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Assessing posture while playing in musicians – A systematic review

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ABSTRACT

Introduction: Playing a musical instrument can potentially lead to musculoskeletal disorders. Postural loads are different considering the instrument they play; for example violin and flute require elevation from both upper limbs, asymmetrical postures are common and instrument weight can be significant. The aim was to explore how musicians' postures are investigated, and potentially if there is evidence of an association between postural impairments and pain.

Methods: A systematic search was performed in several databases, combined with manual search. Study inclusion, data extraction and quality assessment were performed independently by two reviewers.

Results: Twenty seven relevant studies were included in this review covering musicians with the full range of playing experience (professionals, students, teachers, amateurs). The main considered methods to investigate postures are visual assessment and three dimensional analysis using videography.

Discussion: This review provides a synthesis of the different methods used to monitor posture in musicians and provides information in order to build protocols which will allow comparison with previous work.

1. Introduction

Playing music at a professional level can often lead to musculoskeletal disorders. Playing-related musculoskeletal disorders (PRMDs) have been defined as "pain, weakness, numbness, tingling, or other symptoms that interfere with [their] ability to play [their] instrument at the level [they] are accustomed to" (Zaza et al., 1998). Systematic reviews have reported pain prevalence in musicians as ranging between 29 and 90% (depending on the recall period, playing-related pain or symptoms' definitions, choice of the investigated population, etc.) (Silva et al., 2015). These PRMDs are considered as multifactorial health issues and several risk factors are commonly reported such as number of playing hours, sex, repetitive movements, posture, mental health issues or sudden increase in playing load (Rousseau et al., 2021; Baadjou et al., 2016; Kok et al., 2016; Kenny and Ackermann, 2015).

In the current literature, posture and particularly postural impairments, are frequently considered as one of the main injury risk factors in musicians, as the practice of music instruments requires repetitive movements potentially in an awkward posture, often asymmetrical (violin, trumpet, bassoon, etc.), that could lead to important musculoskeletal strains (Blanco-Piñeiro et al., 2017; Chan and Ackermann, 2014; Ranelli et al., 2011; Watson, 2009). For example, maintaining both arms in elevation for a very long duration has been suggested to lead to neck and shoulder pain among upper string players and brass players (trumpet, trombone, etc.), compared to woodwind (oboe, clarinet, etc.) and lower string players (Nyman et al., 2007). By considering differences between musical instruments, Ramella et al. (2014) have pointed out how playing an asymmetrical instrument, associated with the impact of practice years, increases the risk of adopting "non-optimal" postures. Moreover, standing and different sitting postures have been investigated and compared by analysing different elements such as abdominal muscles recruitment or spirometry parameters in woodwind players (Ackermann et al., 2014; Price et al., 2014), while body movements were compared among violinists, depending on if they were orientated on the right or on the left of the music stand (Spahn et al., 2014). Baadjou et al. (2017) have investigated how sitting posture could influence muscle activity or sound quality in clarinettists. Their outcomes highlighted that decrease in muscle activity could be induced by increasing stability and considering sound quality, participants felt it was altering depending on their sitting posture, whilst music experts found no consistent relationships between posture and sound.

However, analysing musicians' posture is not an easy or

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straightforward task. Different methods have been used to evaluate and rate posture in musicians (Valenzuela-Gómez et al., 2020; Blanco-Piñeiro et al., 2015; Chan et al., 2013), such as describing postural alterations before and after an intervention on photographs (Chan et al., 2013) or analysing with the Rapid Entire Body Assessment (REBA) (Valenzuela-Gómez et al., 2020). In 2015, Blanco-Pineiro et al. have developed an instrument to systematically investigate posture in music students: the Postural Observation Instrument (POI).

According to musicians' health experts and past research, posture emerges as an important risk factor that should be considered in musicians' health assessment the treatment and prevention of PRMDs. Nonetheless, studies present heterogeneous methods that are difficult to compare and despite the fact that a recent non-systematic bibliographic review highlights the potential relevance of posture as influence on both performance and musculoskeletal health (Fernandez-Paz et al., 2020), the existence of a relationship between posture and pain remains controversial. As a major example, a systematic review of systematic reviews has highlighted the absence of clear evidence concerning the relationship between low back pain and physical causes in the general population (Swain et al., 2020). Moreover, it has also been shown that no consensus exists between physiotherapists about what could be the "best spinal posture" (O'Sullivan et al., 2012). Therefore, a comprehensive review of the literature was justified to examine how posture is related to PRMDs.

The main objective of this study is to determine how posture while playing has been investigated in instrumentalist musicians so far and the implications for practice. The secondary aim of this review is to examine the evidence in the literature for a relationship between posture and playing-related musculoskeletal disorders.

2. Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) statement (Moher et al., 2009). In order to minimise potential bias, the AMSTAR-2 tool (A Measurement Tool to Assess Systematic Reviews, 2nd Version) was used as a backdrop for this work (Shea et al., 2017). This review was prospectively registered on PROSPERO (CRD42021290730).

2.1. Search strategy

A search for relevant publications was performed electronically between September 2021 and October 2021 in the following databases: Cochrane Register of Clinical Trials, PubMed, Science Direct, PEDro, CINAHL and LILACS. Grey literature, including thesis and conference abstracts, was investigated using Open Grey and Kinedoc. A search of ongoing studies was also performed using Clinicaltrials.gov. Search keywords included the following combination of free text terms and Medical Subject Heading (MeSH) terms: "((*Posture*) OR (*postural*) AND (*musician OR instrumentalist)* AND (*measurement* OR *analysis* OR *assessment*))". In addition, reference lists of included studies were manually screened for further eligibility. Finally, a manual search of the journal *Medical Problems of Performing Artists* was also performed from year 2000.

2.2. Eligibility criteria

Table 1 summarises the inclusion criteria of the review using the PICOS acronym.

2.3. Study selection

After duplicate removal, the title and abstract of all studies were independently screened by two independent reviewers (LT and CR) applying the aforementioned eligibility criteria. All articles presenting non-inclusion criteria were eliminated. If the authors did not describe the PICOTS criteria in the abstract, the article was kept and analysed during the next stage. Subsequently, 27 full text articles of all records eligible for inclusion were independently reviewed by the two same reviewers. Any discrepancies between the two independent reviewers were resolved through discussion until consensus was reached.

Table 1
Review objectives, inclusion and exclusion criteria according to the PICOS components.

	Inclusion	Non-inclusion
Objective	<u>Main</u>: To determine how posture while playing has been investigated in instrumentalist musicians so far. <u>Secondary</u>: To determine if posture influences the development of playing-related musculoskeletal disorders (PRMDs) among instrumentalist musicians. *Research question: How posture while playing has been investigated in instrumentalist musicians?* *Secondary research question: Is there an association between playing posture and the development of PRMDs in instrumentalist musicians?*	
P	• Age $\geq$16 years old; • Male and female instrumentalists; • Professional musician, music student, music teacher, amateur musician, etc. N.B.: No restriction was applied regarding the type of instrument or repertoire nor the level of experience.	• Studies including mixed artistic populations (e.g.: dancers, painters); • Studies including singers.
I	• The study investigated MSD in relation to playing posture as a risk factor; • The study included biomechanical measurements and/or clinical examination measurements; • The study specified the type of instrument; • The study specified the playing duration required during the testing; • The study was written in English or French.	• Studies focusing only on the instrument parameters or position.
C	No restriction (presence of a control group is not required).	
O	• Studies whose primary outcome was the analysis of musicians' posture while playing N.B.: No restriction was applied concerning the tools (used to conduct the measurements nor the timeline of the measurements.	• Studies which focused on PRMDs that are not described as related to the musculoskeletal system (i.e. neurological disorders such as focal dystonia); • Post-operative follow-up measures.
S	• Observational studies: Cross-sectional, cohort (with a prospective or retrospective inclusion pattern), case control and case series • Interventional studies: Randomized Controlled Trials (RCTs) • Grey literature	• Studies relying solely on a self-reported questionnaire for analysing posture; • Reviews.

2.4. Data extraction

Data were extracted by two independent raters (LT and CR) using two previously developed tables. The first table considered studies' general characteristics:

- Title, authors' name, date of publication;
- Study design and setting;
- Sample description: size, gender, age, instrument played, music status;
- Method used to investigate posture;

The second one focused on studies' outcomes:

- Performed task by the participants;
- Type of variables;
- Marker's position (if suitable);
- Form of the results.

2.5. Quality assessment

Methodological quality of the selected studies was assessed by two independent reviewers (LT and CR), using both the Newcastle Ottawa Scale (NOS) (Wells et al., 2013) for both cross-sectional and cohort studies and the Quality Assessment Tool for Before-After (Pre-Post) Studies With No Control Group (National Heart Lung and Blood Institute et al., 2014) for uncontrolled trial of intervention.

2.6. Statistical analysis

The inter-rater agreement between the two reviewers for the quality assessment process using the aforementioned scales will be calculated using Cohen's kappa (κ) coefficient and percent agreement by using Excel® and SPSS® (version 25.0.0.1).

Following Landis and Koch's interpretation, the agreement is considered as:

- "almost perfect" if $\kappa > 0.81$,
- "substantial" if $0.61 < \kappa < 0.80$,
- "moderate" if $0.41 < \kappa < 0.60$,
- "fair" if $0.21 < \kappa < 0.40$,
- "poor" if $\kappa < 0.20$.

However, the interpretation of the kappa coefficient has important limitations. These paradoxes are mainly due to two phenomena: the influence of prevalence and bias (Cicchetti and Feinstein, 1990). This sometimes results in a discordance between the degree of agreement and the kappa value (e.g a high agreement with a low kappa value). Thus, these authors recommend reporting the proportion for both positive (P_{pos}) and negative (P_{neg}) agreements in addition to the overall kappa value as they allow a better understanding and contextualisation of the kappa coefficient.

3. Results

3.1. Study selection

The PRISMA flowchart (see Fig. 1) summarises the whole selection and inclusion process. For the first level of inclusion (from 1972 potential publications to 59 full-text articles), inter-rater agreement was 81,29%, discrepancies were resolved by discussion until consensus was reached. For the second one (from 59 to 18 full-text articles), inter-rater agreement for this second phase was 92,43%, discrepancies were resolved by discussion until consensus was reached. Reference checking of included studies and a manual search in Medical Problems of Performing Artists identified 9 additional papiers. Finally, 27 studies published between 1989 and 2020 were included in this review.

3.2. Studies' and samples' characteristics

Three types of studies were included in this systematic review: case studies ($n = 2$), cross-sectional studies ($n = 21$), uncontrolled trial of intervention ($n = 1$) and cohort studies ($n = 3$) (see Table 2).

Instruments played among the 27 included studies were various: 4

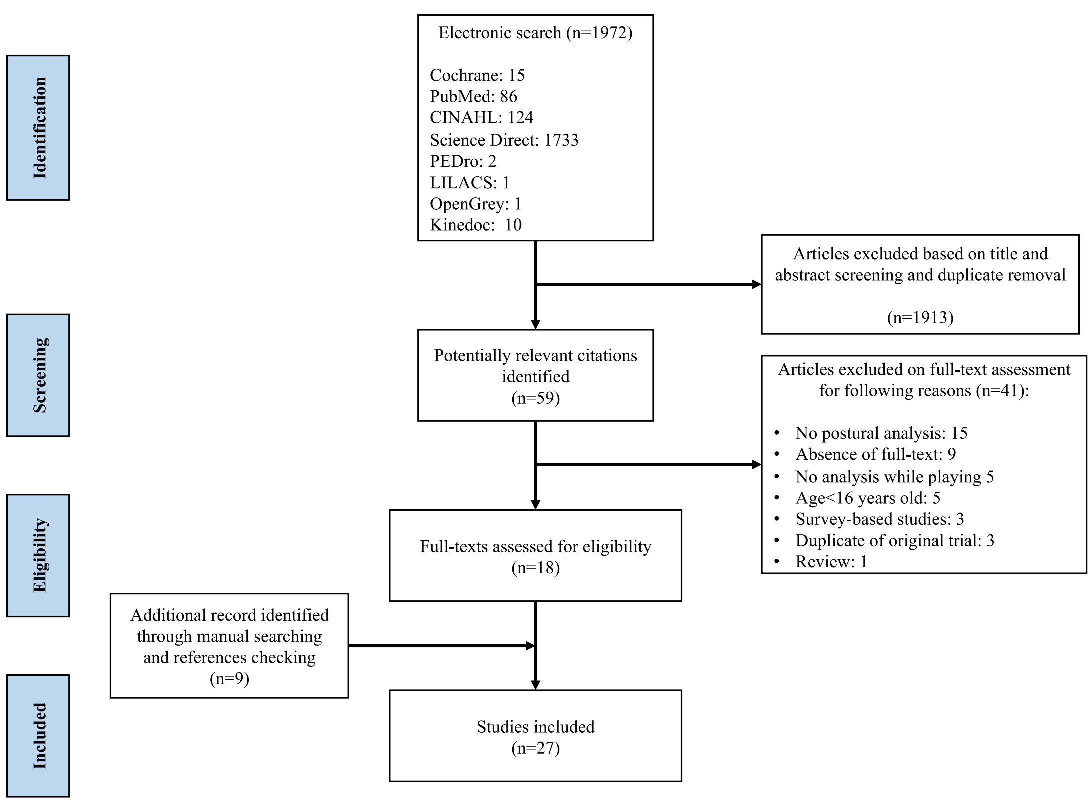

Fig. 1. Inclusion flow-chart.

Table 2
Details of included studies – Characteristics, samples and methods.

No.	Title	Authors	Year of publication	Study design	Study setting	Sample size	Instrument/status	Method used
1	Interobserver Reliability of General Practice Physiotherapists in Rating Aspects of the Movement Patterns of Skilled Violinists	Ackermann et al.	2004	Cross-sectional study (Reliability study)	Australia	N = 30 musicians + 12 PT %M/F = not stated Mean age = not stated	Violin Professional, undergraduate and postgraduate students	Questionnaire (visual assessment)
2	Three-dimensional motion capture applied to violin playing: A study on feasibility and characterization of the motor strategy	Ancillao et al.	2017	Case study	Italy	N = 1 Male Age = 30	Violin Professional	3D motion capture
3	Analysis of the Frequency of Postural Flaws During Violin Performance	Araujo et al.	2009	Cross-sectional study	Brazil	N = 4 Mean age = not stated (16–19)	Violin Students	Videography 2D motion analysis
4	Playing the Clarinet: Influence of Body Posture on Muscle Activity and Sound Quality	Baadjou et al.	2017	Cross-sectional study	Netherlands	N = 20 45% M/55% F Mean age = 29.2 (18–60)	Clarinet Professionals and students	Goniometric analysis 2D motion capture
5	Postural kinematics of trumpet playing	Bejjani & Halpern	1989	Cross-sectional study	United-States	N = 16 100% M/0% F Mean age = 40 (±14)	Trumpet Professionals	Photography 2D motion capture
6	Common postural defects among music students	Blanco-Piñeiro et al.	2015	Cross-sectional study	Spain	N = 100 Mean age = 23.9 (18–30) 60% M/40% F	Brass and woodwind, strings, piano, percussion, bagpipes Students	Videography and visual assessment of the videos
7	Comparison of chairs based on HDsEMG of back muscles, biomechanical and comfort indices, for violin and viola players: A short-term study	Cattarello et al.	2018	Cross-sectional study	Italy	N = 21 62% M/38% F Mean age = 25 (15–53)	Violin and viola Students and professors	Goniometric analysis
8	Can experienced observers detect postural changes in professional musicians after interventions?	Chan et al.	2013	Uncontrolled trial of intervention	Australia	N = 57 37% M/63% F Mean age (exercise group) = 43 (SD 10.1)//mean age (alexander group) = 44 (SD 11.8)	Violin, viola, cello, double bass, flute, clarinet, oboe, bassoon, timpani Professional	Photography and visual assessment of the photos
9	Three-dimensional analysis of the cranio-cervico-mandibular complex during piano performance	Clemente et al.	2014	Cross-sectional study	Portugal	N = 17 %M/%F not stated	Classical piano and jazz piano Students	Accelerometry 3D motion analysis
10	Postural Sway of Percussionists: A Preliminary Investigation	Coker et al.	2004	Cohort study	United-States	N = 14 86% M/14% F Mean age = 20.4	Percussion instruments Students	Stabilometry
11	Musculoskeletal Discomfort of Music Teachers: An Eight-year Perspective and Psychosocial Work Factors	Fjellman-Wiklund et al.	1998	Cohort study	Sweden	N = 6 5% H/50% F Mean age (F) = 37 (SD 5)/Mean age (M) = 45 (SD 11,3)	Violin Music teachers	Micro-switch sensors
12	Torso and Bowing Arm Three-Dimensional Joint Kinematics of Elite Cellists: Clinical and Pedagogical Implications for Practice.	Hopper et al.	2017	Cross-sectional study	Australia	N = 31 45% H/55% F Mean age = 20.3 (tertiary-level students), 31.7 (freelance professionals), 37.6 (orchestra professionals)	Cello Professional, tertiary-level students	Videography 3D motion analysis
13	Analysis and Fem Simulation Methodology of Dynamic Behavior of Human Rotator Cuff in Repetitive Routines: Musician Case Study	Islan et al.	2018	Case study	Spain	N = 1 Female, 24 years old	Violin Professional	RULA (Rapid Upper Limb Assessment) analysis + FEM (Fine Element Method) analysis
14	Voice Parameter Changes in Professional Musician-Singers Singing with and without an Instrument: The Effect of Body Posture	Longo et al.	2020	Cross-sectional study	Italy	N = 17 % M/F = not stated Mean age = 27.7 (±9.4)	Piano and guitar Professional musician-singers	Visual assessment
15	Comparison between the musician-specific seating position of high string bow	Ohlendorf et al.	2018	Cross-sectional study	Germany	N = 13 38% M/62% F	Violin/viola Professional	Video raster stereography 3D motion analysis

(continued on next page)

Table 2 (*continued*)

No.	Title	Authors	Year of publication	Study design	Study setting	Sample size	Instrument/status	Method used
	players and their habitual seating position – a video raster stereographic study of the dorsal upper body posture					Mean age = 43.6 ± 9.9	orchestra musicians	3DMA with VRS or VRS + 3DMA
16	Influence of ergonomic layout of musician chairs on posture and seat pressure in musicians of different playing levels	Ohlendorf et al.	2018	Cross-sectional study	Germany	N = 47 49% M/47% F Mean age = 32.4 ± 13.2	Clarinet, trumpet, saxophone, violin, guitar and concert flute. Professionals, amateurs and students	Video raster stereography + stabilometry
17	Comparison of Electromyographic Activity and Range of Neck Motion in Violin Students with and without Neck Pain During Playing	Park et al.	2018	Cross-sectional study	Korea	N = 18 100% females Mean age (pain group) = 17.88 ± 0.33/mean age (CG) = 17.11 ± 0.33	Violin Students	Ultrasound 3D motion analysis
18	Influence of Different Instrument Carrying Systems on the Kinematics of the Spine of Saxophonists	Piatek et al.	2018	Cross-sectional study	Germany	N = 14 50% M/50% F Mean age = 25.86 ± 4.52 (18–38)	Saxophone Amateur and students	Ultrasound 3D motion analysis
19	Tuning of the Violin–Performer Interface: An Experimental Study about the effects of Shoulder Rest Variations on Playing Kinematics	Rabuffetti et al.	2007	Cross-sectional study	Italy	N = 15 47% M/53% F Mean age = 40.9 ± 10.2 (23–59)	Violin Professionals and students	Optoelectronic motion capture
20	Hand Span and Digital Motion on the Keyboard: Concerns of Overuse Syndrome in Musicians	Sakai et al.	2006	Cross-sectional study	United-States	N = 10 40% M/6% F Mean age = 29 (24–39)	Piano Professionals, semi-professionnals and amateurs	Videography 3D motion analysis
21	A Quantitative Three-dimensional Analysis of Arm Kinematics in Violin Performance	Shan & Visentin	2003	Cross-sectional study	Canada	N = 11 Age and gender not stated	Violin (teachers, professional musicians and students)	Videography 3D motion analysis
22	Comparing violinists' body movements while standing, sitting, and in sitting orientations to the right or left of a music stand	Spahn et al.	2014	Cross-sectional study	Germany	N = 19 16% M/84% F Mean age = 23.6 ± 2.8	Violin Students and (semi)professional orchestra.	Posturography + videography
23	Analyzing working conditions for classical guitarists: design guidelines for new support and guitar positioning	Valenzuela-Gomez et al.	2020	Cross-sectional study	Mexico	N = 9 89% M/11% F Mean age = 19.6 (18–21)	Classical guitar Students	Visual assessment - Rapid Entire Body Assessment (REBA) + 3DMA using 3D Static Strength Prediction Program
24	Distinct digit kinematics by professional and amateur pianists	Winges et al.	2015	Cross-sectional study	United States	N = 10 40% M/60% F Mean age = 33 ± 10 (19–54)	Piano Professionals and amateurs	3D motion capture data device
25	Effect of the Alexander Technique on Muscle Activation, Movement Kinematics, and Performance Quality in Collegiate Violinists and Violists: A Pilot Feasibility Study	Wolf et al.	2017	Cohort study	United-States	N = 8 %M/F not stated Mean age = not stated (18–20)	Violin/viola University orchestra students	3D motion capture magnetic sensors
26	Marker-Based Method for Analyzing the Three-Dimensional Upper Body Kinematics of Violinists and Violists	Wolf et al.	2019	Cross-sectional study	Germany	N = 12 %17% M, 83% F Mean age = not stated (18–20)	Violin/viola Music college students and orchestra musicians	Videography 3D motion analysis
27	Evaluation of Three-Dimensional Motion Analysis of the Upper Right Limb Movements in the Bowing Arm of Violinists Through a Digital Photogrammetric Method	Yagisan et al.	2009	Cross-sectional study	Turkey	N = 9 100% males Mean age = 22.4 (±2.9)	Violin Students	Photogrammetry

Legend.
3D: three-dimensional.
2D: two-dimensional.
CG: control group.
F: females.

N: number of participants.
M: males.
MA: motion analysis.
VRS: verbal rating scale (for pain).

studies included multi-instrumental samples while 23 studies focused on specific instruments or group of instruments (such as upper string players counting violinists and violists). Fig. 2 summarises the repartition of the instruments played in the review, which has been detailed as well in Table 2.

From these 27 studies, 530 musicians were included. In terms of musical status, studies included different populations: professional musicians (in a large extent, orchestra musicians), music students and amateurs. Among the 27 studies, 10 included sample from diverse backgrounds, 6 only professional musicians, 10 only students and one study included only music teachers. Details are listed in Table 2.

3.3. Studies' quality assessment

3.3.1. Risk of bias assessment

- Cross-sectional and cohort studies

Fig. 3 illustrates the risk of bias assessment for the twenty cross sectional and three cohort included studies using the Newcastle Ottawa scale (NOS) (Wells et al., 2013) (see Appendix 1). Considering the three key domains, studies performed poorly comparability with all of the included studies scoring zero stars. This was mainly due to the lack of consideration of confounding factors in the included studies. Regarding the selection domain, most of the studies completed 1 to 2 stars on a maximum of 4. We would like to highlight the lack of use of a secured record or secured interview in the ascertainment of exposure. Similarly, most of the samples used in the included studies were not truly representative of the average in the target population.

- Case reports

Concerning the two case reports, to this day there is no scale recommended by the Cochrane Handbook for systematic reviews of intervention to assess their methodological quality. This is why the authors decided not to assess the quality of these case studies.

- Uncontrolled study of intervention

The Quality Assessment Tool for Before-After (Pre-Post) Studies With No Control Group developed by the National Herat, Blood and Lung Institute (NHLBI) was used (National Heart Lung and Blood Institute, 2014) to assess the quality of one study (Chan et al., 2013). While this tool is not standardized its study-specific design allows it to assess the major flaws in study methods. Key point for this evaluation is the absence of eligibility criteria that result in a selection bias.

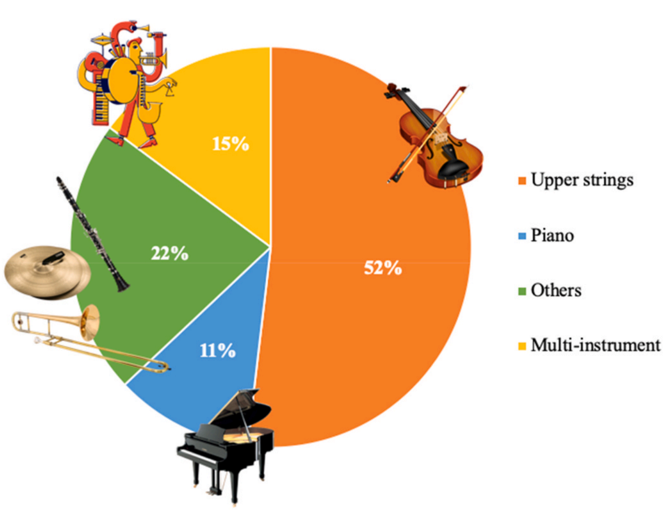

Fig. 2. Graphical representations of the music instruments played in the included samples.

3.3.2. Inter-rater agreement

- Cross-sectional and cohort studies

For all cross sectional (n = 20) and cohorts (n = 3) articles included in this review, Cohen's kappa was 0.82 (cf Table 3) suggesting an almost perfect level of agreement between the two independent reviewers. However, for two of the comparability domain, Cohen's kappa value appears to be zero (cf Table 3), suggesting poor inter-rater agreement. As explained earlier in the material and method section, this situation refers to the paradox we are confronted with when interpreting the Kappa alone, namely that this parameter is strongly influenced by the prevalence of the data measured. This is reflected in the very high P_{neg} value, highlighting the strong consistency between the two raters and not a poor level of agreement as we would have concluded if we had stopped at the interpretation proposed by Landis and Koch. Cohen's kappa, level of agreement as well as P_{pos} and P_{neg} calculations are illustrated in Table 3.

The "overall" section refers to the all of the studies (cross-sectional and cohort) combined all together.

- Uncontrolled study of intervention

The two raters demonstrated a perfect agreement as they were in accordance for all of the twelve items of the NIH tool.

3.4. Posture analysis

Concerning methods used for postural assessment, a large heterogeneity has been observed. Three dimensional analysis using videography (n = 9) and visual assessment (n = 4) remain the most used methods for postural analysis. Two studies employed ultrasound (Park et al., 2012; Piatek et al., 2018), two other records resorted to goniometry (Baadjou et al., 2017; Cattarello et al., 2018). Amongst the other methods we found photogrammetry (Yagisan et al., 2009), accelerometery (Clemente et al., 2014), optoelectronic motion capture (Rabuffetti et al., 2007) and the use of micro-switch sensors (Fjellman-Wiklund and Sundelin, 1998; Wolf et al., 2019). The last column of Table 2 summarises all the different postural assessment methods described among the 27 included studies. Different variables were investigated such range of kinematics parameters (such as velocity, acceleration, jerk) or postural impairments assessed by external raters. For each study, these variables were listed and the protocols (including musical tasks) were briefly described in Table 4. Moreover, Table 4 summarises also the considered body landmarks to evaluate posture using external devices or visual assessments.

3.5. Considerations about physiological posture

Among the 27 included studies, some authors reported several considerations about physiological posture. As an example, Blanco-Piñeiro et al. (2015) defined physiological posture while playing an instrument as "a posture with three fundamental characteristics: 1) maintenance of

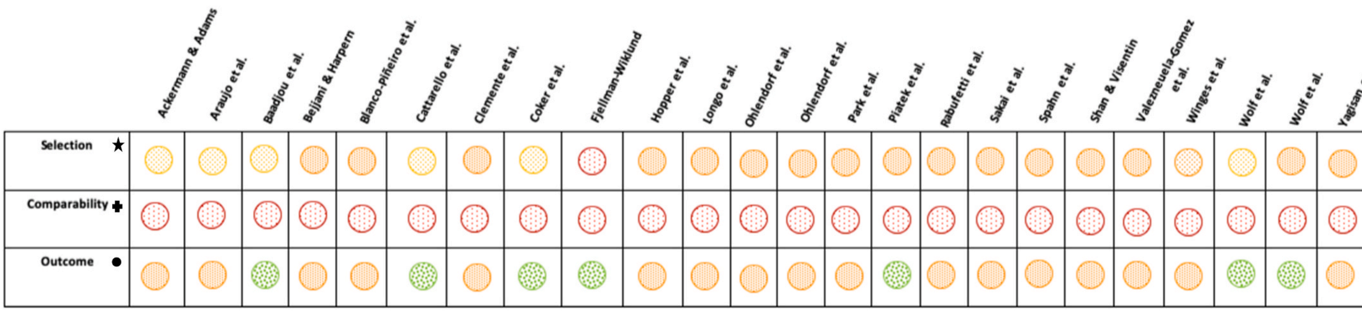

Fig. 3. Quality assessment in cohort and cross-sectional studies.

Table 3
Level of inter-rater agreement for the assessment of cross-sectional and cohort studies.

	Cohen's Kappa	Level of Agreement	P_o	P_{pos}	P_{neg}
Selection	0.98	Almost Perfect	0.99	0.99	0.99
Comparability	0	Poor	1	0	1
Outcome	0.48	Moderate	0.77	0.65	0.83
Overall	0.82	Almost Perfect	0.93	0.88	0.95

Legend.
P_o = Observed proportion of agreement.
P_{pos} = Observed proportion of positive agreement.
P_{neg} = Observed proportion of negative agreement.

the spine, and of the head-trunk unit, along the "axis of gravity", i.e. the vertical axis through the relevant center of gravity (that of the head, trunk and arms if sitting; that of the whole body if standing); 2) total freedom of the arms to play the instrument; and 3) well-planted legs with joints unhindered and free to move". They mentioned that playing a musical instrument should combine "maximum physiological and biomechanical efficiency" and "minimum expenditure of energy". Nonetheless, they took into account how much playing specific instrument could lead to adopt different posture, such as double bass or the violin. Other authors reported elements about posture such as Ackermann and Adams (2004) who asked experts to evaluate "uprightness and apparent muscle tension", or Cattarello et al. (2018) who stated that backrests were recommended for office workers to "promote "good" spinal posture", as well as Longo et al. (2020) who state that "good postural alignment is necessary to achieve excellent voice performances". They defined the ideal position to sing as "erected, with the axes of the neck, jaw, shoulders, back, and pelvis aligned on the sagittal, axial, and transversal body axes" based on previous research (Longo et al., 2020). Moreover, Spahn et al. (2014) reported that musicians should have a standing symmetric posture understood as an equal distribution of the weight over both lower limbs. Finally, one study reported considerations about the potential mobility of the instrumentalists while playing: Ackermann and Adams (2004) asked the raters to evaluate the postural mobility of musicians between static and dynamic on a visual analogue scale. On the contrary, Blanco-Piñeiro et al. (2015) asked their assessors to ignore "transient excursions in the course of performance" and to rate musicians' posture as average position, that is to say, not considering how much the instrumentalists were mobile while playing.

From the different considerations mentioned by all these authors about posture, it is clear is quite complex and difficult to define posture while playing should be or not.

3.6. Potential relationship between posture and PRMDs

Studying the link between possible postural impairments and PRMDs was a secondary objective. Only one study investigated this possible relationship: Park et al. (2012) studied how neck ranges of motion while playing could potentially be associated with neck pain in violinists. The authors reported that lateral bending and rotation to the left side while playing the violin were significantly greater in the group of musicians with neck pain compared to the control group. This result provides a brief but limited insight regarding the possible relation between posture while playing and PRMDs.

4. Discussion

4.1. Main findings of this review

This systematic review determined how posture while playing has been analysed in musicians from different backgrounds and with different levels of expertise for 30 years. Among all the identified methods, visual assessment (using both videos or pictures) and three-dimensional analysis using video cameras were the most reported ways to record posture while playing. Considering the visual assessments, the Postural Observation Instrument (or POI) developed and tested by Blanco-Piñeiro et al. (2015, 2018) seems to be the most comprehensive tool, including overall posture as well as specific body locations (often reported as painful ones in musicians – Silva et al., 2015; Kok et al., 2016) such as shoulders, neck, spine, etc. Nonetheless, this tool considers musicians' posture as "average positions" and requires that the experts who have rated the different postures ignore transient movements while playing. Unfortunately, this does not allow comparing musicians with fixed or changing postures. Considering the investigated body locations and the body landmarks used to assess posture, the area of interest focuses mainly on the spine and upper limbs' positions while playing a music instrument. Indeed, repetitive movements and asymmetrical postures required to play instrument such as the cello (Hopper et al., 2017) or the violin (Ancillao et al., 2017; Shan and Visentin, 2003) affect mainly the spine and the upper limbs compared to the lower body.

Surprisingly, while posture has been investigated in all the included studies (as it was one of the main requirements for inclusion), what is considered as "physiological" posture is not often thoroughly or specifically described in the different papers. Indeed, as mentioned in our results, only a few papers described precisely what the authors considered as being physiological such as Ackermann and Adams (2004), Blanco-Piñeiro et al. (2015) or Longo et al. (2020). The absence of strong evidence for ideal posture and the debate about potential relationships between postural impairments and pain (Swain et al., 2020) could explain the difficulty of precisely stating what is identified as physiological when considering musicians' posture.

All of the studies rated particularly poorly in the comparability domain. This raises concerns about the ability of assessing confounding factors in cross-sectional and cohort studies. Even though many confounders are difficult to identify or measure, the authors didn't even mention the concept of confounding or the fact that the findings should be interpreted carefully regarding the confounding factors. There might be a need for consensus identifying the most common cofounders, thus

Table 4
Variables, protocols, landmarks used and form of the results of included studies.

Authors, year	Task	Type of variables	Used landmarks *(if suitable)*	Form of the results
Ackermann and Adams, 2004	Violinists were asked to play selected musical excerpts and were videotaped using 2 different cameras simultaneously. Videotapes shown to PT for movement pattern rating using an adapted version of a VAS.	- ROM (°) for shoulder, elbow and wrist; - Perceived injury risk for shoulder, elbow, wrist, hand, finger and thumb.	N.A.	Intraclass Correlation Coefficient (ICC) values
Ancillao et al. (2017)	The violinist was asked to perform a legato bowing task (10 bowings). Video streams coming from 6 cameras allowed a reconstruction of markers trajectories to identify the biomechanical strategy of the upper limb and bow positioning	- ROM (°) for shoulder, elbow, wrist, neck, bow - Velocity (°/s) for shoulder, elbow, wrist, bow - Acceleration (°/s^2) for shoulder, elbow, wrist, bow - Jerk (°/$s^{3)}$ for shoulder, elbow, wrist, bow	- 3 markers on the head, - Left and right acromioclavicular joint, - Right sternoclavicular joint, - C7, T8, L1 - Sacrum vertebrae, - Right and left elbow, wrist, hand, - Left four fingers (excluding thumb)	Mean values and coefficient of variation (CV)
Araújo et al., 2009	Musicians were videotaped while playing in a seated position (videotaping duration: 20 min). The captured images provided joint angle measurements.	- Wrist flexion while using the middle third (°) - Wrist flexion while using inferior third (°) - Lateral R/L deviation of the head - Shoulder abduction during playing of the four strings of the violin (°)	- Right acromion - Glabella - Humerus lateral epicondyle - Radius and ulnar styloid process - Wrist joint - Forearm - Third and fifth metacarpal heads	Descriptive analysis
Baadjou et al. (2017)	60 s of the adagio in the clarinet concerto of Mozart in A major (KV.622) played 10 times in two different postural conditions: habitual and experimental sitting postures. Measurement at four moments: start of playing, at selected notes at approximately 20 and 40 s into the piece, and at the end of the piece. Total of experiment: 2 h.	- High thoracic angle - Low thoracic angle - Pelvic tilt angle	- Lateral femur condyle, - Greater trochanter - Anterior superior iliac spine, - Posterior superior iliac spine, - L2, T7, C7 (spinous process level)	Mean + 95% CI
Bejjani and Halpern, 1989	Each trumpetist was asked to perform two different tasks, standing while being videotaped by two cameras: a trumpet exercise, with an equal distribution of notes, and a piece of his own repertoire. Photographs were taken simultaneously as the trumpeter hit specific notes which allowed angle calculation.	- Vectorial sum of body segment angles in neutral standing posture and three-notes relating playing posture - Neck length - Leg length - Spine length	- Inion, - Base of head, - Base of neck, - Apex of thoracic kyphosis and lumbar lordosis - Sacral prominence - Popliteal fossa - Heel.	Mean +standard deviation (SD) Estimated regression coefficient + standard errors + F-ratios
Blanco-Piñeiro et al., 2015	Each student was videotaped (rear + lateral viewpoints in standing and seating positions) while playing a self-chosen piece for 2 min. Photographs of each participant in static standing and seated positions (without instrument) were taken. The photographs were then given to four individually trained experts for postural evaluation	- Overall posture (rigid/slumped/ physiological) - Location of the axis of gravity (in a sagittal plane (forward-shifted, backward-shifted, physio) - Location of the axis of gravity in a frontal plane (right-shifted, left-shifted, physiological) - Pelvic attitude (forward-tilted, backward-tilted, physiological) - Dorsal curvature (excessive, insufficient, physiological) - Alignment of the head in sagittal planes (forward, backward, physiological) - Alignment of the head in frontal planes (tilted sideways, physiological) - Frontal plane of the shoulders (forward, backward, physiological) - Transverse plane of the shoulders (shrugging, physiological) - Lateral tilt of the shoulders (tilted, physiological) - Legs and feet (misplaced, physiological)	N.A.	Descriptive analysis
Cattarello et al. (2018)	Two pieces of medium difficulty for 5 min in five different conditions (25 min of play in total). Pelvic tilt and spine angles in the sagittal plane were evaluated using a palpation meter while lumbar lordosis and thoracic kyphosis spine angles were evaluated using a flexicurve.	- Pelvic tilt standing (S), Standing with the instrument (Sv) in ° - Sagittal spine angles (kyphosis and lordosis angles) standing (S) and standing with the instrument (Sv) in ° - Trunk-thigh angle in sitting in °	- PSIS and ASIS - C7, T1, T12, L1, L5, S1 - Six additional points for the kyphosis curve - Six additional points for the lumbar curve.	p-values + 95% CI
Chan et al. (2013)	Musicians were asked to play their instrument before and after a 10-weeks		Circular retro-reflective markers:	Descriptive analysis

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Table 4 (*continued*)

Authors, year	Task	Type of variables	Used landmarks *(if suitable)*	Form of the results
	intervention program (exercise or Alexander Technique) and photographed. Posture was recorded by anterior and lateral photographs pre and post-intervention. Experienced evaluators had to determine which picture was the better posture using those two sets of photographs	- Probability of selecting the true post-intervention photo as having improved posture (%) - Response according to the judges and intervention (%) (in favor/against/no differences)	- Facial, spinal, pelvic and lower limb standard landmarks - Elbow's lateral epidondyle - Radial styloid process - Base of the fifth metacarpal	
Clemente et al. (2014)	Assessment of the head and cervical posture of piano players during musical performance while wearing glasses including an accelerometer (playing duration = 3 min).	- Head orientation (°) - Global acceleration (g) - F/B and R/L tilt (°)	N.A.	Mean values
Coker et al. (2004)	For both pre- and post-test, musicians were asked to play different percussive exercises under eight different conditions (simple quiet upright bipedal stance followed by seven fundamental percussive exercises in an upright bipedal stance) while standing on a center of pression measuring platform.	- COP displacement in the sagittal and frontal planes for each of the eight conditions. (inches) - Gain Scores for the Center of Pressure Displacement (inches)	N.A.	Mean +SD
Fjellman-Wiklund and Sundelin, 1998	Musicians were first assessed by a PT in order to identify any obstacle to full arm elevation. Subjects were then recorded by an arm-position analyser during a whole working day.	- Upper arm angle - Upper-arm elevations	N.A.	Mean values
Hopper et al. (2017)	Musicians' movements (torso, upper arm and forearm) while playing a C-major scale under two volume conditions were recorded. A 3D motion capture device was used to create a customized biomechanical model that allowed upper arm kinematics calculation.	- <u>Torso</u>: flexion/extension (°), lateral flexion (L/R) (°), rotation (L/R) (°) - <u>Shoulder</u>: flexion/extension (°), abduction/adduction (°), rotation (I/E) (°) - <u>Elbow</u>: flexion/extension (°), pronation/supination (°)	- 5 markers on the torso: acromion, C7 and T10 (spinous processes) - Sterno-clavicular notch and xiphoid process 3 makers on the upper arm and forearm (not listed)	Mean values
Islan et al. (2018)	A RULA analysis was first performed evaluating the different positions of the musician's upper arm during her routine. Subsequently, the use of Finite Element Model (FEM) allowed a simulation of the glenohumeral joint and rotator cuff behavior.	- Position of the right and left arm (°) - Location of the first joint fault - Response of joints to the fatigue	N.A.	Descriptive analysis
Longo et al. (2020)	Musicians were asked to sing different vowels while playing or not. Voice and body posture under those two conditions was then visually assessed by an expert osteopath using a modified version of an Italian validated method	- Head/neck (Straight/Flexion/Hyperextended/anteposition/retroposition/rotated/sloping) - Jaw (open/close/central/lateralized) - Shoulders (neutral position/intrarotated/extrarotated/lifted up/lifted down) - Back (straight/flexion/hyperextended/rotated)	N.A.	Descriptive analysis
Ohlendorf et al. (2018)	Musicians were asked to play on six different chairs with and without their instrument while their upper body (video raster stereography) and the seat pressure (load distribution) were analysed. 3 scans were taken within 2 min which allowed body posture analysis	Spinal parameters - Trunk length D (mm) - Trunk length S (mm) - Sagittal trunk decline (°) - Frontal trunk decline (°) - Axis decline (°) - Thoracic bending angle (°) - Lumbar bending angle (°) - Standard lateral deviation (mm) - Maximal lateral deviation (mm) - Standard deviation rotation (°) - Maximal rotation (°) - Kyphosis angle (°) - Lordosis angle (°) <u>Pelvis parameters</u>: pelvis distance (mm), height (°), height_2 (mm), torsion (°), rotation (°). <u>Shoulder parameters</u>: scapular distance (mm), height (mm), rotation (°), right and left angles (°).	6 self-adhesive markers: - C7 - Inferior scapular angles - Pelvis dimples - Rima ani.	Mean +SD and p-values
Park et al. (2012)	Musicians were asked to play a specific piece from Kreutzer's *42 Études* (No. 2) using their instrument while their muscle activity and neck ROM were recorded.	- Neck flexion and extension (°) - Neck right and left rotation (°) - Neck right and left axial rotation (°) - Right and left lateral bending (°)	N.A.	mean ± SD,

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Table 4 (*continued*)

Authors, year	Task	Type of variables	Used landmarks *(if suitable)*	Form of the results
Piatek et al. (2018)	Musicians were asked to play their instrument with and without different saxophone-carrying systems. A 3D ultrasound device allowed posture measurements in the sagittal, coronal and transverse plane with and without the carrying items.	Sagittal plane: - Head posture to ankle distance [mm], - Head posture angle [°], - Bow head forward angle [°], - Chin to saxophone distance [mm] Coronal plane: - Shoulder obliquity [mm] - Pelvic obliquity [mm], - Lateral flexion of the head [°] Transverse plane: - Head to shoulder rotation [°] - Shoulder to pelvis rotation [°]	- External occipital protuberance, - External auditory canals, - Chin, - Acromion - Anterior points of the iliac spine - Posterior points of the iliac spine, - Apexes of the iliac cres - Ankles	mean + 95%CI
Rabuffetti et al. (2007)	Musicians were asked to play a three-octave ascending and descending scale in the G key while using their instrument in three conditions: no shoulder rest, shoulder rest all-up and all-down. An optoelectronic device allowed the evaluation of kinematic patterns of the right upper limb.	- Head leftward rotation angle (°) - Head rightward bending angle (°) - Chin rightward deviation (mm) - Left acromion elevation (mm) - Left shoulder flexion angle (°) - Left shoulder rotation angle (°) - Left wrist radial deviation (°)	21 passive reflective mar XE “or” kers (Not listed)	Mean values
Sakai et al. (2006)	Musicians were separated in two groups (small and large hand span) and were asked to play a chord and an octave using their instrument while their hand movements were being recorded. Video-based passive marker detection system measured abduction angle of both the thumbs and the small fingers.	- Maximum and minimum abduction angle of the thumb (°) - Maximum and minimum abduction angle of the little finger (°) - Thumb and little finger ROM (°)	26 markers on the dorsal side of the middle finger, small finger, thumb, dorsal hand, and forearm.	Mean +SD
Shan & Visentin (2003)	Musicians were asked to play a two-octave G- major scale in first position using one note per bow while being recorded. A VICON system allowed a 3D motion analysis of the upper-body kinematics.	- Joint moments for the right shoulder, elbow and wrist (Nmm) - Range of load of the shoulder, elbow and wrist.	30 reflective markers (not listed)	Mean +SD
Spahn et al. (2014)	Musicians were asked to play their instrument while being videotaped, sitting on a force platform and in four different conditions (standing, sitting, sitting oriented to the right of the music stand, and sitting oriented to the left of the stand). The posturographic device allowed: weight distribution analysis, 3D motion capture of the back and bowing arm in the 4 set-ups.	- Comparison sitting position to the right or left of the stand (°): right and left head angles, neck lordosis, thoracic kyphosis, elbow angle. - Comparison between sitting and standing position (°): shoulder angle, thoracic kyphosis, lumbar lordosis, hip angle, elbow angle. - Body weight distribution (% of total body weight).	9 markers - Right and left protuberantia occipitalis externa - Acromion - C4 (neck lordosis), T6 (thoracic kyphosis), L3 (lumbar lordosis) - Sacrum - 7 cm next to the right and left posterior superior iliac spine	Mean +SD
Valenzuela-Gómez et al., 2020	Musicians were asked to play their instrument with three different support devices (guitar cushion, rigid lap support and footstool). Body posture was assessed in two phases: first using REBA and then a 3D software (3D Static Strength Prediction Program).	- Hip flexion (°) - Trunk flexion (°) - Trunk axial rotation (°) - Low back compression (N)	Not stated	Mean +SD
Winges and Furuya, 2015	Musicians were asked to play 14 different excerpts while wearing a right-handed glove with open fingertips which provides joint angles data. Authors then proceeded to a movement kinematics analysis using magnetic sensors for motion tracking	- MCP, PIP and Abduction/adduction angles for each of the four fingers - MCP, IP joint angles and rotation angle (ROT) for the thumb - Joint velocity profiles of a professional and amateur pianist during INDEX finger strikes - Joint velocity profiles of a professional and amateur pianist during RING finger strikes. - Peak joint velocity by preceding digit strike.	Not stated	Mean (±SE) and SD (±SE)
Wolf et al. (2017)	Subjects were divided into two groups (AT intervention group and control group). Magnetic sensors permitted head and shoulder motion tracking as musicians played a scale and a Kreutzer *étude*. Descriptive measures of ample entropy and average mutual information (AMI) were then performed.	- Sample Entropy - AMI	6 magnetic sensors: - Occipital lobe - C6 - Left arm, forearm, hand (just above wrist) and humeral head.	Mean +SD
Wolf et al. (2019)	Subjects were asked to play their instrument while being videotaped. A 10-camera Qualysis system allowed a 3D	Angle and ranges of motion for the spine, shoulder, elbow, wrist,	31 single markers (pelvis, thorax, spine, head, both scapulae, upper arms, forearms, hands), 2 pre-built and 4 custom-made	Mean, maximum and minimum

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Table 4 (*continued*)

Authors, year	Task	Type of variables	Used landmarks *(if suitable)*	Form of the results
	motion analysis of the upper-body kinematics.	scapulothoracic joint on G and D-strings.	clusters for thorax, upper arms, right forearm and both scapulae.	angles, range of motion +SD
Yagisan et al. (2009)	Participants were photographed while playing a standard violin with a standard bow performing the basic bow drives. Three measurement points were used for the E, A and G strings. Digital photogrammetric methods then allowed upper-arm kinematics analysis.	- Average angle of the elbow (°) on E, A and G string - Average angle of the wrist (°) on E, A and G string - Arm direction (%) on E, A and G string - Forearm direction (%) on E, A and G string - Hand direction (%) on E, A and G string	6 markers: - Acromion - Lateral epicondyle - Olecranon - Ulnar styloid - Hamate - Fifth metacarpal head	Mean +SD

Legend.
AMI: average mutual information.
AT: Alexander Technique.
SE: Standard error.
SD: standard deviation.
ROM: range of motion.
VAS: visual analogic scale.

leading to more transparent reporting.

Regarding the kappa analysis, by using an overall section, combining all of the studies domain, the authors aimed to assess the quality of the NOS domains and the raters' ability to apply them. The very strong agreement observed between both raters (see Table 3) suggests consensual use of the NOS. However, the overall kappa cannot fully reflect the complexity of the rating. This is the reason for conducting further calculations were conducted, particularly regarding the comparability domain where the Ppos allowed to recontextualise the kappa value.

4.2. Comparison with previous reviews

Authors have investigated posture in musicians, its potential association with pain and which methods were employed to evaluate it both without instrument and while playing (Fernandez-Paz et al., 2019; Blanco-Piñeiro et al., 2017). One of these reviews has not followed a systematic research strategy, data extraction and assessment (Fernandez-Paz et al., 2019). The second one has not evaluated the quality of the primary included studies (Blanco-Piñeiro et al., 2017). In addition to these distinctions, the current review may differ also considering several other elements. First of all, our review did not include work with self-reported questionnaires to analyse posture, as the authors considered this method was not appropriate to assess posture in the best way possible. This review also excluded studies with musicians who were singers only, as that made them too difficult to be compared to instrumentalists. Furthermore, only posture while playing was considered in this work, excluding all postural considerations without the instrument or other musculoskeletal assessments, which were included in the other reviews (Fernandez-Paz et al., 2019; Blanco-Piñeiro et al., 2017).

Finally, Fernandez-Paz et al. (2019) mentioned in their abstract that posture appears to be one relevant risk factors influencing both musculoskeletal health and performance, without stating precisely if they were considering general posture or posture while playing a music instrument. This statement has not been shared with this review's general findings (even if one primary study mentioned association between postural impairments and neck pain in violinists – Park et al., 2012). Indeed, it seems that this association has been based on self-reported measures or musculoskeletal assessments which provide some information but probably not enough to associate positively postural impairments and pain development.

4.3. Strengths and limitations of this review

This review provides a large synthesis of how musicians' postures while playing are currently investigated, excluding self-reported measures. This could potentially help researchers to choose one method or another to investigate and monitor posture while playing, in order to allow potential comparisons with previous findings in literature. Moreover, in contrast to the reviews (systematic or not) which mentioned posture in musicians and in which primary studies were not assessed, in our review the included studies' quality has been evaluated with the Newcastle Ottawa Scale (Wells et al., 2013). This provides additional information regarding the methodological quality of some studies to stimulate further research.

In terms of data extraction and quality assessment, very strong agreement has been observed between both raters, suggesting an important consensus on the inclusion criteria while selecting the studies and on the use of the NOS while assessing the included full-texts. This positive methodological aspect of the review gives more confidence on the data analysis.

Moreover, the relationship between posture (and more specifically postural impairments) and PRMDs is often assumed in research about musicians' injuries. This systematic review highlights the lack of clear evidence to state that an association exist between "bad" posture and PRMDs' development.

Finally, the considered research strategy included studies in French and English only and some studies using interesting methods in other languages could exist. Concerning the use of visual assessment, tool reliability (and particularly interrater reliability) may be questionable in some of the included studies. This element of previous work also provides some perspectives and motivation for further research.

5. Conclusion

Further research is still need to understand better the potential relationship that is often assumed between postural impairments or technical flaws while playing a music instrument and the development of playing-related musculoskeletal disorders.

In the future and in order to be used by a great number of musicians and healthcare practitioners, a tool investigating musicians' posture while playing and particularly how much they are moving while playing, should be developed and tested.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix 1

Newcastle-Ottawa Scale Quality Assessment Scale for Cohort and Case Control studies.

NEWCASTLE - OTTAWA QUALITY ASSESSMENT SCALE
COHORT STUDIES

Note: A study can be awarded a maximum of one star for each numbered item within the Selection and Outcome categories. A maximum of two stars can be given for Comparability

Selection

1) Representativeness of the exposed cohort
   a) truly representative of the average _______________ (describe) in the community Ø
   b) somewhat representative of the average ______________ in the community Ø
   c) selected group of users eg nurses, volunteers
   d) no description of the derivation of the cohort

2) Selection of the non exposed cohort
   a) drawn from the same community as the exposed cohort Ø
   b) drawn from a different source
   c) no description of the derivation of the non exposed cohort

3) Ascertainment of exposure
   a) secure record (eg surgical records) Ø
   b) structured interview Ø
   c) written self report
   d) no description

4) Demonstration that outcome of interest was not present at start of study
   a) yes Ø
   b) no

Comparability

1) Comparability of cohorts on the basis of the design or analysis
   a) study controls for _____________ (select the most important factor) Ø
   b) study controls for any additional factor Ø (This criteria could be modified to indicate specific control for a second important factor.)

Outcome

1) Assessment of outcome
   a) independent blind assessment Ø
   b) record linkage Ø
   c) self report
   d) no description

2) Was follow-up long enough for outcomes to occur
   a) yes (select an adequate follow up period for outcome of interest) Ø
   b) no

3) Adequacy of follow up of cohorts
   a) complete follow up - all subjects accounted for Ø
   b) subjects lost to follow up unlikely to introduce bias - small number lost - > ____ % (select an adequate %) follow up, or description provided of those lost) Ø
   c) follow up rate < ____% (select an adequate %) and no description of those lost
   d) no statement

Note: A study can be awarded a maximum of one star for each numbered item within the Selection and Exposure categories. A maximum of two stars can be given for Comparability.

Selection

1) Is the case definition adequate?
   a) yes, with independent validation Ø
   b) yes, eg record linkage or based on self reports
   c) no description

2) Representativeness of the cases
   a) consecutive or obviously representative series of cases Ø
   b) potential for selection biases or not stated

3) Selection of Controls
   a) community controls Ø
   b) hospital controls
   c) no description

4) Definition of Controls
   a) no history of disease (endpoint) Ø
   b) no description of source

Comparability

1) Comparability of cases and controls on the basis of the design or analysis
   a) study controls for _______________ (Select the most important factor.) Ø
   b) study controls for any additional factor Ø (This criteria could be modified to indicate specific control for a second important factor.)

Exposure

1) Ascertainment of exposure
   a) secure record (eg surgical records) Ø
   b) structured interview where blind to case/control status Ø
   c) interview not blinded to case/control status
   d) written self report or medical record only
   e) no description

2) Same method of ascertainment for cases and controls
   a) yes Ø
   b) no

3) Non-Response rate
   a) same rate for both groups Ø
   b) non respondents described
   c) rate different and no designation

. (*continued*).

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