keyboard [144], and improved footwear [90]). Chan et al. [68] implemented a physio-led onsite triage clinic to examine the feasibility of this intervention, rather than effectiveness.

The most common outcome type for intervention studies was symptoms in general (63%) [58,59,98,112,113,143–145,148,179,180], while 31% of these studies investigated consequences (Table 5). Five studies had outcomes that did not relate directly to symptoms, but instead reported the following: behaviors or responses to discomfort or pain [147], descriptions of the perceived benefits of the intervention [145], perceptions of the intervention effectiveness to manage a current performance-related or non-performance-related musculoskeletal disorder injury [100], reasons for participation in the study [100], awareness of performance-related risk factors for musculoskeletal problems [146], comfort in advising students about musculoskeletal problems [146], and the likelihood of future use and usefulness, and following through with referral advice in an onsite triage clinic [68]. Chan et al. [68] also reported qualitative feedback from musicians and the physiotherapists involved.

Other studies

There were 3 main types of "other" studies, i.e., qualitative studies (6 unique studies), clinical case series (8 unique studies), and quantitative studies (23 studies). The quantitative studies categorized as "other" in this review quantified results in ways which did not fit the above study types, i.e., they reported proportions for various outcomes, listed findings without reporting the proportion or number of participants, or reported responses to open-ended questions.

As with the other types of studies, most studies (80%) in this category concerned professional musicians and/or university music students (Table 2). In addition to a range of instrument groups being investigated (Table 3), 2 studies reported on vocalists [104,139]. A wide range of outcomes were reported, including the lived experience of MSS, illness perceptions, and perceived risk factors for musicians in general, not necessarily their own symptoms (Table 7).

With regards to these outcomes, Rickert et al.'s [61–63] qualitative study of professional orchestral musicians also involved collecting data from orchestral managers in addition to musicians, while their study of university music students involved collecting data from students, as well as professional orchestral musicians and orchestral managers [151]. All musicians in these studies were cellists; hence, the generalizability of these findings to the population of interest is questionable. Two studies compared musicians with other populations. Andersen et al. [103] compared the culture of pain among elite sportspeople with professional musicians, and Kok et al. [55] compared the illness perceptions regarding musculoskeletal complaints between university music and medical students.

In addition to the outcomes reported in Table 7, Ajidahun and Phillips [186] used a Delphi process to determine an optimal warm up program to prevent playing-related musculoskeletal disorders, involving a range of health professionals and musicians. Parents of child instrumentalists were surveyed by Ackermann and Driscoll [175], who reported on

Table 7. Types of musculoskeletal symptom findings reported in "other" studies

Musculoskeletal symptom findings	Reference
Quantitative data from quantitative studies	
perceived timeline for their MSS[a]	55
level of concern regarding their MSS[a]	55
level of understanding regarding their MSS[a]	55
perceived personal control over MSS[a]	55
perceived effectiveness of planned treatment[a]	55
changes in symptoms and disability overtime	149
whether they have the "no pain, no gain" attitude	136, 150
whether MSS were considered a normal part of musical activity	150
whether they believed the university/school should employ a medical specialist/doctor to deal with these symptoms	129
whether they had followed the advice of a health/medical professional regarding playing position, to avoid injury	183
whether the school allowed them to implement the advice provided by doctors to treat their symptoms	129
whether they worried about playing-related pain	150
whether they believed they would not play through pain	150
whether they believed that playing-related pain could lead to serious injury	150
whether they believed they could find a solution to playing-related pain	150
tutors reaction to playing-related MSS	129
whether they spoke to the band leader about injury prevention	73
whether they believed physiotherapy could help manage MSS	94
awareness of descriptions of pianists' injuries	150
awareness of the Alexander Technique as a preventative measure or management strategy for MSS	94
whether they agreed that teachers should be trained in injury prevention and management	183
whether they agreed that players should be trained in injury prevention and management	183
whether they felt they had received enough information/advice during their studies, regarding injury prevention and management	183
whether they believed that a knowledge of basic anatomy would be beneficial in managing injuries	183
whether they took the advice of health professionals, regarding changes to the playing position to prevent injury	183
physical health scale ratings for those with MSS	149
mental health scale ratings for those with MSS	149
reasons for not claiming workers' compensation	29
the number of respondents who believe that information from a health professional would change a musician's behavior	92
whether teachers advise students about performance-related musculoskeletal disorders, and recommend health professionals	102
whether teachers work with health professionals to work through students' performance-related musculoskeletal disorders	102

Table 7. Types of musculoskeletal symptom findings reported in "other" studies – cont.

Musculoskeletal symptom findings	Reference
Quantitative data from quantitative studies – cont.	
what strategies they could use to prevent injuries	73
sources of education for MSS prevention	150
perceived prevention strategies	183
perceived risk or aggravating factors	102, 150, 183
felt that the practice venue was not appropriate at the time problems began	85
felt they had to overblow in rehearsals at the time problems began	85
perceived effectiveness or satisfaction with management strategies used	30, 94, 102, 105, 121, 124, 128, 129, 183
Qualitative studies[b]	
lived experience of symptoms	32, 51, 57, 103
lived experience of working with symptoms	52
experience with rehabilitation	63
impact of symptoms on individuals	57, 63
impact of symptoms on the Irish music community	57
how musicians cope with pain	103
role of the concealment of symptoms	63
culture of pain, compared with elite sportspeople	103
relationship between symptoms and identity	56
relationship between occupation and symptoms	51
why music students pursue a career in music despite the risks	152
social support and collegial attitudes	63
perceptions of the injury risk related to psychosocial, organizational and workplace environmental patterns	61
influence of behavioral norms and attitudes, and organizational culture towards injury	62
injury attitudes and behaviors[c]	151
attitudes and perceptions regarding symptoms	57
Clinical case studies	
whether the MSS were deemed by a physiotherapist to have been preventable	68
injuries affecting playing	68
injuries occurred during or immediately after playing where playing was considered the main contributor	68
treatment success (as determined by the clinician)	101, 167
referral to other professionals	169
duration of time to return to playing post-surgery	114
duration of time to return to work post-surgery	114
whether they could return to full playing post-surgery	114
percentage of those with MSS with impaired lumbopelvic stabilization systems and scapular stabilization system, and upper crossed syndrome	166
perceived risk or aggravating factors	101, 113

Table 7. Types of musculoskeletal symptom findings reported in "other" studies – cont.

Musculoskeletal symptom findings	Reference
Clinical case studies – cont.	
descriptions of the symptoms or diagnosis	68, 101, 113, 167–169
types of management strategies used	101, 166, 169
perceived effectiveness or satisfaction with management strategies used	166
Qualitative data from primarily quantitative studies	
perceived risk or aggravating factors	104, 137, 184
descriptions of the symptoms or diagnosis	39, 184
types of management strategies used	39, 158
how they responded to symptoms	92
perceived causes of symptoms	125
descriptions of symptoms	125

[a] Compared with medical students.
[b] These reflect the aims of these studies rather than each specific outcome.
[c] Within the context of a broader study looking at how tertiary music education programs equip students for careers in music.

whether they considered playing-related pain to be a normal part of playing, and which health professionals, if any, would encourage their child to see if they were experiencing pain. Both Wood [102], and McKechnie and Jacobs [177] surveyed piano teachers, looking at the teachers' perceived knowledge of diagnosis and treatment [102], their willingness to gain knowledge about performance-related MSDs [102], whether they regularly taught students with pain or discomfort experienced when playing [177], whether they taught playing techniques in the same way irrespective of whether the student complained about pain [177], and how they taught students with injuries [177].

Storms et al. [85] asked participants for any comments within their study of military brass musicians with "embouchure problems" (the embouchure refers to the positioning of the oral structures when playing a woodwind or brass instrument), with comments broadly categorized as pressure to perform, quality of performance, impact on the sense of confidence, stresses of military life leading to problems, support from superiors, meaning of embouchure-related symptoms, dystonia treatment, frustrations with medical care, and success of medical care.

DISCUSSION

This systematic mapping review is the first of its kind to explore the musicians' MSS literature. Over a 10-year period (2007–2016), 158 articles reported 138 unique studies of musicians' MSS. Despite this large number of studies, the authors identified a number of gaps in the current evidence base, in terms of populations, risk factors, interventions, outcomes and the broader impact of musicians' MSS.

Geographical bias

There appeared to be a geographical bias in the numbers of primary studies published per continent, with more than a half being from Europe (38%) or North America (29%). Overall, the majority of primary studies (85%) were from high-income countries, mirroring the broader literature around the extent of MSS [187].

This geographical bias is important to consider, because there may be some differences in training, culture, working exposures, work health and safety policy, and access to health and medical consultation between countries, which may lead to differences in the prevalence, characteristics

and impact of MSS on musicians. Even when considering culturally similar regions, such as Australia, Europe and North America, there are differences that should be explored. For instance, in Australia few universities teach their students about musculoskeletal health [188] whereas in the United States this is compulsory [189]. Similarly, there are a number of performing arts, or even music-specific health clinics throughout North America and Europe [190], allowing musicians to obtain advice and treatment from a health professional with ample experience and knowledge of the unique needs of musicians. In contrast, in Australia this kind of access is limited [188]. While there have been both systematic reviews [17–19] and primary quantitative studies [38,39,102,155,183] of the extent of MSS, which have included musicians from numerous countries, there have been no international comparisons made. The geographical differences in the prevalence, impact and management of MSS in musicians should be explored in future research.

Populations investigated

The majority (71%) of primary studies investigated professional musicians and university music students, while adult amateur and child musicians remain under-investigated. Even within the professional musician and university music student populations there are a number of evidence gaps. The majority of studies of professional musicians have focused solely on orchestral musicians despite the fact that orchestral musicians are likely to represent a minority of all professional musicians. For instance, in Australia 6033 people indicated their primary employment was as an instrumental musician in the Census [191], yet Ackermann et al. [66] reported that there were 580 musicians employed in a professional orchestra; hence, orchestral musicians are estimated to account for approximately 10% of all professional musicians. The authors identified few studies of teachers [69,82,93,102], military band musicians [84,85,89,90], or professional singers [75,104], and no studies reporting freelance or self-employed musicians specifically. These are important groups to consider as they have different biomechanical and psychosocial exposures compared to orchestral musicians. The impact of MSS on these musicians may also differ. A self-employed musician, given his or her lack of job security and access to worker's compensation, may lack the financial means to access MSS treatment, and/or to have time off to allow recovery from MSS. Future research of musicians' MSS should consider investigating these under-investigated groups, and make comparisons between different types of musicians, so that various groups could be appropriately targeted, and interventions developed that are specific to the risk factors faced by particular groups of musicians.

Extent/severity studies

Regarding the extent/severity studies, the authors identified 5 studies that focused on the episodic incidence of MSS [68,89,90,117,174], with none investigating true incidence. Investigating the true incidence (i.e., the first ever episode) of MSS presents a number of challenges, given the episodic and recurrent nature of pain, and issues with lifetime recall [192]. Even when incidence is investigated over a 1-year period, the high lifetime prevalence of MSS, even in children (67% reporting symptoms while playing) [41], means that the "at risk" population is diminished. Strategies to overcome this problem may include focusing on specific body regions, e.g., the first ever MSS in the neck region, or considering new or recurrent episodes, as has been reported here [68,89,90,117,174], and deemed acceptable in other reviews of pain [192].

Despite the large number of prevalence studies identified, few statistically compared the MSS prevalence of musicians with other populations [28,53–55,70,75,116,123,161,171]. Such comparisons are required to contextualize the findings of prevalence studies. The selection of comparison groups, and the potential biases of their usage, also need to be considered. As an example, 2 of the included stud-

ies compared university students with medical or health students [53–55,123]. These "reference" students may not be typical of university students as they have an interest in health and are likely to have a greater knowledge of MSS and the best ways to prevent and manage these symptoms, as compared to the general population of university students. More comparative studies are required to further support the claims of musicians being a "high-risk" population; however, the choice of the comparison group should be carefully considered.

Associated factors and mechanisms

A total of 74 studies looked at the factors associated with MSS outcomes in musicians, being mainly focused on professional orchestral musicians and university music students (69%). There were a wide range of factors investigated, including non-modifiable factors such as age and gender, instrument type, psychosocial factors, and modifiable (playing-related) factors such as duration of practice or number of breaks. The majority of outcomes reported were symptoms in general (86%), with only 41% of studies investigating the factors associated with the consequences of MSS. A number of important risk factors for MSS have not yet been investigated specifically in musicians, or have been insufficiently examined, such as effort-reward imbalance, job satisfaction, and illness perceptions. Future studies should aim to position themselves within the wider context of MSS, investigating the modifiable risk factors that have been identified in other populations.

Intervention studies

Relatively few intervention studies were identified, of which 81% were public health interventions, with a particular focus on exercise and education programs. There remain opportunities for investigating a wider range of interventions – ideally based on the risk factors determined with this population. While the expectations of musicians regarding clinical management have been explored [193], the types of public health interventions that musicians would like to see implemented, their facilitators and barriers, as well as expectations, have not yet been investigated. Similarly, little is known about the breadth of the public health interventions that are currently in place, particularly within the organizations that train and employ musicians.

It should also be noted that this review did not investigate the quality of the identified studies. Therefore, it cannot be presumed that the areas in which there have been a large number of studies undertaken (such as the prevalence of MSS among professional orchestral musicians) have been adequately investigated. If the quality of this evidence is found to be poor, further studies will be required to guide policy and practice.

CONCLUSIONS

While there is a reasonably large body of evidence published in 2007–2016 about musicians' MSS, there are a number of gaps in the evidence, highlighting potential areas for future research. The authors have found that non-orchestral professional musicians, non-classical university students, amateur musicians, and children are under-investigated groups of musicians, regarding MSS. Few studies compared the prevalence of MSS outcomes between musicians and non-musicians, so future research in this area would help to substantiate the claims that musicians are at high risk of MSS.

There are opportunities for research with these under-investigated groups, as well as others, to investigate a broader range of risk factors, particularly the potentially modifiable factors such as equipment, psychosocial and organizational factors. The majority of studies about risk factors have used cross-sectional designs; hence, there needs to be a shift towards longitudinal design to improve the current understanding of the risk factors for MSS outcomes in musicians. Doing so would aid in the development of interventions to prevent and manage MSS, which

may optimize education and exercise programs, as well as identify opportunities for a broader range of public health interventions. There is currently no evidence regarding what musicians desire and would find acceptable in terms of public health interventions, as well as facilitators and barriers.

The current evidence suggests that the issue of musicians' MSS has not been adequately addressed. Filling the identified gaps could facilitate work towards reducing the burden of musicians' MSS.

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