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Systematic review: risk factors for musculoskeletal disorders in musicians

V. A. E. Baadjou[1,2], N. A. Roussel[3,4], J. A. M. C. F. Verbunt[1,2], R. J. E. M. Smeets[1,2] and R. A. de Bie[5]

[1]Department of Rehabilitation Medicine, CAPHRI, Maastricht University, 6200 MD Maastricht, The Netherlands, [2]Adelante Centre of Expertise in Rehabilitation and Audiology, 6432 CC Hoensbroek, The Netherlands, [3]Department of Rehabilitation Sciences and Physiotherapy (REVAKI), Faculty of Medicine and Health Sciences, University of Antwerp, 2610 Antwerp, Belgium, [4]Pain in Motion International Research Group, Department of Human Physiology, Faculty of Physical Education and Physiotherapy, Vrije Universiteit Brussel, 1050 Brussels, Belgium, [5]Department of Epidemiology, Musculoskeletal Group, CAPHRI, Maastricht University, 6200 MD Maastricht, The Netherlands.

Correspondence to: V. A. E. Baadjou, Department of Rehabilitation Medicine, Maastricht University, FHML, Universiteitssingel 40, PO Box 616, 6200 MD Maastricht, The Netherlands. Tel: 0031 43 3882160; e-mail: vera.baadjou@maastrichtuniversity.nl

Background Although many musicians suffer from musculoskeletal disorders, aetiological factors are unclear.

Aims To systematically search for and synthesize the best available evidence on risk factors for musculoskeletal disorders in musicians.

Methods A database search was performed in PubMed, EMBASE, CINAHL, Pedro, OTseeker and Psychinfo. A manual search was conducted in the journals *Medical Problems of Performing Artists* and *Psychology of Music*. Studies with an objective to investigate determinants associated with playing-related musculoskeletal disorders were included. Papers were selected based on adequacy of statistical methods for the purpose of the study. Search, first screening and selection were performed by one author. Two reviewers independently performed the final selection using full-text reports. Methodological quality assessment was performed by two reviewers independently.

Results One case–control and 14 cross-sectional studies were included. Methodological quality was in general low. Large heterogeneity existed in study design, population, measurement of determinant and outcome and analysis techniques. Data were presented descriptively. Consistent results were found indicating that previous musculoskeletal injury, music performance anxiety, high levels of stress and being a female playing a stringed instrument seemed to be associated with more musculoskeletal disorders. Influence over or support at work, orchestra category/status, exercise behaviour and cigarette smoking seemed to be unrelated with musculoskeletal disorders. No conclusions could be made on causality, as the current data only represent cross-sectional associations.

Conclusions Because of lack of prospective studies, no causal relations could be identified in the aetiology of (playing-related) musculoskeletal disorders in instrumental musicians.

Key words: Musculoskeletal disease; music; occupational disease; pain; risk factors; WRULD

Introduction

Musicians are at risk for musculoskeletal symptoms, frequently referred to as playing-related musculoskeletal disorders (PRMD). PRMD are defined as 'pain, weakness, numbness, tingling or other symptoms that interfere with the ability to play the instrument at the level you are accustomed to' [1]. A recent systematic review in musicians concluded that lifetime prevalence of pain affecting the playing capacity was as high as 85% [2]. Factors such as job insecurity, denial, injury stigmatization and fear of judgment mean that musicians often play regardless of the existence of injury to the point of chronic disability [3].

Insight into the aetiology of PRMD is necessary to be able to implement preventative measures. Until now, mainly single, physical and biomechanical, factors have been studied [3]. Two previous reviews judged that no conclusions on causality could be made since studies are of retrospective design, lack an operational definition of PRMD, do not use valid and reliable measurement tools or use inappropriate statistical tests [4,5]. In addition, possible effects of differences in biomechanical playing load between instruments were often ignored [4]. A model with multiple risk factors combining physical, biomechanical and psychosocial risk factors seems more likely to predict the occurrence of PRMD [3]. The optimal way to search for risk factors is to conduct a prospective study, with an *a priori*-defined (multivariate) risk model based on current literature [6]. The study sample should adequately represent the population, and data should adequately represent the study sample. Furthermore, it is important to provide clear definitions and valid measurements of risk factor, outcome and possible confounders. The statistical model should be adequate for the design of the study [6].

The objective of the current study was to review prospective cohort, case–control or cross-sectional studies examining risk factors for musculoskeletal pain or disability of spine and/or extremities as measured by a questionnaire in a population of pre-professional (full-time music students) and professional instrumentalists. Since the publication of the two previous reviews, new quality assessment instruments have become available to assess the risk of bias in studies of prognostic factors allowing us to better interpret results [4–6].

Methods

The study protocol was registered: PROSPERO 2013:CRD42013006929. The preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement and checklist were used for reporting [7]. Ethical approval was not required for this review. A search for peer-reviewed articles was performed in the following databases: PubMed (1971–April 2015), EMBASE (1974–April 2015), CINAHL (1982–April 2015), Pedro (1929–April 2015), OTseeker (2002–April 2015), Psychinfo (2001–April 2015). A manual search was performed in the journals *Medical Problems of Performing Artists* (1986–April 2015) and *Psychology of Music* (1973–April 2015). Reference lists from included papers were screened for unidentified papers. A comprehensive search string was formulated for PubMed consisting of three parts: 1. 'Musculoskeletal Diseases' [Mesh] with relevant related terms; AND 2. 'Music' with relevant related terms; AND 3. 'Risk factor' with relevant related terms (Appendix 1, available as Supplementary data at *Occupational Medicine* Online). For CINAHL, EMBASE, Psychinfo, Pedro and OTseeker, only parts 1 and 2 of the search string ('music' AND 'musculoskeletal' with relevant synonyms) were explored.

Eligibility criteria were presented according to the PICOS (*p*articipant, *i*ntervention, *c*ontrol, *o*utcome, *s*tudy design) model in Table 1. Two additional categories

Table 1. PICOS model of eligibility criteria

	Inclusion	Exclusion
Population	Pre-professional (full-time music students) and professional instrumentalists All instruments	Amateur musicians High school students College (not full-time music) students Marching band musicians Vocalists
Intervention	Objective to investigate determinants associated with (playing-related) musculoskeletal disorders	Studies with aim only to investigate prevalence of complaints
Control (only applicable in case–control design)	Instrumentalists without musculoskeletal complaints	
Outcome	Musculoskeletal pain/disability (playing-related) of spine and/or extremities as measured by questionnaire	Neurologic disease Temporomandibular disorders Headache Trauma Physical parameters
Study design	Cohort Case–control Cross-sectional	Case studies Qualitative research Review Randomized controlled trial
Language	All	
Statistics	Use adequate statistical method to determine risk factors (i.e. regression analysis) Present adequate measure of association (i.e. standardized beta/r^2, OR/RR with 95% CI or present sufficient data to calculate OR/RR)	Only descriptive statistics When comparing prevalence of complaints between groups only using simple *t*-tests or correlations

were added: language and statistics. Only peer-reviewed papers were considered for inclusion. Conference proceedings and dissertations were excluded.

Study titles were first screened on relevance by the first author (V.A.E.B.), thereafter a second selection was made on title and abstract using eligibility criteria (V.A.E.B.). Third and last selection was performed independently by two authors (V.A.E.B. and N.A.R.) using full text, applying eligibility criteria, with a strong focus on outcome measurements used and quality of statistical analyses. In case of discrepancy, consensus was reached by discussion (V.A.E.B. and N.A.R.) and consultation of a third reviewer (R.A.B.). Corresponding authors were contacted when the paper lacked information to perform adequate selection or quality assessment. Given that a standard tool to assess quality of retrospective observational studies is lacking, we constructed a specific quality assessment tool for this review. The tool was based on information provided in a review on tools for assessing quality and susceptibility to bias in observational studies, the quality in prognostic studies (QUIPS) tool' the strengthening the reporting of observational studies in epidemiology (STROBE) statement and a previously used quality assessment checklist in observational research [6,8–10]. Key domains were study objective and design, study population, measurement instruments, data reporting and analysis. In total, 14 criteria were included. For case–control studies, one extra item was taken into account (rationale for cases and controls). Criteria and scores are presented in Table 2. A positive score (1) indicated that the item was well described and well performed. A negative score (0) indicated that the item was not reported, not well performed or unclear. Quality assessment was performed by two reviewers independently (V.A.E.B. and N.A.R.). Interrater agreement was calculated with a four-field Cohen's kappa.

One reviewer (V.A.E.B.) extracted study methods and outcomes. Extracted items were participant characteristics, instrument, demographics, study design, outcome definition, (adjusted) analysis, univariate and multivariate

Table 2. Results of methodological quality assessment

First author, publication year	Ackermann, 2003 [20]	Davies, 2002 [21]	Fotiadis, 2013 [22]	Kaufman-Cohen, 2011 [23]	Kenny, 2015 [15]	Leaver, 2011 [24]	Liljeholm J0hansson, 2003 [25]	Mehrparvar, 2012 [12]	Miller, 2002 [26]	Nyman, 2007 [27]	Paarup, 2011 [28]	Roach, 1994 [16]	Steinmetz, 2015 [17]	Yoshimura, 2006 [29]	Zaza, 1997 [30][a]	Total quality score per item
Study objective and design																
1. Clearly stated objective	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	14
Study population																
2. Description of eligibility criteria	0	0	0	0	1	1	0	0	0	0	1	0	0	0	1	4
3. Description of selection of study population	0	1	0	1	1	1	1	0	0	1	1	1	0	0	1	9
4. Description of population characteristics	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	14
5. If case–control study: provide rationale for cases and controls	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1
6. Participation rate > 80%	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Measurement instruments																
7. Appropriate outcome definition and assessment	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	4
8. Appropriate definition and assessment of determinants	1	0	0	1	1	1	0	0	1	0	0	0	0	1	1	7
Data reporting																
9. Frequencies of most important outcome measures	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	3
10. Frequencies of most important determinants	1	1	0	1	1	0	0	0	0	0	1	1	1	1	1	9
11. Measures of association presented	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
Analysis																
12. Appropriate statistical model	0	1	0	0	1	1	1	0	0	1	0	0	1	1	1	8
13. Controlled for confounding or effect modification	0	1	0	1	1	1	1	0	0	1	1	0	1	0	1	9
Other																
14. No conflicts of interest, identification of funding sources	0	0	0	1	0	1	0	0	0	0	1	0	1	0	0	4
15. Other sources of bias, not mentioned before	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	3
Total quality score per study	5	7	3	8	11	11	5	4	4	6	9	5	8	7	12	

1, positive score, item is well described and/or well performed; 0, negative score, item is not reported, not well performed or unclear; –, not applicable.
[a]Case–control study.

results. Determinants were categorized in socio-demographic, health-related, physical, psychosocial, work-related and prevention. If data were sufficient, results were categorized according to instrument group and pain localization. The principle summary measure was the odds ratio (OR) with its corresponding 95% confidence interval (CI). When OR was unavailable, standardized beta values (*b*) with corresponding *P* value and/or r^2 were presented. Data extraction was discussed with three other reviewers (N.A.R., R.A.B. and R.J.E.M.S.) in separate sessions.

If results could be compared methodologically and clinically, pooling was considered. If the quality of data were sufficient, a subgroup analysis was performed on instrument type. When pooling was not possible, a qualitative analysis would be executed. Quality of the studies was rated according to the Royal College of General Practitioners (RCGP) three-star system grading of evidence [11]. A three-star (***) rating was given in case of a generally consistent finding in a majority of multiple acceptable studies. A two-star (**) rating was either based on a single acceptable study or a weak or inconsistent finding in some of multiple acceptable studies. One star (*) was given when limited scientific evidence does not meet all the criteria of acceptable studies. Acceptable studies were defined as cohort or case–control studies. Retrospective observational studies were found inadequate to research risk factors.

Results were defined as consistent if at least two papers reported the determinant to be associated or not to be associated with the outcome. Univariate and multivariate results were described separately.

Results

The electronic search yielded 2141 citations. After first screening and removal of duplicates, 131 papers remained. Hand search yielded 38 additional papers. After a second selection on title and abstract using eligibility criteria, 61 papers remained. Most articles were excluded because of intervention (for example studies with the aim only to investigate prevalence of complaints), study design or outcome measures. Three authors were contacted to provide more information on population [12–14]. In a third selection round using full-text reports, another 46 papers were excluded. Adequacy of statistical analysis was the main reason for exclusion in this round. Six authors were contacted to provide additional information concerning statistical analysis [12,15–19]; for example, when insufficient data were provided in the text to assess whether appropriate statistical analysis was performed or when not enough data were provided to calculate OR/risk ratio (RR). Finally, 15 papers were included [12,15–17,20–30] (Figure 1).

The results of methodological quality assessment are presented in Table 2. Proportion of agreement over and above chance (Cohen's kappa) between the two quality assessors was based on 211 items for the 15 papers, and was 0.773, $P < 0.001$, indicating substantial agreement [31]. Fourteen of the included papers used a cross-sectional design [12,15–17,20–29] and one paper used a case–control design [30], in which a maximum quality score of 14 and 15 points could be obtained, respectively. In general, methodological quality was low. Median score per paper for the cross-sectional studies was 6.5 (minimum 3, maximum 11). The case–control study scored 12 out of 15 points. Median total quality score per item was 7.5 (range 1–15). Quality of statistical analyses was moderate (8/15 papers appropriately described the statistical model used, 9/15 papers appropriately controlled for confounding or effect modification). Items with a score below the median were (from lowest to highest) participation rate, other sources of bias, description of eligibility criteria, reporting of frequencies of most important outcome measures, appropriate outcome definition and assessment, presentation of conflicts of interest or identification of funding sources. Due to heterogeneity between studies, pooling of results was not possible. The case–control study received a RCGP ** rating [30]. The 14 cross-sectional studies were not considered to be acceptable studies to research risk factors and were scored RCGP * [12,15–17,20–29]. Quality of data was not sufficient to perform subgroup analysis on instrument type. A qualitative analysis was executed presenting results from cross-sectional and case–control research separately.

Participant characteristics are presented in Table 3. Number of participants varied between 32 [20] to 408 [17], with a response rate between 45% [21] and 99.7% [16]. Most studies included classical professional orchestra players [12,15,17,21–25,27,28]. One paper also included non-classical and freelance musicians [21]. Five papers included music students or a combination of professionals and students [16,20,26,29,30]. Mean age varied between 23 [16] and 48 years [28]. One paper only included players of viola or violin [20], one paper only pianists [29].

Study design and significant results of final models are presented in Table S1 (available as Supplementary data at *Occupational Medicine* Online). Appendices 2 and 3 (available as Supplementary data at *Occupational Medicine* Online) present all determinants with univariate and multivariate results by category. Two papers used the same data set and reported on psychosocial [25] and postural determinants [27], separately. Two papers only presented univariate results [12,22], four only multivariate results [20,26–28], nine reported both univariate and multivariate results [15–17,21,23–25,29,30]. From one study, only univariate results have been analysed in this review since interaction terms in multivariate analysis were unclear [16]. Outcome was described as pain, musculoskeletal complaints, PRMD, number of symptomatic upper limbs, pain severity, frequency of complaints, disability or functional limitations. Studies reported on complaints overall or specific complaints per body region. Outcome was assessed at different moments in time (current pain, last

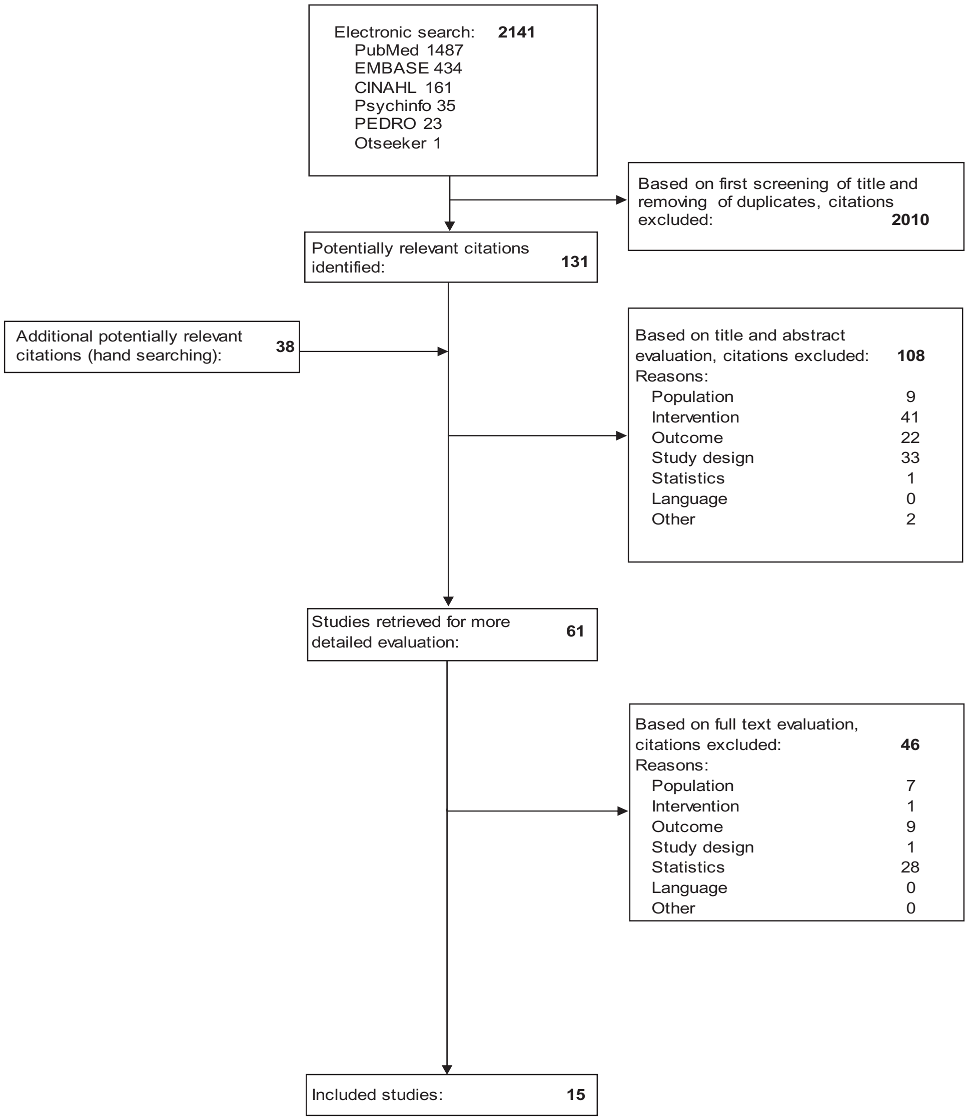

Figure 1. Flow chart of search and selection.

7 days, last 4 weeks, last 12 months, ever). Outcome was often measured using self-developed non-validated questionnaires. Adaptations from the Nordic Musculoskeletal Questionnaire and questions adapted from the PRMD definition by Zaza were also used as outcome measures [1]. In total, 84 distinct determinants for musculoskeletal disorders in musicians were analysed.

Overview of consistent results by category

Socio-demographic factors

Effect of gender as a determinant for musculoskeletal disorders has been frequently examined [12,16,17,21,23–28,30]. In multivariate analysis in the case–control study, it was found that women were more likely to experience a first episode of PRMD compared with men (OR 2.84, 95% CI 1.08–7.46) [30]. Also, the results of three multivariate and four univariate analyses in cross-sectional papers showed that females were more likely to experience musculoskeletal disorders [16,17,21,23–25,28]. However, results of papers reporting both univariate and multivariate analysis showed that the positive univariate association between gender and musculoskeletal disorders often disappeared when applied in a multivariate model [17,24,25]. Moreover, it has been shown that there is an interaction between female gender and violin playing, meaning that women have a higher probability of experiencing symptoms while playing the violin [21]. Age was not found to be associated with first-episode PRMD in the case–control study [30]. Univariate results suggest that a higher age was related to more PRMD [17,24]. However, when applied in multivariate analyses, no effect of age was found [17,24,26–28].

Health-related factors

Past PRMD was found to be positively associated with recurrent PRMD in multivariate analysis in the

Table 3. Participant characteristics

First author, publication year	Participants	Instrument	Demographics
Ackermann, 2003 [20]	*n* = 32 9 M/23 F RR unknown	Violin: 94% Viola: 6%	Professionals and students Mean age 27 years; range 19–60 Mean experience 20 years Mean daily practice 3.5 h; range 1–6
Davies, 2002 [21]	*n* = 240 135 M/105 F RR 45%	String: 42% Woodwind: 18% Brass: 16% Percussion: 7% Keyboard: 12% Guitar: 5%	Professionals Mean age 36.7 years; SD 11.0 Mean playing experience 29 years; SD 10.9 Mean total playing per week 29.1 h; SD 10.1
Fotiadis, 2013 [22]	*n* = 147 97 M/50 F RR 60%	String: 63% Woodwind: 17% Brass: 14% Percussion: 5% Harp: 1% Piano: 1%	Professionals Mean age 39.97 years Mean orchestra experience 14.2 years
Kaufman-Cohen, 2011 [23]	*n* = 61 30 M/31 F RR 66%	String: 66% Woodwind: 34%	Professionals Mean age 42.9 years; SD 11.43 Mean total playing per day 4.9 h; SD 2.5
Kenny, 2015 [15]	*n* = 377 185 M/192 F RR 70%	Not presented	Professionals Mean age 42.1 years; SD 10.3
Leaver, 2011 [24]	*n* = 243 136 M/107 F RR 51%	String: 62% Woodwind: 15% Brass: 16% Other: 7%	Professionals Median age 44 years; IQR 37–53 58% > 20 years professional experience Mean total playing per week 30 h
Liljeholm Johansson, 2003 [25]	*n* = 250 155 M/93 F RR 78%	String: 58% Woodwind: 18% Brass: 19% Other: 4%	Professionals Mean age 39 years
Mehrparvar, 2012 [12]	*n* = 356 296 M/60 F RR 79%	Plucked strings: 52% Bowed strings: 6% Wind: 5% Percussion: 19% Keyboard: 8% Santur: 11%	Professionals Mean age 34.58 years; SD 10.26 Mean employment duration 16.59 years; SD 9.19 Mean playing time per day 4.22 h; SD 2.43
Miller, 2002 [26]	*n* = 92 35 M/57 F RR 77%	String: 59% Keyboard: 41%	Students Mean age 21 years Duration of studying music 14 years
Nyman, 2007 [27]	*n* = 235 143 M/92 F RR 73%	String: 61% Woodwind: 19% Brass: 20%	Professionals Mean age 38 years[a] Mean employment duration 11 years[a]
Paarup, 2011 [28]	*n* = 342 109 M/133 F RR 78%	High string: 44% Low strings: 17% Woodwind: 18% Brass: 16% Other: 6%	Professionals Median age M 48 years, F 39 years Median total playing per week M 31 h, F 32 h
Roach, 1994 [16]	*n* = 90 49 M/41 F RR 99.7%	Not presented	Students Mean age 23 years Mean total playing per week 22.5 h
Steinmetz, 2015 [17]	*n* = 408 236 M/172 F RR 57%	String: 56% Woodwind: 15% Brass: 14% Percussion: 3% Miscellaneous: 3% Unknown: 10%	Professionals Mean age 43.9 years; SD 10.3 Mean total playing per day 4.1 h; SD 2.1

Table 3. *Continued*

First author, publication year	Participants	Instrument	Demographics
Yoshimura, 2006 [29]	n = 35 8 M/27 F RR unknown	Piano: 100%	Students Mean age 27 years Mean total practice per week 25 h; SD 8.5
Zaza, 1997 [30]	n = 281 110 cases, 171 controls 126 M/155 F RR 66.7%	Strings: 33% Others not specified	Professionals and students Cases/controls Mean number of years played 21.4/22.5 years

F, female; IQR, interquartile range; M, male; *n*, number; RR, response rate; SD, standard deviation.
[a]Mean calculated by reviewers using data from paper.

case–control study (OR 2.52, 95% CI 1.03–6.15) and in two cross-sectional studies (b = −0.24 and OR 9.31, 95% CI 1.02–85) [22,26,30]. No association was found between sports activities or exercise behaviour and musculoskeletal disorders [20,21,23]. Although cigarette smoking was found to be correlated with musculoskeletal disorders in univariate analysis, papers performing multivariate analysis showed no such effect [23,24].

Physical factors

Several physical or anthropometric factors (e.g. hand span, tendon anomalies, hypermobility) have been considered, but no consistent results were found [10,18,23,24].

Psychosocial factors

A positive association between performance anxiety and musculoskeletal disorders was found in the multivariate analysis of two cross-sectional studies [15,17]. In the case–control study, an association between performance anxiety and recurrent PRMD (OR 1.09, 95% CI 1.00–1.18) was shown in the univariate analysis [30]. In multivariate analysis, no effect was found for first-episode or recurrent PRMD [30]. Trait anxiety was found not to be associated with complaints in multivariate analysis [15,30].

Work-related factors

A protective effect of number of years playing on first episode PRMD was found in the multivariate analysis in the case–control study (OR 0.95, 95% CI 0.91–0.99) [30]. Of the cross-sectional studies, one also found a small protective effect of playing years in multivariate results (b = −0.01) [21]. Another study found several univariate associations between duration of employment and pain in different body parts; however, in multivariate analysis, only the negative association between duration of employment and right shoulder pain remained (OR 0.90, 95% CI 0.84–0.97) [17]). Two papers found no association in univariate or multivariate analysis [25,28].

Eight papers studied the association between instrument and musculoskeletal disorders [12,17,21,24–26,28,30]. Results seem to indicate that (upper) string players are more likely to experience symptoms when compared with players of other instruments [17,24,25,28,30]. The case–control study reported a multivariate positive association for first episode (OR 4.69, 95% CI 1.52–14.52) and recurrent PRMD (OR 1.94, 95% CI 1.02–3.70) [30]. When adjusted for other factors as, for example, gender, the univariate positive association often decreased or disappeared [17,21]. One paper reported a positive association between average weekly orchestra hours with number of symptomatic upper limb joints in univariate (r = 0.30) and multivariate (b = 0.25) analyses [23]. Other papers only presented positive univariate association for the wrist/hand region (b = −0.21), or no positive association at all [21,22,26]. Different papers reported on biomechanical risk factors related to playing the musical instrument [23,24,27]. As they all studied different biomechanical risk factors, no consistent results could be identified.

Work-related psychosocial factors were studied in seven papers [21,23–25,27,28,30]. Work-related stress was shown to be positively associated with first episode and recurrent PRMD in univariate (not multivariate) results in the case–control study (OR 1.66, 95% CI 1.15–2.39 and OR 1.41, 95% CI 1.10–1.81, respectively) [30]. This association was also found in univariate (b = 0.44) and multivariate (b = 0.20) results in one cross-sectional study [21]. Consistent results showed that choice over work/influence, support at work and orchestra category/status were not related to musculoskeletal disorders [24,25,27].

Prevention

In the case–control study, a musical warm-up was found to be protective for a first episode PRMD in univariate and multivariate analysis (OR 0.37, 95% CI 0.15–0.91) but was not associated with recurrent PRMD [30]. Considering physical warm-up, univariate results for recurrent PRMD showed a negative relationship (OR 0.38, 95% CI 0.17–0.84), but no effect could be found in multivariate analysis [21,24,30]. Also, lack of warm-up/break provision was found to be positively associated with PRMD in univariate results ($b = 0.26$), not in multivariate results of one cross-sectional study [21]. However, one cross-sectional paper did find an association between warm-up and severity of symptoms, both in univariate ($r = -0.55$) and multivariate analysis ($b = 0.31$) [23].

Discussion

The principle finding of this review is that no conclusion can be drawn regarding risk factors for musculoskeletal disorders in (pre-) professional instrumental musicians because of the low methodological quality and large heterogeneity of the available studies. No studies using a prospective design were found, making it impossible to draw conclusions about causality. Terms such as prognostic factor or predictor are inappropriately used to indicate associations. Current available information only gives us an indication of possible relationships. Consistent results indicate that (upper) string players experience more musculoskeletal disorders than other instrumentalists. An interaction between being female and violin playing suggests that not gender, but rather type of instrument is the most important factor in the relationship between gender and PRMD. Performance anxiety and work-related stress seemed to be positively related with musculoskeletal disorders in musicians. Musicians who have experienced PRMD seemed to be at higher risk of developing recurrent PRMD. Consistent results indicating no association with PRMD were found for sports or exercise behaviour, cigarette smoking and work-related factors such as choice/influence over work, support at work or orchestra category. No consistent results were found considering the effect of physical/anthropometric features of the musician and biomechanical factors or playing load related to playing the instrument. Also, no conclusions can be made regarding the association of age, number of years playing or duration of employment with PRMD and the possible protective role of physical or musical warm-up.

A strength of this study is that a critical review of the quality of included studies was performed before interpreting results and differences between univariate and multivariate analyses were clarified. Several types of bias were considered: detection bias due to systematic differences in outcome definition and measurement period; selection bias because of systematic differences between instrument groups; and recall bias when asking musicians about complaints in the past. The healthy worker effect could have occurred since often only the musicians still working were questioned. Weakness of the current study is that our subject, including all instrumentalists, is broad. This might explain why no consistent results were found regarding the effect of physical/biomechanical features and playing load. A subgroup analysis was planned but was not possible due to heterogeneity of the included studies. Application of strict selection criteria especially regarding objective, outcome measurement and statistical analysis is both a strength and a weakness of this study. We aimed to set up a review encompassing high-quality articles. On the contrary, applying these strict eligibility criteria may also have resulted in exclusion of articles with an additive value to the topic of this review.

When initiating this review, it was assumed that additional studies would be available with better methodologic quality and a biopsychosocial (multivariate) risk factor model for the aetiology of PRMD. This review adds to the reviews already performed, by the application of PRISMA guidelines and a thorough quality assessment to assess risk of bias. It is striking that the conclusions are comparable. This review again highlights the lack of adequate research into risk factors for musculoskeletal complaints in musicians. Although additional studies were included, they were not of the high quality, which is to be expected when researching prognostic factors. At this moment, there is too little scientific information on which clinical prevention of PRMD can be based. Based on international guidelines, to be able to draw conclusions on causation between risk factors and PRMD, a prospective cohort study, with a large sample size and follow-up duration of minimally 1 year should be performed [6]. The study should include only one instrument group, so that biomechanical playing load is equal for every participant. Validated questionnaires should be used to measure outcome and determinants and there is a need for guidelines on how to measure outcome in musicians. Multivariate analysis is required to be able to control for confounders. The interaction between instrument and gender should be examined more thoroughly. As musculoskeletal disorders are believed to be multifactorial in origin, the combination of biological, psychological and social factors should always be taken into account in the multivariate model.

Currently, no clear evidence on risk factors for (playing-related) musculoskeletal disorders in instrumental musicians could be found mainly due to the lack of prospective studies and large heterogeneity between studies.

Key points

- Insight into risk factors for musculoskeletal disease in musicians is needed to be able to prevent playing-related musculoskeletal disorders.
- Current literature investigating risk factors for musculoskeletal disease in musicians is mostly of cross-sectional design, with a low methodologic quality and large heterogeneity between studies.
- Well-designed prospective research is needed to identify causal relations in the aetiology of (playing-related) musculoskeletal disorders in instrumental musicians.

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Conflicts of interest

None declared.

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