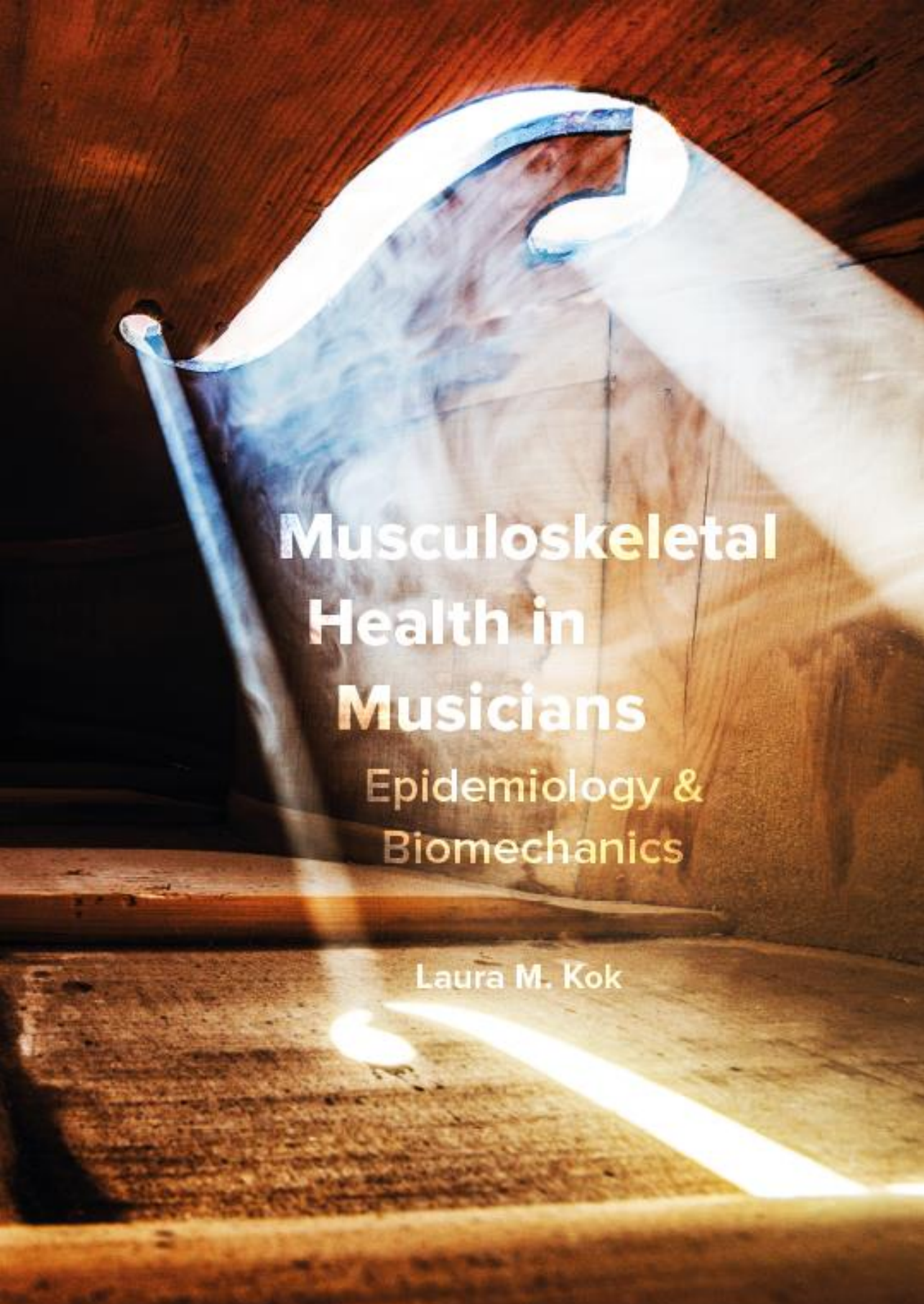

Musculoskeletal Health in Musicians

Epidemiology & Biomechanics

Laura M. Kok

Musculoskeletal Health in Musicians

Epidemiology & Biomechanics

Laura Madelinde Kok

The digital version of this thesis is available online:

PhD thesis, Leiden University Medical Center, Leiden, The Netherlands

ISBN:	978-94-9301-442-8
Cover concept:	Laura Kok & Emma Kropman
Cover design:	Ilse Modder
Cover photo:	Adrian Borda
Printing:	Gildeprint

The publication of this thesis was kindly supported by:
Nederlandse Orthopaedische Vereniging
Nederlandse Vereniging voor Dans- en Muziekgeneeskunde
Universiteit Leiden
Stichting Orthopedisch Onderzoek Spaarne
Anna Fonds te Leiden
Kaptein Orthopedie
Bauerfeind Benelux
Implantcast Benelux
Penders Voetzorg
Pro-Motion Medical
Hanssen Footcare
Voetmax Orthopedie
Chipsoft

Musculoskeletal Health in Musicians

Epidemiology & Biomechanics

PROEFSCHRIFT

Ter verkrijging van de graad van Doctor aan de Universiteit Leiden.

Op gezag van Rector Magnificus Prof.mr. C.J.J.M. Stolker, volgens besluit van het College voor Promoties te verdedigen op dinsdag 20 november klokke 11.15 uur

door

Laura Madelinde Kok

Geboren te Zwolle

in 1987

Promotoren:	Prof. Dr. R.G.H.H. Nelissen
	Prof. Dr. Ir. J. Harlaar (Amsterdam UMC, TU Delft)
Copromotor:	Dr. B.M.A. Huisstede (UMC Utrecht)

Leden promotie commissie:	Prof. dr. A.A. Kaptein
	Prof. dr. G. Kloppenburg
	Prof. dr. B.J. van Royen (Amsterdam UMC)
	Prof. dr. S.K. Bulstra (UMC Groningen)
	Dr. J.H. Stubbe (Codarts)

CONTENTS

CHAPTER 1

General introduction

BACKGROUND OF THIS THESIS

Musculoskeletal complaints are highly prevalent; they are the most common cause of severe long-term pain and physical disability in the general population.(1–3) Furthermore, musculoskeletal complaints are the main cause of years lived with disability, thereby seriously effecting quality of life.(1,4,5)

During our daily life we are exposed to several risk factors for musculoskeletal complaints: Heavy physical work, high psychosocial work demands, excessive repetition, awkward postures, and heavy lifting are known work-related risk factors for musculoskeletal complaints.(6) Moreover, also our free time activities such as sports, are associated with musculoskeletal complaints.(7) Whether these conditions are considered problematic depends on the functional demands of each individual, as has been formalized by the ICF (International Classification of Functioning, Disability and Health).(8,9) According to the ICF model health problems can be characterised in body structures and functions, activities and participation *(Figure 1)*. The functional demands of musicians are extremely high, as playing an instrument, especially at a professional level, requires optimal musculoskeletal functioning. Also, musicians are typically exposed to several of the earlier mentioned risk factors for musculoskeletal complaints. Therefore, according to the ICF model, a challenging combination of high musculoskeletal demands and consequently a high risk for musculoskeletal complaints exists in musicians.

A HISTORICAL PERSPECTIVE OF PERFORMING ARTS MEDICINE

For a long time, complaining about medical problems by performing artists was considered a taboo.(10) A report in the New York Times in 1981 opened the eyes of both musicians and health care providers. In this article 'When a pianist's fingers fail to obey' the impact of hand problems of two world famous pianists Gary Graffman and Leon Fleisher were described.(11) Many musicians recognized the reported struggle with musculoskeletal problems. Following this article many of them visited the same clinic as these famous pianists did. Subsequently, acquired knowledge on the health problems of these musicians was gathered and published. This marked the start of a new field of medical interest: *Performing Arts Medicine*.(10)

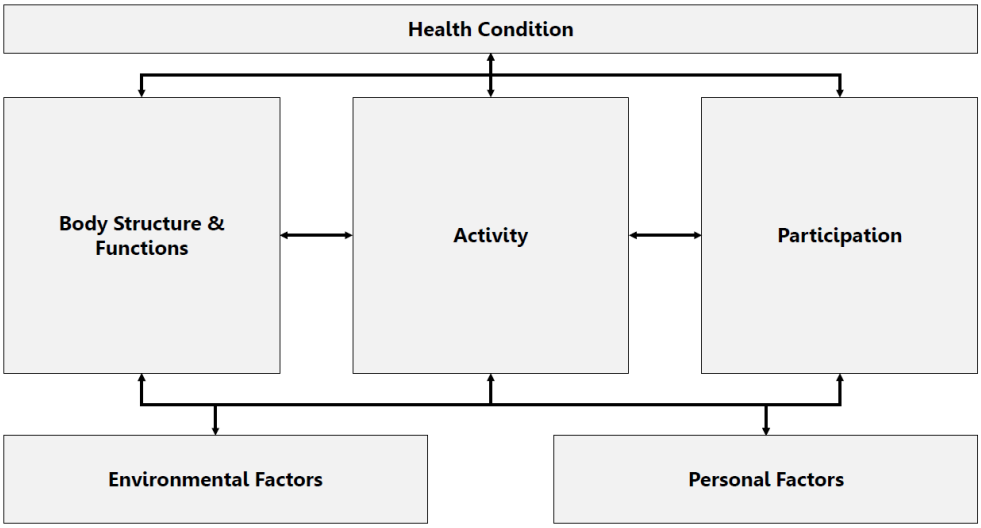

Figure 1: The ICF model (8)

The growing clinical interest was followed by a scientific inquisitiveness into the health of the performing artist. The first large study examining the health of musicians was published in 1988.(12,13) Middlestadt and Fishbein performed a cross-sectional study, in which 82% of the studied professional orchestra musicians in North America reported medical problems at a certain point in time during their careers, and of which 76% had experienced a problem which had affected their ability to perform. In this study, most health problems were caused by musculoskeletal disorders. This publication was followed by other studies addressing musculoskeletal health complaints among musicians, mainly among professional orchestra musicians.(14–19) A wide range of prevalences of musculoskeletal complaints were reported in these studies. However, partly due to varying methodological quality (e.g. heterogeneity of the study population, questionable outcome measures), firm statements concerning the severity of these musculoskeletal complaints of musicians could not be made.

Moreover, despite the generally high prevalence rates of musculoskeletal complaints in musicians, it was unknown if musicians actually had more musculoskeletal complaints than the general population. Apart from two small studies with a weak study design and contrasting outcomes(18,20), no studies comparing musicians with non-musicians were performed. Furthermore, although risk factors for musculoskeletal complaints in the

general population were defined, extrapolation of these risk factors to the musician population remained questionable, even more so when taking the ICF model into account for both patient groups. Remarkably, despite a growing clinical and scientific interest for the health of professional musicians, the musculoskeletal health effect of playing music on an amateur level has not been properly studied at all.(21,22)

Therefore, the main aim of this thesis is to evaluate the prevalence and severity of musculoskeletal health complaints in both professional and amateur musicians. Secondly, factors associated with these complaints are studied, as well as the impact of the complaints on daily functioning as a musician. Thereby the ICF model is used to explore the several domains of musculoskeletal health of musicians.

Knowledge of the epidemiology of musculoskeletal complaints and its risk factors among musicians is an essential step in addressing potential treatment targets and, most important, prevention of these complaints. For that matter, determining the occurrence and severity of these injuries is the first step in a sequence of prevention methods according the approach as described by Van Mechelen.(23) According to this model it is followed by a second step in which the aetiology is established, which is aimed for in the last part of this thesis. This knowledge is essential for improving the health of the musicians by introducing preventive measures.(23)

The evaluation of the musculoskeletal health complaints in musicians in this thesis therefore serves two goals: At first evaluating as a first time study the prevalence of musculoskeletal complaints in professional and amateur musicians in The Netherlands. And secondly, to serve as a wake-up call for musicians, employers and teachers at music institutions, society and last but not least healthcare providers, so they can recognize these musculoskeletal complaints in an early stage with subsequent advice for treatment and prevention. Awareness and knowledge of this subject among these groups of musicians as well as their teachers is essential for prevention and thus improvement of the health of both professional as well as amateur musicians.

THESIS OUTLINE

PART 1: EPIDEMIOLOGY

The first part of this thesis focuses on the epidemiology of musculoskeletal complaints among different groups of professional and amateur musicians. In **Chapter 2** the prevalence of musculoskeletal complaints in a group of professional musicians is studied. In this study musicians are compared to a control group of non-musicians. In **Chapter 3** the results of a systematic review evaluating the prevalence of musculoskeletal complaints among professional musicians are presented. A critical appraisal of the literature, describing the occurrence of musculoskeletal complaints in professional instrumental musicians, is performed. Next, in **Chapter 4** amateur musicians are studied. The prevalence of and prognostic factors for musculoskeletal complaints in amateur musicians playing in local student orchestras are evaluated, as well as several potentially associated risk factors. In **Chapter 5** a sample of amateur musicians are studied; evaluating the association between arm position and playing time with the prevalence of CANS (i.e. Complaints of the Arm, Neck and/or Shoulder not caused by trauma and/or systemic disease). In **Chapter 6** a longitudinal study design is used to evaluate the effect of a sudden increase in playing time on the prevalence musculoskeletal complaints in high level amateur musicians. This study is performed during an intensive rehearsal period of two high-level amateur orchestras. **Chapter 7** comprises a narrative literature review on musculoskeletal complaints in musicians, with a focus on gender differences.

PART 2: IMPACT & ILLNESS PERCEPTIONS

The second part of this thesis focusses on the impact of musculoskeletal complaints and illness perceptions of professional musicians. In **Chapter 8** the impact of CANS on a sample of professional musicians is evaluated, as is healthcare use due to these complaints. Again, musicians are compared to a reference population. In **Chapter 9** illness perception mechanisms of musicians with musculoskeletal complaints are evaluated using a patient perceived outcome score.

PART 3: BIOMECHANICAL ANALYSIS OF VIOLIN PLAYING

The high prevalence of complaints in the shoulder and neck region in violinists, as studied in the first part of this thesis was the main reason to initiate an analysis of this specific

group of musicians in the last part of this thesis. In **Chapter 10** the associations between complaints of the neck and shoulder region, violin fixation force, and muscle activity of the superficial neck and shoulder muscles are studied during playing the violin. In **Chapter 11** the influence of the shoulder rest adjustment on the jaw-shoulder violin fixation force and muscle activity of the superficial neck and shoulder muscles is evaluated in a group of professional violinists.

Finally, in **Chapter 12** the findings presented in this thesis are summarised. **Chapter 13** comprises the general discussion of this thesis in relation to the current status of the literature. Finally, the practical implementation of the knowledge by this thesis is discussed in this last chapter.

REFERENCES

1. Woolf AD, Pfleger B. Burden of major musculoskeletal conditions. BullWorld Heal Organ. 2003;81(0042–9686 (Print)):646–56.
2. Woolf AD, Akesson K. - Can we reduce the burden of musculoskeletal conditions? The European action towards better musculoskeletal health. - Best Pr Res Clin Rheumatol2007 Feb;21(1)1-3. (1521-6942 (Print)).
3. Picavet HSJ, Gils van HW V, Schouten JSAG. Klachten van het bewegingsapparaat in de Nederlandse bevolking. Vol. RIVM 26680. Rijksinstituut voor volksgezondheid en milieu, RIVM; 2010.
4. Vos T, Barber RM, Collaborators GB of DS 2013. Global, regional, and national incidence, prevalence, and years lived with disability for 301 acute and chronic diseases and injuries in 188 countries, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet. 2015 Aug 22;386(1474–547X (Electronic)):743–800.
5. Brooks PM. The burden of musculoskeletal disease--a global perspective. ClinRheumatol. 2006 Nov;25(0770–3198 (Print)):778–81.
6. da Costa BR, Vieira ER. - Risk factors for work-related musculoskeletal disorders: A systematic review of recent longitudinal studies. - Am J Ind Med2010 Mar;53(3)285-323. (1097-0274 (Electronic)).
7. Bahr R, Holme I. Risk factors for sports injuries—a methodological approach. Br J Sport Med. 2003;37:384–92.
8. ICF website WHO [Internet]. [cited 2018 Feb 17]. Available from: http://www.who.int/icidh
9. Towards a Common Language for Functioning, Disability and Health. 2002.
10. Sataloff RT, Brandfonbrener AG, Lederman RJ. Performing arts medicine. Vol. 3rd. Science & Medicine; 2013.
11. DunningJ. When a pianist's fingers fail to obey. NY Times. 1981 Jun 14;
12. Middlestadt SE, Fishbein M. The prevalence of severe musculoskeletal problems among male and female symphony orchestra string players. MPPA. 1989 Mar;4(1):41–8.
13. Fishbein M, Middlestadt SE, Ottati V, Straus S, Ellis A. Medical problems among ICSOM musicians: overview of a national survey. MPPA. 1988;3(1):1–8.
14. Zaza C. Playing-related musculoskeletal disorders in musicians: a systematic review of incidence and prevalence. CMAJ. 1998 Apr 21;158(0820–3946 (Print)):1019–25.
15. Guptill C, Zaza C, Paul S. An occupational study of physical playing-related injuries in college music students. MPPA. 2000;15(2):86–90.
16. Paarup HM, Baelum J, Holm JW, Manniche C, Wedderkopp N. Prevalence and consequences of musculoskeletal symptoms in symphony orchestra musicians vary by gender: a cross-sectional study. BMCMusculoskeletDisord. 2011 Oct 7;12(1471–2474 (Electronic)):223.
17. Leaver R, Harris EC, Palmer KT. Musculoskeletal pain in elite professional musicians from British symphony orchestras. Occup Med. 2011 Dec;61(1471–8405 (Electronic)):549–55.
18. Roach KE, Martinez MA, Anderson N. Musculoskeletal pain in student instrumentalists: a comparison with the general student population. MPPA. 1994 Dec;9(4):125–30.

19. Kaufman-Cohen Y, Ratzon NZ. Correlation between risk factors and musculoskeletal disorders among classical musicians. OccupMed(Lond). 2011 Mar;61(1471–8405 (Electronic)):90–5.

20. Fry HJH. The Treatment of Overuse Syndrome in Musicians - Results in 175 Patients. J R Soc Med. 1988;81(10):572–5.

21. Dawson WJ. Upper extremity difficulties in the dedicated amateur instrumentalist. MPPA. 2001;16(4):152–6.

22. Newmark J, RJ L. Practice doesn't necessarily make perfect: incidence of overuse syndromes in amateur instrumentalists. MPPA. 1987;2(4):142–4.

23. van Mechelen W, Hlobil H, Kemper HCG. Incidence, Severity, Aetiology and Prevention of Sports Injuries. Sport Med. 1992 Aug;14(2):82–99.

PART 1

EPIDEMIOLOGY

Chapter 2

A comparative study on the prevalence of musculoskeletal complaints among musicians and non-musicians

Laura M. Kok

Theodora P.M. Vliet Vlieland

Marta Fiocco

Rob G.H.H. Nelissen

BMC Musculoskelet Disord. 2013 Jan 4;14:9

ABSTRACT

Background Research comparing the frequency of musculoskeletal complaints between musicians and non-musicians is scarce. The aim of this study was to compare the prevalence of musculoskeletal complaints between musicians and non-musicians.

Methods A cross-sectional study among 3215 students from three music academies (n=345) and one medical school (n=2870) in The Netherlands was performed, using an electronic questionnaire. The questionnaire included socio-demographic characteristics, use of music instruments and the occurrence of musculoskeletal complaints in six body regions. Questions were related to musculoskeletal complaints over the last twelve months and at the time of the questionnaire. Chi-square, t-tests and Kruskal-Wallis tests were used for comparison between the two groups. The association between musculoskeletal complaints and possible predictors was analysed using a logistic and Poisson regression.

Results Eighty-seven music academy students and 503 medical students returned the questionnaire, of which respectively eighty-three and 494 were included in the study. Seventy-four music academy students (89.2%) reported one or more musculoskeletal complaints during the last twelve months, compared to 384 (77.9%) medical students (p=0.019). Moreover, 52 music academy students (62.7%) and 211 medical students (42.7%) reported current musculoskeletal complaints (p=0.001). The Odds ratio (OR) for the development of musculoskeletal complaints during the last twelve months in music academy students versus medical students is 2.33 (95% CI 1.61–3.05, p=0.022). The OR at the time of the questionnaire is 2.25 (95% CI 1.77–2.73, p=0.001). The total number of complaints have been modelled by employing a Poisson regression; the results show that non-musicians have on average less complaints than musicians (p=0.01). The adjusted means are 2.90 (95% CI 2.18–3.63) and 1.83 (95% CI 1.63–2.04) respectively for musicians and non-musicians. Regarding the localization of complaints, music academy students reported more complaints concerning the right hand, wrists, left elbow, shoulders, neck, jaw and mouth in contrast to medical students.

Conclusion Musculoskeletal complaints are significantly more common among musicians compared to non-musicians, mainly due to a higher number of upper extremity complaints.

BACKGROUND

Musculoskeletal complaints are a common problem in the general population. Nearly 75% of the Dutch population aged 25 years and older suffered from a complaint of the musculoskeletal system during a one-year period.(1) These complaints are a major cause of limitations in daily activities, healthcare usage and work disability.(2–4)

Apart from musculoskeletal complaints leading to work disability, some occupations may cause specific work-related musculoskeletal complaints. It has been consistently demonstrated that jobs with frequently repeated movements like computer use and work with high physical demands are associated with musculoskeletal complaints.(2,3,5) Also psychosocial work characteristics and increased stress symptoms such as high job demands and lack of control or social support are related with musculoskeletal complaints.(6)

Musicians have a work environment with high musculoskeletal and psychosocial demands.(7) In order to play their instrument, musicians need to frequently repeat physically strenuous movements. On average a musician plays 1300 hours a year in an ergonomically unfavourable position.(8) Instruments, requiring different positions and playing techniques, are associated with a different prevalence of musculoskeletal complaints.(9–14) Musculoskeletal complaints have been reported frequently (14–16), and they have a considerable physical but also psychological, social and financial impact on musicians.

Previous research shows a prevalence of musculoskeletal complaints varying from 39% up to 90% in adult musicians.(13–17) The severity of the complaints studied and the relation with playing the instrument ('playing-related musculoskeletal disorders' (18)) have a considerable impact on the prevalence. It is difficult to interpret these results since musculoskeletal complaints are also common in the general population. Actually, there are only two small studies comparing the prevalence of musculoskeletal complaints between musicians and non-musicians, with contrasting outcomes.(19,20) Fry et al. (20) compared 98 secondary school students playing in the school orchestra to an age- and sex matched group of students who did not play. Occurrence of playing-related pain was 63% in girls and 49% in boys. A questionnaire concerning playing-related pain in the instrument-playing group was only compared with hand pain in the control group,

without further specifications in localization of the playing-related pain. Roach et al. (19) examined 99 instrumentalists, and 159 non-instrumentalist university students. The former did not report more joint pain than the latter, but showed more pain in the upper-body than in the lower. A methodological flaw in that study was that the two groups were not comparable for age and sex, nor was corrected for this difference.

Given the scarcity of data and research on musculoskeletal complaints in musicians, this study aimed to compare prevalence, localization and associations between type of instrument and musculoskeletal complaints between musicians and non-musicians.

METHODS

STUDY DESIGN AND PATIENTS

This cross-sectional study compared year- and point prevalences of musculoskeletal complaints among music students and medical students. The study was performed at four Dutch institutions: the Royal Conservatoire, The Hague; the CODARTS University for the Arts, Rotterdam; the Amsterdam School of the Arts; and the medical faculty of the Leiden University between February and May 2011. All Dutch-speaking students of the above mentioned music academies with a classical instrument as main subject (singers and conductors were excluded) and medical students from the Leiden University (all of them speaking Dutch) received an invitation. They were selected from the student registries of the four centers. All eligible students received an e- mail with an invitation to complete the online questionnaire, with a reminder invitation three weeks after the first. After completing the questionnaire, students younger than 18 or older than 30 years were excluded. The Medical Ethical Committee (CME) of the Leiden University Medical Center approved the protocol. Informed consent was obtained from all participants.

ASSESSMENTS

The electronic questionnaire included the following items: Sociodemographic characteristics and general health. Age, gender, length, weight, right/left-handed, study-year (bachelor 1 till 4, master 1 or 2), playing an instrument and study (music academy student / medical student playing an instrument / medical student not playing an instrument), main instrument (violin, viola, cello, base, piano/keyboard, guitar/ mandolin, bassoon, oboe, clarinet, flute / piccolo, horn, trombone, tuba, harp, percussion, recorder and other, in which the participants had to fill in their instrument) were asked. The

instruments were divided in five categories: (1) bowed strings, (2) plucked strings, (3) woodwinds, (4) brass and (5) percussion and keyboards. For students playing an instrument, information like the number of years already spent to play the instrument and the average number of hours per week devoted to practice was asked. In addition, the questionnaire included questions concerning smoking (none / up to a half package a day / half to one package a day / more than one package a day), alcohol (number of glasses per week), and sports (number of hours per week).

MUSCULOSKELETAL COMPLAINTS

Since no validated scores were available for musicians, a questionnaire on musculoskeletal complaints was constructed. The first author, who is both Medical Doctor and has a Master degree in music, extensively discussed the questionnaire with colleagues in the medical and performing arts field. The score consisted of 144 questions on the occurrence of complaints in six specific body regions, subdivided in 21 localizations (yes/no). Questions on each of these regions started by asking about complaints of -the specific body region- during the last 12 months, The first body region 'elbows, wrists and hands' was subdivided in six localizations (elbow, wrist and hand left and right). The second one 'neck, shoulders and upper back' was subdivided in four localizations (shoulders left and right, neck, upper back). The third region 'lower back' was not subdivided. The fourth one 'hips and knees' was subdivided in four localizations (hip and knee left and right). 'Ankles and feet' (fifth region) was subdivided in four sub regions (ankle and foot left and right). The last region 'jaw and mouth' was subdivided in the two regions. The total prevalence score was calculated by adding all subjects with at least one complaint. The prevalence in a specific body region was also calculated by adding all subjects with at least one complaint in that particular body region. If the above mentioned question concerning complaints during the last twelve months was positive, it was also asked whether the complaint was still present and at which localization of the body (yes/no). The same procedure was applied to each body region of interest.

The total number of students with complaints was calculated by adding all students with at least one complaint. The one-year prevalence was calculated by dividing the percent of subjects with complaints during the last twelve months by one hundred. The point-prevalence was calculated by dividing the percentage of subjects reporting at least one complaint which was present at the time of the questionnaire by one hundred.

STATISTICAL ANALYSIS

All Statistical analysis were performed in SPSS version 18. For continuous normally distributed variables mean and standard deviation were calculated or median, in case of departure from the normal distribution the range have been computed. Comparisons between the two groups were performed by employing Chi-square, t-tests and Kruskal-Wallis tests. Complaints and the total number of complaints in the two groups have been investigated respectively by a univariate logistic and a Poisson regression. Details are given in the section results.

RESULTS

The questionnaire was sent to 345 musical and 2870 medical students. Initially, 590 students completed the questionnaire, 87 music academy students and 503 medical students, leading to response rates of 25% for the music academy students and 18% for the medical students (18% overall response rate). Thirty-three of the 135 students of the Royal Conservatory completed the questionnaire (response 24%), 26 of the 124 students of the Amsterdam school of the Arts (response 21%) and 24 of the 86 students of the CODARTS University for the arts (response 28%). Three subjects from the music academy group were excluded since they were younger than eighteen while eight subjects were excluded from the medical students group because they were older than 30 years. An additional two subjects were excluded because they were singers. Finally 577 students were included: 83 from the music academies and 494 from the medical school. In *Table 1* the characteristics of the responders are illustrated.

In the group of the medical students, 162 (32.8%) played an instrument. The instruments played by the music academy students were very different from the instruments played by the medical students; 29 (34.9%) music academy students played a bowed string instrument, 3 (3.6%) a plucked instrument, 27 (35.2%) a woodwind, 7 (8.4%) brass and 17 (20.5%) percussion or keyboard. Medical students played more often percussion or keyboard (73, 45.1%), or a plucked string instrument (39, 24.1%). Sixteen of them (9.9%) played a bowed string instrument, 26 (16.0%) played a woodwind and 8 (9.4%) played brass.

Table 1: Baseline characteristics of music academy and medical students participating in a survey on musculoskeletal complaints

	Music academy students (n = 83)	**Medical students (n = 494)**	**Difference (p)**
Age (years) (mean (SD))	21.5 (2.2)	22.1 (2.6)	0.062 ~
Gender (%)	Male: 21 (25.3%) Female: 62 (73.8%)	Male: 120 (24.3%) Female: 374 (75.7%)	0.843 *
Study (%)	Bachelor: 72 (86.7%) Master: 11 (13.3%)	Bachelor: 248 (50.2%) Master: 246 (49.8%)	< 0.001 *
Smoking (%)	10 (11.9%)	26 (5.3%)	0.019 *
Sport (hours in one week) (mean (SD))	2.2 (2.4)	3.0 (2.8)	0.005 ~
Alcohol consumption (E/week) (mean (SD))	3.9 (4.5)	5.5 (6.9)	0.090 ~
Body mass index (kg/m2) (mean (SD))	21.2 (3.0)	22.0 (2.5)	0.001 ~
Hours of practicing the main musical instrument in one week (mean (SD))	20.7 (8.7)		
Experience (number of years playing the main musical instrument) (mean (SD))	13.0 (3.3)		
Hand preference (%)	Right: 71 (85.5%) Left: 12 (14.5%)	Right: 433 (87.7%) Left: 61 (12.3%)	0.593 *

*~ = Kruskal Wallis Test. * = Chi-squared Test.*

The music academy students were comparable with the medical students with respect to age, gender, length, alcohol consumption and hand preference. However, they differed with respect to the degree of the study (bachelor/master), hours of sport in a week, smoking, and body mass index *(Table 1).*

More music academy students reported complaints during the last twelve months on the body regions 'elbows, wrists and hands', the neck, 'shoulders and upper back' and the 'jaw and mouth' compared to medical students *(Table 2).* Contrary, music academy students reported fewer complaints of the hips and knees. The proportions of students reporting complaints of the lower back or ankles and feet were similar between the two groups. In *Table 3* complaints during the last twelve months specified by exact localizations are presented, showing differences between right and left sides.

Table 2: Musculoskeletal complaints among music academy and medical students specified by body region

		Music academy students (n = 83)	Medical students (n = 494)	Difference (p)
Elbows, wrists, hands (%)	Subjects with complaints during the last twelve months	40 (48.2%)	109 (22.1%)	< 0.001 *
	Subjects with complaints at the time of filling in the questionnaire	14 (16.9%)	39 (7.9%)	0.009 *
	Reported number of complaints of the elbows, wrists and hands (0–6) (Mean (SD))	0.7 (0.98)	0.3 (0.56)	< 0.001 ~
Neck, shoulders, upper back (%)	Subjects with complaints during the last twelve months	65 (78.3%)	233 (47.2%)	< 0.001 *
	Subjects with complaints at the time of filling in the questionnaire	39 (47.0%)	96 (19.4%)	< 0.001 *
	Reported number of complaints of the neck, shoulders and upper back (0–4) (Mean (SD))	1.2 (1.00)	0.6 (0.66)	< 0.001 ~
Lower back (%)	Subjects with complaints during the last twelve months	33 (39.8%)	191 (38.7%)	0.860 *
	Subjects with complaints at the time of filling in the questionnaire	19 (22.9%)	63 (12.8%)	0.014 *
Hips, knees (%)	Subjects with complaints during the last twelve months	11 (13.3%)	146 (29.6%)	0.002 *
	Subjects with complaints at the time of filling in the questionnaire	6 (7.2%)	71 (14.4%)	0.077 *
	Reported number of complaints of the hips and knees (0–4) (Mean (SD))	0.2 (0.57)	0.3 (0.57)	0.017 ~
Ankles, feet (%)	Subjects with complaints during the last twelve months	7 (8.4%)	82 (16.6%)	0.057 *
	Subjects with complaints at the time of filling in the questionnaire	6 (7.2%)	41 (8.3%)	0.741 *
	Reported number of complaints of the ankles and feet (0–4) (Mean (SD))	0.1 (0.57)	0.2 (0.47)	0.201 ~
Jaw, mouth (%)	Subjects with complaints during the last twelve months	21 (25.3%)	38 (7.9%)	0.001 *
	Subjects with complaints at the time of filling in the questionnaire	9 (10.8%)	24 (4.9%)	0.030 *
	Reported number of complaints of the jaw and mouth (0–2) (Mean (SD))	0.3 (0.50)	0.1 (0.30)	0.001 ~
Total (%)	Subjects with complaints during the last twelve months	74 (89.2%)	384 (77.7%)	0.019 *
	Subjects with complaints at the time of filling in the questionnaire	52 (62.7%)	211 (42.7%)	0.001 *
	Reported total number of complaints (0–21) (Mean (SD))	2.9 (2.61)	1.8 (1.52)	< 0.001 ~

*~ = Kruskal Wallis Test.; *= Chi-squared Test.*

Table 3: Musculoskeletal complaints during the last twelve months among music academy and medical students specified by localization

		Music academy students (n = 83)	**Medical students (n = 494)**	**Difference (p)**
Hand	Right	14 (16.9%)	35 (7.1%)	0.003*
	Left	7 (8.4%)	21 (4.3%)	0.101*
Wrist	Right	14 (16.9%)	31 (6.3%)	0.001*
	Left	13 (15.7%)	27 (5.5%)	0.001*
Elbow	Right	2 (2.4%)	9 (1.8%)	0.717*
	Left	6 (7.2%)	8 (1.6%)	0.002*
Shoulder	Right	25 (30.1%)	42 (8.5%)	0.001*
	Left	23 (27.7%)	32 (6.5%)	0.001*
Neck		38 (45.8%)	135 (27.3%)	0.001*
Upper back		16 (19.3%)	68 (13.8%)	0.188*
Lower back		33 (39.8%)	191 (38.6%)	0.860*
Knee	Right	5 (6.0%)	74 (15.0%)	0.028*
	Left	5 (6.0%)	61 (12.3%)	0.094*
Hip	Right	2 (2.4%)	13 (2.6%)	0.906*
	Left	3 (3.6%)	22 (4.5%)	0.728*
Ankle	Right	2 (2.4%)	29 (5.9%)	0.196*
	Left	3 (3.6%)	32 (6.5%)	0.312*
Foot	Right	5 (6.0%)	19 (3.8%)	0.358*
	Left	2 (2.4%)	15 (3.0%)	0.755*
Jaw		13 (15.7%)	31 (6.3%)	0.003*
Mouth		9 (10.8%)	10 (2.0%)	< 0.001*

** = Chi-squared Test*

With respect to the number of complaints (number of involved localizations/joints) reported, music academy students did report a higher number of complaints of elbows, wrists and hands (mean 0.67 (95% CI 0.46–0.88) versus 0.27 (95% CI 0.23–0.319), $p < 0.001$), shoulders, neck and upper back (1.24 (95% CI 1.03–1.45) versus 0.56 (95% CI 0.50–0.62)), $p < 0.001$) and on the jaw and mouth (0.27 (95% CI 0.17–0.37) versus 0.08 (95% CI 0.06–0.11), $p = 0.001$). No statistical significant differences in the number of complaints on the hips, knees, ankles, feet and lower back have been found.

Between medical students playing and not playing an instrument there were no significant differences except for a significant difference in the baseline factors BMI (p=0.04) and study year (p=0.025) and the number of facial complaints is different (p=0.025). For all other outcomes there were no significant differences.

In *Table 4* the occurrence of musculoskeletal complaints is compared between different instrument groups. The prevalence of musculoskeletal complaints was the highest in musicians who used a plucked string, or percussion, or a keyboard instrument. They were followed by the woodwind, bowed string, and brass players, but the differences between these groups of music academy students were not significant.

The CODARTS University of the Arts had the highest number of students with musculoskeletal complaints (year prevalence of 95.8% and point prevalence of 66.7%). However, no significant differences between the three music academies have been found in this study.

Table 4: Musculoskeletal complaints during the last twelve months in music academy students according to instrumental sections

	Strings, bowed (n = 29)	**Strings, plucked (n = 3)**	**Wood-winds (n = 27)**	**Brass (n = 7)**	**Percussion and keyboards (n = 17)**	**Difference (p)**
Musculoskeletal complaints during the last twelve months (year prevalence) (%)	24 (83%)	3 (100%)	25 (93%)	6 (86%)	16 (94%)	0.655*
Musculoskeletal complaints at the moment of filling in the questionnaire (point prevalence) (%)	18 (62%)	3 (100%)	17 (63%)	2 (29%)	12 (71%)	0.221*

**=Chi-squared test*

DISCUSSION

Music academy students reported more musculoskeletal complaints compared to medical students. Shoulders, neck and upper back were the regions being most affected within the musician group, followed by hands and wrists. Differences in occurrence existed between the right and left side. Current complaints and complaints during the last year showed comparable results regarding the localization of the complaints.

Since playing an instrument will usually affect the upper extremity and the neck region, it is conceivable that musicians have more upper body-part complaints. Others found the same distribution of musculoskeletal complaints.(19) In this study medical students did report significantly more lower-body part complaints; A hypothesis is that music academy students possibly avoid sports which could easily invoke an injury to the upper extremity, which will have a direct impact on their instrument performance and thus career opportunities.

Musculoskeletal complaints are reported with different prevalence rates between instrument groups.(8,10,14,21) This study shows clear differences, although the sample size in this study is too small to investigate associations between a specific instrument type and the occurrence of complaints. The type of instrument played is a known risk factor for the development of musculoskeletal complaints among musicians.(8–10,13–15,21) The difference in prevalence between instrument groups (strings, woodwinds, brass, keyboard, percussion) implies that mechanical overuse is an important factor, which is contrary to repetitive strain injuries in which psychosocial are predominant factors in the aetiology and not the mechanical repetition as such.(6,22)

Besides two small studies with conflicting outcomes(19,20), no study comparing musicians with non-musicians with respect to musculoskeletal complaints have been performed before. Literature comparing the results of a musculoskeletal questionnaire among musicians with a general workforce sample does exist, however due to heterogeneity between study populations (e.g. age, sex, activities), different research questions and methodologies, no comparisons can be made.(8)

Compared to other studies on professional and adolescent musicians (8–10,14,16,21), this research shows a relative high prevalence of complaints of the musculoskeletal system. A possible explanation could be related to the questions formulated in the questionnaire. In many studies, pain is the only complaint questioned, while in this study also other musculoskeletal complaints are taken into account. The reason for our different approach is the fact that not all musculoskeletal problems are associated with pain, but nevertheless they can cause severe disability. Although pain is often one of the main complaints, sometimes other discomfort symptoms are the main problem, for example in focal dystonia (in which painless loss of coordination is the main complaint).(23,24) Besides, we choose not to make a distinction between playing- and non-playing-related

musculoskeletal complaints as of course playing-related complaints do not exist in non-musicians.

Most studies concerning the prevalence of musculoskeletal complaints, or 'playing-related musculoskeletal disorders', in orchestras and music schools, show high prevalence rates (14–16), but in those studies no control group was used. Comparing the complaints between musicians and non-musicians is important since the prevalence of musculoskeletal complaints in the general population is high. Thus, the additional effect of the exposure of playing a musical instrument cannot be evaluated, if an age and sex matched control group is absent.

Some limitations are present in our study. Compared to other studies using a mailed questionnaire the response rate is low.(25) A possible reason for the low response rate is the fact that the invitation for the questionnaire was sent by e-mail only twice. It was not possible to send a reminder in another form or perform a telephone interview. Possible selection bias due to the response rate should be kept in mind. By choosing medical students as a control group a possible selection bias might be present since these students might be more aware of health problems, and therefore they might report problems easier. On the other hand they might also consider musculoskeletal complaints as being of none importance or even ignoring them. This implies that the effect of this potential bias is unclear.

CONCLUSIONS

This research emphasizes that musicians do have significant more musculoskeletal complaints than non-musicians, which seems to be associated with the part of the body which is used to play the instrument, (i.e. the upper body and upper extremity). Both medical doctors and teachers in music academies should be aware of this problem and an analysis of how the instruments are played is important to identify musculoskeletal complaints and might be important to start preventive measurements. Since the prevalence is high compared to the general population, research into effective interventions to prevent and treat musculoskeletal complaints among musicians is necessary.

REFERENCES

1. Picavet HSJ, Gils van HW V, Schouten JSAG. Klachten van het bewegingsapparaat in de Nederlandse bevolking. Vol. RIVM 26680. Rijksinstituut voor volksgezondheid en milieu, RIVM; 2010.
2. Cote P, van V der, Cassidy JD, Carroll LJ, Hogg-Johnson S, Holm LW, et al. The burden and determinants of neck pain in workers: results of the Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders. JManipulative Physiol Ther. 2009 Feb;32(1532–6586 (Electronic)):S70–86.
3. Roquelaure Y, Ha C, Leclerc A, Touranchet A, Sauteron M, Melchior M, et al. Epidemiologic surveillance of upper-extremity musculoskeletal disorders in the working population. Arthritis Rheum. 2006 Oct 15;55(0004–3591 (Print)):765–78.
4. da Costa BR, Vieira ER. - Risk factors for work-related musculoskeletal disorders: A systematic review of recent longitudinal studies. - Am J Ind Med2010 Mar;53(3)285-323. (1097-0274 (Electronic)).
5. Sim J, Lacey RJ, Lewis M. The impact of workplace risk factors on the occurrence of neck and upper limb pain: a general population study. BMCPublic Heal. 2006;6(1471–2458 (Electronic)):234.
6. Huisstede BM, Wijnhoven HA, Bierma-Zeinstra SM, Koes BW, Verhaar JA, Picavet S. - Prevalence and characteristics of complaints of the arm, neck, and/or shoulder (CANS) in the open population. - Clin J Pain2008 Mar-Apr;24(3)253-9. (0749-8047 (Print)).
7. Holst GJ, Paarup HM, Baelum J. - A cross-sectional study of psychosocial work environment and stress in the Danish symphony orchestras. - Int Arch Occup Env Heal Oct 20. (1432-1246 (Electronic)).
8. Paarup HM, Baelum J, Holm JW, Manniche C, Wedderkopp N. Prevalence and consequences of musculoskeletal symptoms in symphony orchestra musicians vary by gender: a cross-sectional study. BMCMusculoskeletDisord. 2011 Oct 7;12(1471–2474 (Electronic)):223.
9. Kaufman-Cohen Y, Ratzon NZ. Correlation between risk factors and musculoskeletal disorders among classical musicians. OccupMed(Lond). 2011 Mar;61(1471–8405 (Electronic)):90–5.
10. Fry HJH. Incidence of overuse syndrome in the symphony orchestra. MPPA. 2011;1(2):51–5.
11. Guptill C, Golem MB. Case study: musicians' playing-related injuries. Work. 2008;30(1051–9815 (Print)):307–10.
12. Heinan M. A review of the unique injuries sustained by musicians. JAAPA. 2008 Apr;21(1547–1896 (Print)):45–46,48,50.
13. Lederman RJ. Neuromuscular and musculoskeletal problems in instrumental musicians. Muscle Nerve. 2003 May;27(0148–639X (Print)):549–61.
14. Middlestadt SE, Fishbein M. The prevalence of severe musculoskeletal problems among male and female symphony orchestra string players. MPPA. 1989 Mar;4(1):41–8.
15. Hoppmann RA, Reid RR. Musculoskeletal problems of performing artists. CurrOpinRheumatol.

1995 Mar;7(1040–8711 (Print)):147–50.

16. Zaza C. Playing-related musculoskeletal disorders in musicians: a systematic review of incidence and prevalence. CMAJ. 1998 Apr 21;158(0820–3946 (Print)):1019–25.

17. Caldron PH, Calabrese LH, Clough JD, Lederman RJ, Williams G, Leatherman J, et al. A survey of musculoskeletal problems encountered in high-level musicians. MPPA. 1986 Dec 12;1(4):136–9.

18. Zaza C, Charles C, Muszynski A. The meaning of playing-related musculoskeletal disorders to classical musicians. SocSciMed. 1998 Dec;47(0277–9536 (Print)):2013–23.

19. Roach KE, Martinez MA, Anderson N. Musculoskeletal pain in student instrumentalists: a comparison with the general student population. MPPA. 1994 Dec;9(4):125–30.

20. Fry HJH, Ross P, Rutherford M. Music-Related Overuse in Secondary-Schools. MPPA. 1988;3(4):133–4.

21. Zaza C, Farewell VT. Musicians' playing-related musculoskeletal disorders: an examination of risk factors. Am J Ind Med. 1997 Sep;32(3):292–300.

22. Keijsers E, Feleus A, Miedema HS, Koes BW, Bierma-Zeinstra SM. - Psychosocial factors predicted nonrecovery in both specific and nonspecific diagnoses at arm, neck, and shoulder. - J Clin Epidemiol2010 Dec;63(12)1370-9. (1878-5921 (Electronic)).

23. Zetterberg C, Backlund H, J. K, Werner HOL. Musculoskeletal problmes among male and female music students. MPPA. 1998 Dec;13(4):160–6.

24. Enders L, Spector JT, Altenmuller E, Schmidt A, Klein C, Jabusch HC. Musician's dystonia and comorbid anxiety: Two sides of one coin? Mov Disord. 2011 Mar 2;(1531–8257 (Electronic)).

25. Asch DA, Jedrziewski MK, Christakis NA. - Response rates to mail surveys published in medical journals. - J Clin Epidemiol1997 Oct;50(10)1129-36. (0895-4356 (Print)).

CHAPTER 3

The occurrence of musculoskeletal complaints among professional musicians

A systematic review

LAURA M. KOK

BIONKA M.A. HUISSTEDE

VERONIQUE M.A. VOORN

JAN W. SCHOONES

ROB G.H.H. NELISSEN

Int Arch Occup Environ Health. 2016 Apr;89(3):373-96

ABSTRACT

Purpose This study gives a systematic overview of the literature on the occurrence of musculoskeletal complaints in professional instrumental musicians.

Methods A systematic review. Nine literature databases were searched without time limits on the 25th of June 2015, also the complete index of the journal Medical Problems of Performing Artists (MPPA) until June 2015 (30;2) was searched, and citation tracking and reference checking of the selected articles was performed. The search consisted of the combination of three groups of keywords: musician (e.g. musician, violin, music student, instrument player) AND musculoskeletal (e.g. musculoskeletal, tendon, shoulder, arthritis) AND epidemiology (e.g. prevalence, incidence, occurrence).

Results The initial literature search strategy resulted in 1258 potentially relevant articles. Finally, 21 articles describing 5424 musicians were included in this review. Point prevalences of musculoskeletal complaints in professional musicians range between 9% and 68%; twelve months prevalences range between 41% and 93%; and lifetime prevalences range between 62% and 93%. Ten out of twelve studies show a higher prevalence of musculoskeletal complaints among women. Brass instrumentalists are reported to have the lowest prevalence rates of musculoskeletal complaints. The neck and shoulders are the anatomic areas most affected; the elbows are the least affected. Although some information is reported concerning age, the high risk of bias in and between these studies makes it impossible to present reliable statements with respect to this.

Conclusions Musculoskeletal symptoms are highly prevalent among musicians, especially among women instrumentalists. Future research concerning the epidemiology of musculoskeletal complaints among musicians should focus on associated risk factors and follow the current guidelines to optimize scientific quality.

INTRODUCTION

'There is no exercise, though never so healthful and innocent, but what may produce great disorders, if it is used with intemperance', are the words of Bernardino Ramazzini, who was in 1713 the first to describe an overview of occupational diseases of musicians.(1,2) Only at the end of the 19th century, a number of physicians turned their interest to some specific musicians' complaints like musicians' cramp. Tenotomies of the finger flexors were performed in order to improve finger independency among pianists.(1) However, real interest in the health and well-being of musicians by medical practitioners, researchers and music professionals, was developed since the 1980s. This was reflected in a growing number of publications, journals, conferences and organizations which focused on the health of the performing artists.(1,2) Nowadays, the level of knowledge on this topic and the necessary specialized healthcare is still in a developmental stage when compared to, for instance, sports medicine, thus room for improvement remains.

Musculoskeletal complaints are one of the main medical problems among musicians.(3–5) These complaints have considerable physical, psychological, social and financial impact on musicians.(6,7) Impaired level of functioning at both work and at daily activities at home due to these musculoskeletal complaints is reported in the majority and sleep disturbances related to these complaints are reported in half of the professional musicians.(8,9) Most professional musicians will suffer from musculoskeletal complaints during their life; some of them will stop playing their instrument due to these complaints.(9–11)

Zaza published in 1998 a systematic review of incidence and prevalence of playing-related musculoskeletal complaints.(12) In this study eighteen cross-sectional and cohort studies published between 1980 and 1996 were reviewed. Due to different definitions of musculoskeletal complaints the point prevalence of the playing-related musculoskeletal disorders varied between 39% and 87%. A development since this review is the introduction of the term 'playing-related musculoskeletal disorder (PRMD)(7), which aims to exclude minor irrelevant musculoskeletal symptoms experienced by musicians. Musicians defined PRMDs as personal, chronic and disabling health problems that affect the whole person, physically, emotionally, occupationally and socially.(7) However, the term PRMD is used in the literature of performing arts medicine without strictly following

this definition. Recently another reviewed was published concerning pain prevalence in musicians.(13) In this review heterogenic studies are compared, with no distinction between professional and amateur musicians, impeding extrapolation of the results.

An up to date critical systematic review of the literature to assess prevalence rates of musculoskeletal complaints among musicians will indicate the extent of the problem, and a critical appraisal of the used prevalence rates and definitions of studies complaints will give an overview of the current science of musculoskeletal problems in musicians. Furthermore, subgroups with a higher prevalence can be identified. This may be helpful in the prevention of complaints due to the possibility to target prevention and interventions at these high risk groups. Therefore the objective of this systematic review is to give an overview of the prevalence of musculoskeletal complaints among professional instrumental musicians, and to evaluate groups and localizations at risk.

MATERIALS AND METHODS

SEARCH STRATEGY

A search on articles was performed on the 25h of June 2015, using the following databases without time and language restrictions: PubMed, Embase, Web of Science, Cochrane, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Academic Search Premier, PsycINFO, ScienceDirect and Lippincott Williams & Wilkins (LWW). The search consisted of the combination of three groups of keywords: musician (e.g. musician, violin, music student, instrument player) AND musculoskeletal (e.g. musculoskeletal, tendon, shoulder, arthritis) AND epidemiology (e.g. prevalence, incidence, occurrence). The complete search strategy is presented in *Appendix A*. Moreover, the complete index of the journal Medical Problems of Performing Artists (MPPA) until June 2015 (30;2) was searched manually, and citation tracking and reference checking of the selected articles was performed.

INCLUSION CRITERIA

Articles were included if they fulfilled all of the following criteria: 1. The study had a cross-sectional, case-control or cohort design; 2. The study population consisted of adult (aged 18 or older) professional instrumental musicians and/or music academy students; The definition of professional was dependent on the definition of the original article. 3. The outcome measure reported was a clearly described prevalence rate of musculoskeletal

complaints of the complete body or half of the body (at least upper extremities, back and neck) of musicians; 4. the article was published in a peer-reviewed scientific journal. If a subset of the total number of subjects included in a study met our inclusion criteria, the study was included only if the outcomes of the subset were assessed and reported independently.

EXCLUSION CRITERIA

Studies with subjects aged 17 or younger were excluded. In case of unclear age limits, an indistinct description of the prevalence rate or questions concerning the professionalism of the study subjects, the authors were sent an e-mail. In case of non-response the study was excluded. Case series that included less than 50 subjects were excluded. Also studies reporting a prevalence of musculoskeletal complaints measured within in a population visiting a healthcare professional were excluded. In case of a mixed study population, in which only a part of the study subjects met the inclusion criteria, authors were e-mailed and asked for split results. In case of a non-responding author or the inability of the author to present the relevant information, the study was excluded.

STUDY SELECTION

Two reviewers (L.M.K., V.M.A.V.) independently performed the screening of title, abstract and full-text articles respectively on eligibility. Disagreements in the selection process were resolved by consensus. When no consensus was reached, a third reviewer (B.M.A.H.) was consulted. In case of incomplete information in potentially relevant studies, the author was contacted by e-mail twice.

DATA EXTRACTION

Two reviewers (L.M.K., V.M.A.V.) independently extracted the data from the included articles. General manuscript information (authors, title, year and journal) was collected. Information on the study population, sample size and response rate was listed. The prevalence rates of musculoskeletal complaints and specifications of these prevalence rates for different age, gender, occupation, localisation and type of instrument were made. We also recorded whether the musculoskeletal complaints were playing-related (yes/no). Disagreement between the reviewers was resolved by consensus.

ASSESSMENT OF METHODOLOGICAL QUALITY

The methodological quality assessment was performed using a scoring system developed by Loney et al.(14,15) This scoring system is specifically designed for studies reporting incidence and prevalence rates and consists of an eight point checklist. *Table 1* shows the quality criteria in eight categories: design and method; sampling; sample size; measurement criteria; bias; response and non-responders; outcomes; setting. A score ranging between zero (lowest score) and eight (highest score) indicates the quality of the included study (*Table 1).* Two independent reviewers (L.M.K., V.M.A.V.) assessed the quality of the studies. Disagreements were resolved by consensus. When no consensus was found, a third reviewer (B.M.A.H.) was consulted if the disagreement persisted.

Table 1: Methodological quality scoring system

	Study-specific requirements
1. Are the study design and sampling method appropriate for the research question?	Is it an observational study? And is there an adequate sample of the total population studied in the research question?
2. Is the sampling frame appropriate?	Is the 'list for study recruitment' from which subjects are selected (sampling frame) appropriate? (no under- or overrepresentation of the problem in the subpopulation?)
3. Is the sample size adequate?	An adequate sample size calculation in this study and/or n>100
4. Are objective suitable and standard criteria used for measurement of the health outcome?	Are validated questionnaires used?
5. Is the health outcome measured in an unbiased fashion?	Is there a possible bias in the interpretation of the results?
6. Is the response rate adequate? Are the refusers described?	>66.6% response rate and dropouts described and compared with the study population
7. Are the estimates of prevalence or incidence given with confidence intervals and in detail by subgroup if appropriate?	
8. Are the study subjects and the setting described in detail and similar to those of interest to you?	Are the sociodemographic characteristics adequately described?
Total	0-8 points Scoring system: 0-4 points = low; 5-8 points = high

RESULTS

STUDY SELECTION

The initial literature search strategy resulted in 957 potentially relevant articles. Another 301 articles were identified after citation tracking and by checking the references of the selected articles. After screening of title and abstract, 162 articles were considered eligible

for inclusion and the full text was screened. Searching the MPPA database resulted in another 11 articles selected for full-text assessment. Finally, 21 articles, describing 17 studies and 5424 professional instrumental musicians, met our inclusion criteria and were included. Three study populations were reported in more than one article (16–21); results of these studies were pooled and presented as a single study. A flowchart of the inclusion and exclusion process is presented in *Figure 1*.

Articles without a clear description of age of the study population(22–27), and articles lacking a clearly described type of prevalence rate (22,24,28–36) were excluded. Also studies with a mixed under aged population(34,35,37–39) or mixed occupation(40,41) (e.g. partly conductors or singers and not primary instrumental musicians) in which the authors were not able to present split data were excluded. Many articles derived from the UNT-MHS database (42) had to be excluded after e-mail contact with the main author due to the lack of a professional study population.

Characteristics of the included studies

Table 3 gives an overview of the included studies. All included studies had a cross-sectional design. In fourteen articles symphony orchestra musicians were studied, in four articles music academy students, and in three other articles a mixed population of professional musicians and music academy students was studied. The included studies showed a variety of gender distribution, 26-79% of the in the separate studies included participants were male. The studies were performed in a variety of continents: seven European, one Asian, five North American, two South American and two Oceanic studies were included. Response rates to questionnaires varied between 26% and 99%, one study did not report a response rate (40); and the number of participants of each separate study ranged between 59 and 2212.

Assessment of methodological quality

The results of the methodological quality assessment are presented in *Table 2*. Only two studies reported an adequate response rate (over 66.6%), and an adequate description of the non-responders.(43,44) Three studies used a validated outcome measure(10,44–46), compared to fourteen studies which used a non-validated outcome measures or non-validated modifications of existing questionnaires. Overall the quality of the included studies was variable; however many studies of low scientific quality were excluded from this review due to the strict exclusion criteria for reporting outcomes.

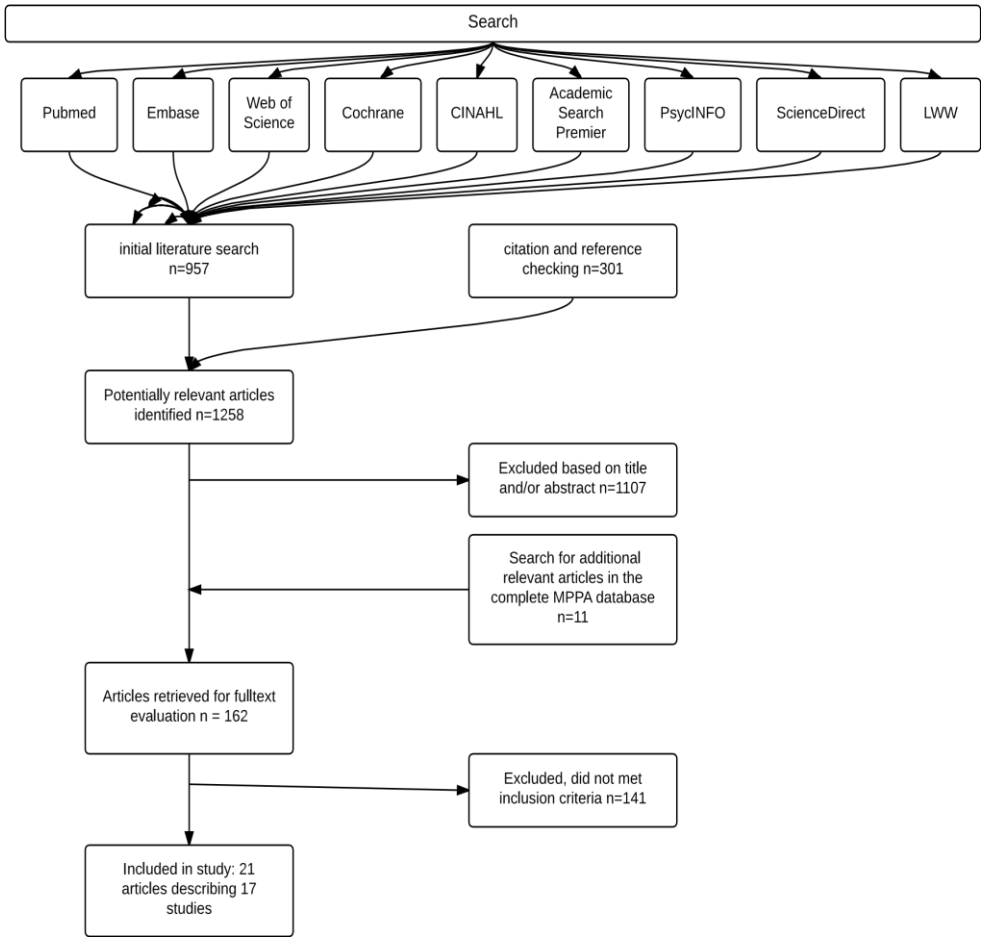

Figure 1: Systematic literature review process

PREVALENCE RATES

A uniform definition of musculoskeletal complaints in the included studies was lacking; some authors used the definition of playing-related musculoskeletal complaints by Zaza et al.(7,20) ('any pain, weakness, numbness, tingling, or other symptoms that interfere with your ability to play your instrument at the level you are accustomed to'), whereas others (10,43–45) used the questions based on the standardized Nordic Questionnaire.(43–47) In other studies different descriptions such as '(joint-) pain', or 'trouble' to describe the complaints were used.(9,16–18,48,49)

Among the included studies there was heterogeneity in the type of prevalence rates. Point prevalence, 12-month prevalence and life-time prevalence were most frequently reported. However, also four-week prevalence, 'chronic' prevalence (with different definitions in the two reporting studies), and three-month and two-year prevalence were reported.

Two studies concerned all musculoskeletal complaints (without making a difference between playing-related or other complaints), whereas twelve studies measured only playing-related complaints. Three studies reported both playing-related and all musculoskeletal complaints. This variety of definition of 'musculoskeletal complaints', the heterogeneity of the reported prevalence types and the variability within study subjects made it impossible to pool the data in this review.

PREVALENCE RATES

Reported point prevalence rates of musculoskeletal complaints, presented in *Table 4a*, varied from 57 to 68% for all musculoskeletal complaints, and from 9 to 68% for playing-related complaints. Non-playing-related twelve-month prevalence ranged between 86-89%, playing-related twelve-months prevalence ranged between 41-93%. Playing-related lifetime prevalence ranged between 62-93%. No study reported non-playing-related lifetime prevalence.

GENDER

Ten out of twelve studies comparing the gender of the professional musicians showed a higher prevalence of musculoskeletal complaints among women. One study only stated 'no significant difference' without presenting the data(10), and another study reported a higher prevalence among female compared to male strings players, but a lower prevalence among females playing another instrument.(50) However, no exact data were given in this study. *Table 4b* shows the results of the gender-specific prevalence rates.

OCCUPATION

There were no studies that compared prevalence rates of musculoskeletal complaints between different occupational groups (e.g. orchestral musicians, music teachers, music academy students).Kok et al. reported a point prevalence of 63% of musculoskeletal complaints among music academy students.(16,17) The latter was in concordance with Kaneko et al.(9) and Engquist et al.(44) who reported prevalence rates of 68% and 61%

respectively in orchestra musicians. Also the 12-months prevalence of 89% among music academy students in the study of Kok et al. was comparable to the prevalence rates of orchestra musicians of Leaver et al.(45) and Paarup et al.(43); 86% and 88% respectively. No information was presented in the included articles concerning prevalence rates between different occupations among professional musicians; e.g. teachers, chamber musicians, soloists and orchestra musicians.

Table 2: Methodological quality score of the included articles

	1. Design & sampling method	2. Sampling frame	3. Sample size	4. Objective, suitable, standard criteria	5. measured unbiased	6. Response rate adequate & describing non-participants	7. Confidence intervals	8. Interest for this study	Total score	Quality of the study
Leaver et al. (2011)	1	1	1	1	1	0	0	1	6	High
Paarup et al. (2011)	1	1	1	0	1	1	1	1	7	High
Kaufman-Cohen et al. (2011)	1	1	0	1	1	0	0	1	5	High
Zaza et al. (1997)	1	1	1	0	1	0	0	1	5	High
Abréu-Ramos et al. (2007)	1	1	0	0	1	0	0	1	4	Low
Kaneko et al. (2005)	1	1	1	0	1	0	0	1	5	High
Engquist et al. (2004)	1	1	1	1	1	1	0	1	7	High
Davies et al. (2002)	1	1	1	0	1	0	0	1	5	High
Roach et al. (1994)	1	0	0	0	1	0	0	1	3	Low
O'Neill et al. (2001)	1	1	1	0	1	0	0	1	5	High
Kok et al. (2013), Kok et al. (2013)	1	1	1	0	1	0	0	1	5	High
Fishbein et al. (1988); Middlestadt et al.(1988); Middlestadt et al. (1989)	1	1	1	0	1	0	0	1	5	High
Ackermann et al. (2012); Kenny et al. (2013)	1	1	1	0	1	0	0	1	5	High
Árnason (2014)	1	1	0	0	0	0	0	0	2	Low
Steinmetz (2015)	1	1	1	0	1	0	0	1	5	High
Chimenti (2013)	1	1	1	0	1	0	0	0	4	Low
Fotiadis (2013)	1	1	1	1	1	0	0	1	6	High

Instrument

In addition to the above-mentioned heterogeneity in definition of measured complaints and the type of prevalence reported in each study, heterogeneity in the grouping of instrumentalists and the presentation of differences between these instrument groups was presented in the included studies. Some authors reported no total prevalence rates split for instrument groups, only body area specific prevalence rates split for instrument groups.(43,45,51) As there is a possibility to have multiple complaints, this numbers could not be summed up. An overview of the reported prevalence rates for each instrument group was presented in *Table 4d*. Overall, no specific instrument group had an evidently higher prevalence rate of musculoskeletal complaints. However, brass instrumentalists were reported to have the lowest prevalence rates of musculoskeletal complaints.(9,16,18,20,40,43,45,48,51,52)

Age

One study compared lifetime prevalence rates of musculoskeletal complaints among age groups.(48) The highest prevalence rates were reported in the highest (50-61 years; 91%) and youngest (22-29, 83%) age groups.

Anatomic region

Above mentioned differences in the reporting of complaints are also reflected in the heterogeneity of studied body areas. The number of reported body regions differed from four (e.g. neck, shoulder (both/left/right), fingers (each separate, or in general) up to 32. This high variability between affected anatomical areas (i.e. heterogeneity in location of complaints) made comparison between the included studies difficult. Even more since multiple complaints at several anatomic regions can be present, as well as radiation of these complaints to different anatomical regions. In *Table 4e* the prevalence rates for each anatomic region are presented. Overall, the neck and shoulders were most frequently affected and the elbows had the lowest prevalence rate of musculoskeletal complaints. No differences between left and right side of the body were evident.

Table 3: Study and study population characteristics

	Response rate (%)	Number participants (n)	Age	Gender (% Male)	Instruments (%)	Job characteristics	Definition or description of 'musculoskeletal complaints	Localization of complaints
Leaver et al. (2011)	51%	243	Mean 44 (range 23-64)	56%	String 62% Woodwind 15% Brass 16% Other 17%	British symphony orchestra musicians	'The questions on musculoskeletal symptoms were based on the standardized Nordic questionnaire and concerned pain' 'disabling pain was defined as pain in the past 12 months present for at least a month and which prevented attendance at work for at least 1 day'	Low back, neck, upper extremities
Paarup et al. (2011)	78%	441	Mean men 48 (CI 46-50) Mean women 39 (CI 37-43)	61%	String 47% Woodwind 14% Brass 12% Other 4%	Danish symphony orchestra musicians	'…adapted from the Nordic Musculoskeletal Questionnaire. The symptoms were measured as presence of trouble (ache, pain, or discomfort)' 'As in the DASH questionnaire four questions were asked to assess if the symptoms had led to difficulties in playing, but the time span of interest was extended to 12 months'	Neck, back, upper extremities
Kaufman-Cohen et al. (2011)	66%	59	Mean 43 (range 26-66 SD 11)	49%	String 66% Wind 34%	Israelian symphony orchestra musicians	'The presence of pain'	Upper extremities
Zaza et al. (1997)	67%	281	Mean 31	45%	String 33% Other 67%	USA classically trained musicians and university music students	'playing-related musculoskeletal problem (i.e. any pain, weakness, numbness, tingling, or other symptoms that interfere with your ability to play your instrument at the level you are accustomed to)'	Not specified
Abréu-Ramos et al. (2007)	90%	75	Mean 38 +/- 10 (Range 22-61)	79%	String 43% Woodwind 15% Brass 17% Percussion 4% Other 1%	Puerto Rico symphony orchestra musicians	'questions related to musculoskeletal problems, including pain, allodynia, and dysesthesias (expressed as burning, electrical sensation, 'pins and needles', tingling, numbness), weakness, cramps and involuntary movements'	Neck, back, upper extremities, mouth

Kaneko et al. (2005)	56%	241	Mean 32 (range 18-73, SD 11)	70%	String 61% Woodwind 17% Brass 12% Percussion 8% Conductor 2%	Brazilian symphony orchestra musicians	Pain. 'The McGill pain questionnaire was used to specify subjective pain experience using sensory, affective and evaluative word descriptors, and a body diagram was used to locate the pain.'	Head, neck, back, upper extremities
Engquist et al. (2004)	43%	103	Mean 40 (20-61)	61%	String 56% Wind 36% Other 5%	Swedish orchestra musicians	Extension of the Standardized Nordic Questionnaire	Total body
Davies et al. (2002)	45%	240	Mean 37 (SD 11)	56%	String 42% Woodwind 18% Brass 16% Percussion 7% Keyboard 12% Guitar 5%	Australian classical and non-classical instrumental musicians	'playing-related pain and/or symptoms (pins and needles, swelling, muscle weakness or loss of control)'	Not specified
Roach et al. (1994)	99%	90	Mean 23	54%		USA music academy instrumentalists	'Subjects were asked to report joint pain for any site at which they had experienced pain for at least 2 days during the preceding 4 weeks.'	Neck, upper back, upper extremities
O'Neill et al. (2001)	50%	103	Mean 36 (range 18-66)	49%	String 34% Trumpet 9% Piano 8% Percussion 8%	Instrumentalists from orchestras, a music academy and privately studying musicians in Canada	'Respondents reported that they had experienced pain as a result of playing their instrument at least once in the course of their musical studies' 'Chronic injury, that is, pain lasting for longer than three months'	Not specified
Kok et al. (2013), Kok et al. (2013)	26%	83	Mean 22 (SD 2) (>18)	26%	String 39% Woodwind 33% Brass 8% Percussion and keyboard: 20%	Dutch music academy students	'Questions on each of these body regions started by asking about complaints of – the specific body region – during the last 12 months'	Total body
Fishbein et al. (1988); Middlestadt et al. (1988); Middlestadt et al. (1989)	55%	2212	Mean 42	64%	String 62% Woodwind 16% Brass 16% Percussion 4% Keyboard: 1% Other: 1%	USA orchestra instrumentalists	'Thus musicians were asked to circle the number of all those problems they had experienced' '… of ICSOM musicians at one particular point in time. Thus, the data reflect prevalence, but not incidence.'	Total body

Ackermann et al. (2012), Kenny et al. (2013)	70%	377	Mean 42 (SD 10)	49%	String 63% Woodwind 18% Brass 15% Percussion 3% Other 1%	Australian symphony orchestra musicians	'performance-related musculoskeletal disorders were defined as 'any pain, weakness, numbness, tingling or other physical symptoms that interfere with your ability to play your instrument at the level to which you are accustomed. This definition does not include mild transient aches or pains'	Total body
Árnason (2014)	?	60 (74 including vocalists)1	Mean 22 (SD 4)	57%	String: 32% Woodwind and brass: 23% Keyboard: 23% Percussion: 4% Vocalist: 19%[1]	Icelandic music school students	'both the cumulative and current prevalence, as well as the severity of PRMD among musicians' Adapted and translated formerly used questionnaire	Total body
Steinmetz (2014)	57%	408	Mean 44 (SD 10)	58%	String: 56% Woodwinds 15% Brass: 14% Percussion: 3% Other: 3% Missing: 10%	German orchestra musicians	'Regarding playing-related musculoskeletal pain, participants were asked whether they had experienced current or past pain in several body regions'	Total body
Chimenti (2013)	26%	261	Range 22-75; 78% between 30 and 59	47%	String: 66% Woodwind: 18% Brass: 14% Other: 3%	Professional orchestra musicians of the international conference of symphony and opera musicians	'playing-related symptoms, including but not limited to: pain, weakness, stiffness, swelling, numbness, and/or decreased coordination associated with playing'	Total body
Fotiadis (2013)	60%	147	Mean 39 (SD?)	66%	String: 63% Woodwind: 17% Brass: 14% Percussion: 5% Other: 1%	Greek professional orchestra musicians	Standardized Nordic Questionnaire	Total body

1: Excluded in the reviewed prevalence rates

Table 4a: Total prevalence rates of musculoskeletal symptoms among professional musicians

	Point prevalence, not playing-related	Point prevalence, playing-related	12-months prevalence, not playing-related	12-months prevalence, playing-related	Life-time prevalence, not playing-related	Life-time prevalence, playing-related	Other prevalence
Leaver et al. (2011)			86%	41%			71% [1]
Paarup et al. (2011)			88%	73%			
Kaufman-Cohen et al. (2011)				83%			
Zaza et al. (1997)		39%				70%	
Abréu-Ramos et al. (2007)						81%	
Kaneko et al. (2005)	68% / 57% [2]						
Engquist et al. (2004)	61%			52%			47%[3]
Davies et al. (2002)		50%				93%	
Roach et al. (1994)							67%[4]
O'Neill et al. (2001)						90%	58%[5] / 36%[6]
Kok et al. (2013), Kok et al. (2013)	63%		89%				
Fishbein et al. (1988); Middlestadt et al. (1988); Middlestadt et al. (1989)		68%					
Ackermann et al. (2012), Kenny et al. (2013)		50%				84%	
Árnason (2014)						62%	
Steinmetz (2015)		9%				90%	63%[7]
Chimenti (2013)				93%			
Fotiadis (2013)						82%	

1: 4-weeks prevalence, not playing-related; 2: Differences in reported prevalence rates in text and tables; 3: Chronic, not playing-related (chronic defined as often, or all the time, in contrast to no, never, once or twice, or sometimes during the past 12 months); 4: 4-weeks prevalence of pain at least 2 days present; 5: Two-year prevalence, playing-related; 6: Pain lasting longer than three months ('chronic injury'); 7: Pain within the last 3 months, playing-related

Table 4b: Prevalence rates of musculoskeletal complaints among professional musicians; gender-specific results

	Type of prevalence	Specification body part	Men	Women	OR (SD) Women compared to Men	Other information on sex differences in the manuscript
Leaver et al. (2011)	12-months prevalence, not playing-related	Low back	47%	56%	1.4 (0.9-2.4)	
		Neck	48%	65%	2.0 (1.2-3.3)	
		Shoulders	42%	62%	2.2 (1.3-3.8)	
		Elbows	24%	17%	0.6 (0.3-1.2)	
		Wrists	29%	37%	1.4 (0.8-2.5)	
Paarup et al. (2011)	12-months-prevalence, not playing-related	Total	83%	97%		
		Neck			2.9 (1.9-4.6)	
		Upper back			2.8 (2.1-3.8)	
		Lower back			1.3 (0.8-2.4)	
		Left shoulder			2.4 (1.6-3.7)	
		Right shoulder			3.2 (1.8-5.6)	
		Left elbow			3.5 (1.2-10.1)	
		Right elbow			1.7 (0.8-3.6)	
		Left hand & wrist			3.3 (1.6-7.2)	
		Right hand & wrist			2.1 (1.5-3.0)	
Kaufman-Cohen et al. (2011)	12-months prevalence, playing-related	Upper extremities				'No significant differences'
Zaza et al. (1997)	Point prevalence, playing-related	Not specified			2.8 (1.1-7.5)	
Abréu-Ramos et al. (2007)	Lifetime prevalence, playing-related	Neck, back, upper extremities, mouth	80%	88%		
Kaneko et al. (2005)	Point prevalence, not playing-related	Head, neck, back, upper extremities				$p<0.001$

Engquist et al. (2004)	Point prevalence, not playing-related	Neck, back, shoulders	26%	37%		
Davies et al. (2002)		Not specified				'Female string players were more affected in the previous 12 months than male strings players. Related to his last result is the finding that for the previous year, men were significantly more affected by pain/symptoms than women, unless the women were string players'
Roach et al. (1994)	Four-weeks prevalence, not playing-related	Neck, upper back, upper extremities	61%	73%	1.7 (0.7-4.2)	
O'Neill et al. (2001)	Two-year prevalence, playing-related	Not specified	56%	60%		
Kok et al. (2013), Kok et al. (2013)		Total body				No information presented
Fishbein et al. (1988); Middlestadt et al. (1988); Middlestadt et al. (1989)	Point prevalence, playing-related	Total body	52%	70%		($p<0.05$)
Steinmetz (2015)	Lifetime prevalence, playing-related	Total body	88%	92%		

Table 4d: Prevalence rates of musculoskeletal complaints among professional musicians; instrument specific results

	Type of prevalence	Specification body part	Strings, prevalence	OR Strings[1]	Prevalence woodwinds	OR woodwinds1	Prevalence brass	OR brass[1]	Other[1]
Leaver et al. (2011)	12-months prevalence, not playing-related	Back		1		0.8 (0.4-1.7)		0.5 (0.2-1.0)	1.12 (0.4-3.2)
		Neck		1		2.5 (1.1-6.0)		1.0 (0.4-2.1)	1.42 (0.5-4.2)
		Shoulders		1		1.1 (0.5-2.5)		0.7 (0.3-1.7)	0.52 (0.2-1.6)
		Elbows		1		0.6 (0.2-1.7)		0.4 (0.1-1.2)	1.02 (0.3-3.2)
		Wrists/ hands		1		2.9 (1.3-6.7)		0.4 (0.2-1.2)	2.62 (0.8-7.7)
Paarup et al. (2011)	12-months prevalence not playing-related; OR compared with high strings	Neck		High: 1.0 Low: 1.0 (0.6-1.6)		0.5 (0.3-0.7)		0.8 (0.3-2.1)	0.62 (0.3-1.6)
		Upper back		High: 1.0 Low: 1.4 (0.6-3.0)		1.0 (0.5-2.0)		0.9 (0.4-1.9)	1.52 (0.8-2.9)
		Lower back		High: 1.0 Low: 0.7 (0.4-1.5)		0.5 (0.3-0.8)		0.8 (0.3-2.2)	0.82 (0.2-3.2)
		Left shoulder		High: 1.0 Low: 0.6 (0.3-1.1)		0.5 (0.3-0.8)		1.2 (0.6-2.4)	0.32 (0.1-0.8)
		Right shoulder		High: 1.0 Low: 1.7 (0.7-3.9)		0.8 (0.3-2.1)		1.3 (0.6-2.7)	0.82 (0.1-5.2)
		Left elbow		High: 1.0 Low: 1.5 (0.6-3.9)		0.4 (0.1-1.9)		1.7 (0.9-3.4)	4.72 (1.2-18.4)
		Right elbow		High: 1.0 Low: 1.1 (0.5-2.5)		1.0 (0.4-2.6)		0.6 (0.2-2.1)	1.22 (0.4-3.4)
		Left hand & wrist		High: 1.0 Low: 1.3 (0.7-2.6)		0.5 (0.2-1.2)		0.8 (0.4-1.8)	1.12 (0.2-6.7)
		Right hand & wrist		High: 1.0 Low: 1.8 (0.8-3.9)		1.2 (0.5-2.7)		0.4 (0.2-0.8)	1.82 (0.4-7.5)
Kaufman-Cohen et al. (2011)	12-months prevalence, playing-related	Upper extremities							'no statistically significant difference between string and wind musicians'

Zaza et al. (1997)	Point prevalence, playing-related	Not specified						Strings compared to keyboard OR 4.7 (CI 1.5-14.5)
Abréu-Ramos et al. (2007)	Lifetime prevalence, playing-related	Neck, back, upper extremities, mouth	High 78% Low 93%		82%	69%		100%[2]
Kaneko et al. (2005)	Point prevalence, not playing-related	Neck, back, upper extremities, mouth	69%		65%	55%		55%[2] All differences p>0.05
Engquist et al. (2004)	12 months prevalence, playing-related	Head, neck, back, upper extremities	39%	OR 2.0 (0.7-5.2) compared with non-string (adjusted for gender and age)				Non-strings: 23%
Davies et al. (2002)		Neck, back, shoulders						'String players were significantly more likely to have frequent and severe pain/symptoms over the playing lifetime'
Roach et al. (1994)	Four-weeks prevalence, not playing-related	Not specified		3.7 (1.4-9.2)9			0.5 (0.1-1.8)[8]	1.4 (0.8-2.6)[3] 1.7 (0.6-5.1)[4] 1.4 (0.5-3.7)[3]
		Upper back		6.3 (2.6-15.2)[9]			0.6 (0.1-2.8)[8]	0.8 (0.1-3.1)[4] 1.6 (0.8-3.1)[2] 0.5 (0.1-2.1)[3]
		Shoulders		6.5 (2.7-15.6)[9]			0.1 (0.0-2.1)[8]	0.7 (0.1-3.2)[4] 1.6 (0.8-3.0)[2] 1.2 (0.4-3.9)[3]
		Elbows		4.4 (0.9-20.5)[9]			0.9 (1.1-16.7)[8]	13.8 (4.0-47.6)[4] 0.9 (0.2-4.6)[2] 2.0 (0.2-16.7)[3]
		Wrists		3.3 (1.0-10.5)[9]			0.3 (0.0-5.9)	5.7 (1.8-18.0)[4] 1.8 (0.7-4.4)[2] 3.9 (1.2-12.2)[3]

		Hands	2.9 (1.0-8.4)[9]		0.5 (0.1-4.2)[8]	2.3 (0.6-8.6)[4] 1.2 (0.5-2.7)[2] 6.3 (2.4-16.4)[3]
Kok et al. (2013), Kok et al. (2013)	12-months prevalence, not playing-related	Total body	83%	93%	86%	94%[5] 100%[6]
	Point prevalence, not playing-related		62%	63%	29%	71%[5] 100%[6]
Fishbein et al. (1988); Middlestadt et al. (1988); Middlestadt et al. (1989)	Point prevalence playing-related	Total body	66%	48%	32%	60%[7]
Ackermann et al. (2012), Kenny et al. (2013)	Point prevalence, playing-related	Total body	Upper 45% Lower 54%	49%	55%	50%[2]
Árnason (2014)	Lifetime prevalence, playing-related	Total body	67%		Woodwinds and brass: 59%	69%[3] 0%[2] (n=3)
Steinmetz (2015)	Lifetime prevalence, playing-related	Total body	Upper: 90% Lower: 91%	87%	84%	85%[2]

1: OR compared to strings, unless otherwise stated; 2: Percussion; 3: Keyboard; 4: Guitar; 5: Percussion and keyboard; 6: Plucked strings; 7: Unspecified; 8: Horn; 9: Violin

Table 4e: Prevalence rates of musculoskeletal complaints among professional musicians; anatomic region results

	Type of prevalence	Neck	Upper back	Lower back	Shoulders	Elbows	Wrists	Hands	Other
Leaver et al. (2011)	12-months prevalence, not playing-related	56%		51%	51%	21%	Wrist+ hands: 33%		
	Four-weeks prevalence, not playing-related	36%		33%	37%	12%	Wrists + hands: 24%		
Kaufman-Cohen et al. (2011)	12-months prevalence, playing-related	39%	42%	49%	55%				
Abréu-Ramos et al. (2007)									Only figure presented, no exact prevalence rates.
Kaneko et al. (2005)	Point prevalence, not playing-related	7%	7%	11%	L:7% R:6%	L:4% R:6%	L:6% R:5%	L:8% R:5%	
Engquist et al. (2004)	Point prevalence, not playing-related	21%	13%	14%	26%	6%		10%	
	12-months prevalence, playing-related	21%	16%	6%	22%	10%		10%	
	Chronic prevalence1	18%	12%	8%	19%	3%		8%	
Davies et al. (2002)									No information presented
Roach et al. (1994)	Four-weeks prevalence, not playing-related	40%	28%	26%	28%	6%	14%	20%	Hips: 0% Knees: 17% Ankles/feet: 8%
O'Neill et al. (2001)									(among violinists) 'of note, is the preponderance of problems in the neck and upper back, and the greater number of injuries on the left side of the neck where the violin is held'
Kok et al. (2013), Kok et al. (2013)	12-months prevalence, not playing-related	46%	19%	40%	L:28% R:30%	L:7% R:2%	L:16% R:17%	L:8% R:17%	Knee L:6%; Knee R:6% Hip L:4%; Hip R:4% Ankle L:4%; Ankle R:2% Foot L:6%; Foot R:2% Jaw: 16%

Fishbein et al. (1988); Middlestadt et al.(1988); Middlestadt et al. (1989)	Point prevalence, not playing-related	L:22% R:21%	L:16% R:16%	L:22% R:22%	L:20% R:20%	L:8% R:10%	L:9% R:10%	L:14% R:9%	Finger L:16%; Finger R:9& Forearm L:8%; Forearm R:7% Middle back L:11%; Middle back R:11% Hip L:3%; Hip R:3% Knee L:4%; Knee R:4% Calf L:1%; Calf R:1% Ankle L:2%; Ankle R:2% Foot L:2%; Foot R:2% Toe L:1%; Toe R:1%
	Point prevalence playing-related (=severe)	L:12% R:13%	L:8% R:9%	L:11% R:13%	L:11% R:13%	L:4% R:6%	L:5% R:5%	L:10% R:5%	Finger L:9%; Finger R:5& Forearm L:5%; Forearm R:4% Middle back L:5%; Middle back R:5% Hip L:1%; Hip R:1% Knee L:1%; Knee R:1% Calf L:0%; Calf R:0% Ankle L:0%; Ankle R:0% Foot L:0%; Foot R:0% Toe L:0%; Toe R:0%
Ackermann et al. (2012), Kenny et al. (2013)	Point prevalence, playing-related	14%	12%	8%	Shoulder and upper arm L:6% Shoulder and upper arm R:11%	Elbow and forearm L:3% Elbow and forearm R:4%	Wrist and hand L:4% Wrist and hand R:3%		
Steinmetz (2015)	Lifetime prevalence, playing-related	73%	24%	51%	L:55% R:52%	L:17% R:20%	L:55% R:24%	Fingers L:17% Fingers R:20%	30%[2] 26%[3]
	Point prevalence, playing-related	18%	7%	9%	L:12% R:10%	L:4% R:4%	L:4% R:4%	Fingers L:5% Fingers R:2%	4%[2] 3%[3]
	3-months prevalence, playing-related	30%	11%	22%	L: 21% R: 22%	L: 6% R: 6%	L: 7% R: 6%	Fingers L: 8% Fingers R: 5%	9%[2] 7%[3]

1: Pain often, or all the time, in contrast to never, once or twice, sometimes during the last 12 months; 2: Teeth/Jaw; 3: Tempomandibular joint

DISCUSSION

This systematic review focused on the prevalence of musculoskeletal complaints among professional musicians. In the included articles there was a wide variability in the definition of these complaints as well as on the used outcome measures. The point prevalence of all musculoskeletal complaints ranges between 57 to 68% and for playing-related musculoskeletal complaints between 9 and 68%. Twelve-month prevalence ranged between 86-89%, playing-related twelve-months prevalence ranged between 41-93%. Playing- related lifetime prevalence ranged between 62-93%. In most studies women have a higher prevalence of complaints compared to men.

LIMITATIONS OF THIS STUDY

Due to heterogeneity on several aspects between the studies in this systematic review, pooling of study data was not possible. Since the critical review of Zaza et. al. in 1998(12), more than a hundred new articles describing musculoskeletal complaints among musicians were published. Of these articles twelve were included in this review. Many of these recently published articles lack essential methodological information (e.g. biased or non-described selection of participants, lack of reporting a response rate or a clear cut definition of the measured complaints). Also in the results section important information is often missing (e.g. location as well as duration of the complaints). Furthermore selection bias is often present in these studies. The latter is exemplified by missing, general baseline information, like age and gender on the study subjects (as well as which patients are selected to be included in the study and what the loss of follow-up is (i.e. response rate).(22–24,26,27,29–34,40,53)

As described in the methods section, all articles lacking a clear description of the study population or the measured prevalence rate the studies were excluded from this review. Therefore, the quality of the included studies in this review is generally high compared to the overall performing arts medicine literature. This is confirmed by the used methodological quality score on which 17 out of 21 studies score high.

Another limitation of this study is the lack of 'non-classical' professional musicians, e.g. musicians playing in a marching or pop/rock band. As these musicians have both another musculoskeletal load (e.g. standing performance instead of sitting) and another lifestyle,

they have possibly other musculoskeletal problems compared with the classical trained musicians.

MUSCULOSKELETAL COMPLAINTS IN MUSICIANS AND SUBGROUPS AT RISK

We found that females have a higher prevalence of musculoskeletal complaints when compared with men, this is in line with the literature of musculoskeletal complaints in the general population: female gender is a known risk factor for development of these complaints.(54)

Although comparing of the studies describing prevalence rates in music academy students and professional musicians was difficult due to heterogeneity no evident difference in prevalence rate between music academy students and professional orchestra musicians existed.

Comparison of prevalence rates of musculoskeletal complaints between musicians who play different instruments did not show a specific instrumental group with an evidently highest prevalence rate, although brass instrument players had the lowest prevalence. It should be noted that some of musicians play multiple instruments where all included studies describe only the main instrument. Besides, the instrument categories used, consist of instruments which vary in size and playing position and technique. By example the category strings consists of violin, viola (somewhat larger and heavier compared to the violin), cello and base players and in some studies even guitar players. The playing position of a base player is completely different compared to a violinist, since the instrument is larger, a sitting position is used and the repertoire of the base player (heavy, slow and often repetitive) is different compared to the fast and virtuoso repertoire of the violin. Thus, since the included articles combine the prevalence rates in groups of players, no distinction between subgroups of string players could be made.

No valid conclusion can be drawn from this review concerning the relation between age and musculoskeletal complaints among professional musicians. Only one study compared age groups, but this study used a lifetime prevalence rate and the risk of recall bias is high when using lifetime prevalence rates.(55) However, musculoskeletal complaints in the open population are most frequent among subjects in the fifth, sixth and seventh decade of their life.(54,56,57) As musicians pass through the same ageing process, it is supposed that the highest prevalence of musculoskeletal complaints among them would be the same compared to the general population. However, there might be

a 'healthy player effect', in which musicians with severe musculoskeletal complaints quit their career before reaching this age. Therefore, musicians could have another distribution of musculoskeletal complaints in age groups compared to the general population.

PRMDs / non-PRMDs

The term 'PRMDs' was introduced to evaluate musculoskeletal symptoms which interfere with the ability to play the instrument.(7) Since then, many studies evaluated these playing-related symptoms instead of evaluating all musculoskeletal symptoms, thereby excluding minor symptoms.(20,50,58) The use of this term has an important advantage; symptoms without impact on the musician (and therefore irrelevant symptoms) are excluded. However, the comparison of musicians with non-musicians is difficult with this definition. Besides, although Zaza et al. made a clear definition of the term PRMD(7), studies using other descriptions of the term are published.(48,59) The current definition of PRMD does not include a causality of the complaints (e.g. is the complaint the result of playing of the instrument, or is it i.e. the result of a trauma and influencing the ability to play).

Recommendations for future research

We recommend that future research should aim at a higher level of methodological quality to contribute to the existing knowledge of the occurrence and risk factors for musicians' musculoskeletal complaints. A minimum required is data on the included cohort, a brief definition of the measured musculoskeletal complaints (i.e. anatomic area) data on loss of follow-up as well as the use of validated outcome measures of this high demanding population of musicians. Focus should be on selecting subjects while avoiding bias (adequate response rate, describing non-responders and selection procedure), using adequate and validated instruments for measuring all outcomes; Using the DASH, SF-36, Michigan hand score, Nordic Musculoskeletal Questionnaire etc., has strong preference above using a non-validated self-made or adapted (modified existing, and not re-validated) questionnaire.(49) Scientific guidelines, by example the STROBE or IDEAL and NOS are recommended for increasing the quality of future studies.(60,61)

Conclusion

Musculoskeletal symptoms are highly prevalent among musicians, especially among women. In contrast to the literature on musculoskeletal complaints in the open

population, evidence is scarce concerning prevalence rates in subgroups of age or occupation. Future research concerning the epidemiology of musculoskeletal complaints among musicians should focus on associated risk factors and follow the current guidelines to optimise scientific quality.(60,61)

REFERENCES

1. Sataloff RT, Brandfonbrener AG, Lederman RJ. Performing arts medicine. Science & Medicine; 2010.
2. Bejjani FJ, Kaye GM, Benham M. Musculoskeletal and neuromuscular conditions of instrumental musicians. Arch Phys Med Rehabil. 1996;77(4):406–13.
3. Guptill C, Golem MB. Case study: musicians' playing-related injuries. Work. 2008;30(1051–9815 (Print)):307–10.
4. Hoppmann RA, Reid RR. Musculoskeletal problems of performing artists. CurrOpinRheumatol. 1995 Mar;7(1040–8711 (Print)):147–50.
5. Heinan M. A review of the unique injuries sustained by musicians. JAAPA. 2008 Apr;21(1547–1896 (Print)):45–46,48,50.
6. Spahn C, Ell N, Seidenglanz K. Psychosomatic aspects of occupational diseases in musicians: Cross-section study of hand surgery patients in talk therapy. Psychother Psychosom Medizinische Psychol. 2001;51(2):116.
7. Zaza C, Charles C, Muszynski A. The meaning of playing-related musculoskeletal disorders to classical musicians. SocSciMed. 1998 Dec;47(0277–9536 (Print)):2013–23.
8. Holst GJ, Paarup HM, Baelum J. - A cross-sectional study of psychosocial work environment and stress in the Danish symphony orchestras. - Int Arch Occup Env Heal Oct 20. (1432-1246 (Electronic)).
9. Kaneko Y, Lianza S, Dawson WJ. Pain as an incapacitating factor in symphony orchestra musicians in Sao Paulo, Brazil. MPPA. 2005;20(4):168–74.
10. Kaufman-Cohen Y, Ratzon NZ. Correlation between risk factors and musculoskeletal disorders among classical musicians. OccupMed(Lond). 2011 Mar;61(1471–8405 (Electronic)):90–5.
11. Parry CB. Prevention of musicians' hand problems. Hand Clin. 2003 May;19(0749–0712 (Print)):317–24, vii.
12. Zaza C. Playing-related musculoskeletal disorders in musicians: a systematic review of incidence and prevalence. CMAJ. 1998 Apr 21;158(0820–3946 (Print)):1019–25.
13. Silva AG, La FM, Afreixo V. Pain prevalence in instrumental musicians: a systematic review. MPPA. 2015 Mar;30(1):8–19.
14. Loney PL, Chambers LW, Bennett KJ, Roberts JG, Stratford PW. Critical appraisal of the health research literature: prevalence or incidence of a health problem. ChronicDisCan. 1998;19(0228–8699 (Print)):170–6.
15. Shamliyan T, Kane RL, Dickinson S. A systematic review of tools used to assess the quality of observational studies that examine incidence or prevalence and risk factors for diseases. JClinEpidemiol. 2010 Oct;63(1878–5921 (Electronic)):1061–70.
16. Kok LM, Vlieland TPV, Fiocco M, Nelissen RG. A comparative study on the prevalence of musculoskeletal complaints among musicians and non-musicians. BMC Musculoskelet Disord. 2013;14.
17. Kok LM, Vlieland TPMV, Fiocco M, Kaptein AA, Nelissen RGHH. Musicians' illness perceptions of musculoskeletal complaints. Clin Rheumatol. 2013;32(4).
18. Fishbein M, Middlestadt SE, Ottati V, Straus S, Ellis A. Medical problems among ICSOM musicians:

overview of a national survey. MPPA. 1988;3(1):1–8.

19. Middlestadt SE, Fishbein M. The prevalence of severe musculoskeletal problems among male and female symphony orchestra string players. MPPA. 1989 Mar;4(1):41–8.

20. Ackermann B, Driscoll T, Kenny DT. Musculoskeletal pain and injury in professional orchestral musicians in Australia. MPPA. 2012 Dec;27(0885–1158 (Print)):181–7.

21. Kenny D, Ackermann B. Performance-related musculoskeletal pain, depression and music performance anxiety in professional orchestral musicians: A population study. Psychol Music. 2015;43(1):43–60.

22. Fjellman-Wiklund A, Chesky K. Musculoskeletal and general health problems of acoustic guitar, electric guitar, electric bass, and banjo players. MPPA. 2006;21(4):169–76.

23. Kreutz G, Ginsborg J, Williamon A. Music students' health problems and health-promoting behaviours. MPPA. 2008;23(1):3–11.

24. Hagglund KL, Jacobs K. Physical and mental practices of music students as they relate to the occurrence of music-related injuries. Work. 1996;6(Ireland LG-English PT-Journal: Short Survey EM-199600 DD-19960214):11–24.

25. Larsson LG, Baum J, Mudholkar GS, Kollia GD. Benefits and disadvantages of joint hypermobility among musicians. NEnglJMed. 1993 Oct 7;329(0028–4793 (Print)):1079–82.

26. Miller G, Peck F, Watson JS. Pain disorders and variations in upper limb morphology in music students. MPPA. 2002 Dec;17(United States LG-English PT-Journal: Conference Paper EM-200200 DD-20030104):169–72.

27. de Sousa CMG, Greten HJ, Machado J, Coimbra D. The Prevalence of Playing-related Musculoskeletal Disorders (PRMSD) Among Professional Orchestra players. Music Hodie. 2014;14(2):111–21.

28. Mishra W, De A, Gangopadhyay S, Chandra AM. Playing-related musculoskeletal disorders among Indian tabla players. MPPA. 2013 Jun;28(2):107–11.

29. Brandfonbrener AG. Orchestral injury prevention intervention study. MPPA. 1997;12(1):9–14.

30. Nemoto K, Arino H. Hand and upper extremity problems in wind instrument players in military bands. MPPA. 2007;22(2):67–9.

31. Mehrparvar AH, Mostaghaci M, Gerami RF. Musculoskeletal disorders among Iranian instrumentalists. MPPA. 2012 Dec;27(0885–1158 (Print)):193–6.

32. Nunes Marques D, Rosset-Llobet J, Fonseca Marques MF, Gurgel IGD, Augusto LGS. Flamenco guitar as a risk factor for overuse syndrome. MPPA. 2003;18(1):11–4.

33. Eller N, Skylv G, Ostri B, Dahlin E, Suadicani P, Gyntelberg F. Health and lifestyle characteristics of professional singers and instrumentalists. Occup Med. 1992 May;42(0962–7480 (Print)):89–92.

34. Caldron PH, Calabrese LH, Clough JD, Lederman RJ, Williams G, Leatherman J, et al. A survey of musculoskeletal problems encountered in high-level musicians. MPPA. 1986 Dec 12;1(4):136–9.

35. Wood GC. Prevalence, risk factors, and effects of performance-related medical disorders (PRMD) among tertiary-trained jazz pianists in Australia and the United States. MPPA. 2014 Mar;29(1):37–45.

36. T.M. L, Farias MJ. Strategies to promote health and prevent musculoskeletal injuries in students from the high conservatory of music of Salamanca, Spain. MPPA. 2013 Jun;28(2):100–6.

37. Barton R, Kallian C, Bushee M, Callen J, Cupp T, Ochs B, et al. Occupational performance issues and predictors of dysfunction in college instrumentalists. MPPA. 2008 Jun;23(United States LG-English PT-Journal: Article EM-200800 DD-20080827):72–8.

38. Zetterberg C, Backlund H, J. K, Werner HOL. Musculoskeletal problmes among male and female music students. MPPA. 1998 Dec;13(4):160–6.

39. Shields N, Dockrell S. The prevalence of injuries among pianists in music schools in Ireland. MPPA. 2000;15(United States LG-English PT-Journal: Article EM-200000 DD-20001220):155–60.

40. Arnason K, Arnason A, Briem K. Playing-related musculoskeletal disorders among icelandic music students: differences between students playing classical vs rhythmic music. MPPA. 2014 Jun;29(2):74–9.

41. Wristen BG, Fountain SE. Relationships Between Depression, Anxiety, and Pain in a Group of University Music Students. MPPA. 2013;28(3):152–8.

42. Chesky K. UNT-MHS website. 2000.

43. Paarup HM, Baelum J, Holm JW, Manniche C, Wedderkopp N. Prevalence and consequences of musculoskeletal symptoms in symphony orchestra musicians vary by gender: a cross-sectional study. BMCMusculoskeletDisord. 2011 Oct 7;12(1471–2474 (Electronic)):223.

44. Engquist K, Orbaek P, Jakobsson K. Musculoskeletal pain and impact on performance in orchestra musicians and actors. MPPA. 2004;19(2):55–61.

45. Leaver R, Harris EC, Palmer KT. Musculoskeletal pain in elite professional musicians from British symphony orchestras. Occup Med. 2011 Dec;61(1471–8405 (Electronic)):549–55.

46. Fotiadis DG, Fotiadou EG, Kokaridas DG, Mylonas AC. Prevalence of musculoskeletal disorders in professional symphony orchestra musicians in Greece: a pilot study concerning age, gender, and instrument-specific results. MPPA. 2013 Jun;28(2):91–5.

47. Kuorinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sorensen F, Andersson G, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. ApplErgon. 1987 Sep;18(0003–6870 (Print)):233–7.

48. Abreu-Ramos AM, Micheo WF. Lifetime prevalence of upper-body musculoskeletal problems in a professional-level symphony orchestra: Age, Gender, and Instr-ument-specific results. MPPA. 2007;22(3):97–104.

49. Poolman RW, Swiontkowski MF, Fairbank JCT, Schemitsch EH, Sprague S, Vet de H. Design, Conduct, and Interpretation of Nonrandomized Orthopaedic Studies--A Practical Approach . JBJS. 2009 Jan 5;supplement(91):41–9.

50. Davies J, Mangion S. Predictors of pain and other muscoloskeletal symptoms among professional instrumental musicians - Elucidating specific effects. MPPA. 2002;17(4):155–68.

51. Roach KE, Martinez MA, Anderson N. Musculoskeletal pain in student instrumentalists: a comparison with the general student population. MPPA. 1994 Dec;9(4):125–30.

52. Steinmetz A, Scheffer I, Esmer E, Delank KS, Peroz I. Frequency, severity and predictors of playing-related musculoskeletal pain in professional orchestral musicians in Germany. Clin Rheumatol. 2015 May;34(5):965–73.

53. Larsson LG, Baum J, Mudholkar GS, Kollia GD. Nature and Impact of Musculoskeletal Problems in A Population of Musicians. MPPA. 1993;8(3):73–6.

54. Picavet HS, Schouten JS. Musculoskeletal pain in the Netherlands: prevalences, consequences

and risk groups, the DMC(3)-study. Pain. 2003 Mar;102(0304–3959 (Print)):167–78.

55. Moffitt TE, Caspi A, Taylor A, Kokaua J, Milne BJ, Polanczyk G, et al. How common are common mental disorders? Evidence that lifetime prevalence rates are doubled by prospective versus retrospective ascertainment. PsycholMed. 2010 Jun;40(1469–8978 (Electronic)):899–909.

56. Huisstede BM, Wijnhoven HA, Bierma-Zeinstra SM, Koes BW, Verhaar JA, Picavet S. - Prevalence and characteristics of complaints of the arm, neck, and/or shoulder (CANS) in the open population. - Clin J Pain2008 Mar-Apr;24(3)253-9. (0749-8047 (Print)).

57. Huisstede BM, Bierma-Zeinstra SM, Koes BW, Verhaar JA. Incidence and prevalence of upper-extremity musculoskeletal disorders. A systematic appraisal of the literature. BMCMusculoskeletDisord. 2006 Dec 31;7(1471–2474 (Electronic)):7.

58. O'Neill L, Taunton J, MacIntyre DL. Making music: challenging the physical limits of the human body: a survey of musicians in western Canada. Physiother Canada. 2001 Apr;53(2):101.

59. Davies C. Musculoskeletal pain from repetitive strain in musicians: Insights into an alternative approach. MPPA. 2002;17(1):42–9.

60. Elm E vo., Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet. 2007 Oct 20;370(1474–547X (Electronic)):1453–7.

61. McCulloch P, Altman DG, Campbell WB, Flum DR, Glasziou P, Marshall JC, et al. No surgical innovation without evaluation: the IDEAL recommendations. Lancet. 2009 Sep 26;374(1474–547X (Electronic)):1105–12.

APPENDIX A: LITERATURE SEARCH

(Prevalence OR prevalence* OR incidence OR incidence* OR morbidity OR morbidit* OR epidemiology OR epidemics OR frequency OR surveillance OR outbreaks OR endemics OR mortality OR occurrence) AND ("Musculoskeletal Diseases"[Mesh] OR "Musculoskeletal System"[Mesh] OR "Musculoskeletal Physiological Phenomena"[Mesh] OR musculoskeletal OR musculo-skeletal OR "musculo skeletal" OR "musculoskeletal complaints" OR "musculoskeletal complaint" OR "musculoskeletal problems" OR "musculoskeletal problem" OR "musculoskeletal disorders" OR "musculoskeletal disorder" OR "Musculoskeletal Diseases" OR bone OR bones OR skeletal OR skeleton OR tendon OR tendons OR (joint NOT "joint improvisation") OR joints OR arthritis OR osteoarthritis OR shoulder OR shoulders OR wrist OR wrists OR knee OR knees OR hip OR hips OR elbow OR elbows OR leg OR legs OR arm OR hand OR hands OR feet OR foot OR spine OR spinal OR disc OR discs OR disk OR disks OR neck OR extremity OR extremities OR feet OR foot OR "Face"[Mesh] OR "face"[tw] OR orofacial*[tw] OR "facial"[tw] OR "Facial Pain"[Mesh] OR "Facial Nerve Diseases"[Mesh] OR "Facial Muscles"[Mesh] OR "Cheek"[tw] OR "Chin"[tw] OR "Eye"[tw] OR "Eyebrows"[tw] OR "Cheeks"[tw] OR "Chins"[tw] OR "Eyes"[tw] OR "Eyebrow"[tw] OR "Eyelids"[tw] OR "Eyelid"[tw] OR "Conjunctiva"[tw] OR "Eyelashes"[tw] OR "Eyelash"[tw] OR "Meibomian Glands"[tw] OR "Meibomian Gland"[tw] OR "Forehead"[tw] OR "Mouth"[tw] OR "Lip"[tw] OR "Nasolabial Fold"[tw] OR "Nose"[tw] OR "Foreheads"[tw] OR "Mouths"[tw] OR "Lips"[tw] OR "Nasolabial Folds"[tw] OR "Noses"[tw] OR "Parotid Region"[tw] OR "Nasal"[tw] OR "Facial Injuries"[Mesh] OR PRMDs OR PRMD OR muscle OR muscles OR myopathy OR myopathies OR dystonia) AND (((music OR "Music"[mesh]) AND ("Occupational Diseases"[mesh] OR occupation OR occupational OR occupation*)) OR musicians OR musician OR musician* OR "musical performance" OR "music academy students" OR "music students" OR "instrument players" OR "instrument player" OR pianist OR pianists OR "piano playing" OR "piano player" OR "piano players" OR violinist OR violinists OR "violin player" OR "violin players" OR "viola player" OR "viola players" OR cellist OR cellists OR "cello player" OR "cello players" OR "double base player" OR "double base players" OR "bass player" OR "bass players" OR bassist OR bassists OR "flute player" OR "flute players" OR flutist OR flutists OR "oboe player" OR "oboe players" OR oboeist OR oboeists OR "clarinet player" OR "clarinet players" OR clarinetist OR clarinetists OR "bassoon player" OR "bassoon players" OR bassoonist OR bassoonists OR "trumpet player" OR "trumpet players" OR trumpetist OR trumpetists OR trumpeter OR trumpeters OR "trombone player" OR "trombone players" OR trombonist OR trombonists OR "tuba player" OR "tuba players" OR "horn player" OR "horn players" OR hornist OR hornists OR "percussion player" OR "percussion players" OR percussionist OR percussionists OR "harp player" OR "harp players" OR harpist OR harpists OR "organ player" OR "organ players" OR organist OR organists OR "guitar player" OR "guitar players" OR guitarist OR guitarists OR "string player" OR "string players" OR "woodwind player" OR "woodwind players" OR "wind instrument player" OR "wind instrument players" OR "brass players" OR "brass player" OR drummer OR drummers OR "piano playing" OR "violin playing" OR "viola playing" OR "cello playing" OR "double base playing" OR "bass playing" OR "flute playing" OR "oboe playing" OR "clarinet playing" OR "bassoon playing" OR "trumpet playing" OR "trombone playing" OR "tuba playing" OR "horn playing" OR "percussion playing" OR "harp playing" OR "organ playing" OR "guitar playing" OR "string playing" OR "woodwind playing" OR "wind instrument playing" OR "brass playing").

Chapter 4

The high prevalence of playing-related musculoskeletal disorders (PRMDs) and its associated factors in amateur musicians playing in student orchestras

A cross-sectional study

Laura M. Kok

Karlijn A. Groenewegen

Bionka M.A. Huisstede

Rob G.H.H. Nelissen

A. Boni M. Rietveld

Saskia Haitjema

PLoS One. 2018 Feb 14;13(2)

ABSTRACT

Objective Despite the high number of amateur musicians in the general population, little is known about the musculoskeletal health of amateur musicians. Playing a musical instrument is supposed to be a risk factor for the development of musculoskeletal complaints. This study aimed to evaluate playing-related musculoskeletal disorders (PRMDs) among amateur musicians playing in student orchestras.

Design A cross-sectional study.

Participants 357 members of eleven Dutch student orchestras across the Netherlands were included in this study.

Intervention A paper-based questionnaire on PRMDs was used.

Outcome measures Sociodemographic characteristics and PRMDs were evaluated using an adaptation of the Nordic Musculoskeletal Questionnaire (NMQ) and the music module of the Disabilities of Shoulder and Hand (DASH) questionnaire.

Results The year prevalence of PRMDs among amateur musicians was 67.8%. Female gender, younger age, higher BMI and playing a string instrument were independently associated with a higher prevalence of PRMDs. The left shoulder was affected more frequently in violinists and violists, whereas the right hand and wrist was more frequently affected in woodwind instrumentalists. Of the subjects with PRMDs during the last week, the score of the music module of the DASH was 18.8 (6.3-31.2)

Discussion This study is the first to report on PRMDs and its associated factors in a large group of amateur musicians. The prevalence of PRMDs in amateur musicians is high, however the DASH scores reflect a confined impact of these PRMDs on functioning as a musician. Preventive measures are needed aiming at reducing PRMDs among amateur musicians.

INTRODUCTION

Playing a musical instrument is a risk factor for the development of musculoskeletal complaints, a phenomenon repeatedly confirmed in professional musicians.(1–5) However, only a minority of the musicians is professional, in the Netherlands an estimated 20.000-25.000 of a total population of 17 million people.(6) Contrary, 18% of the Dutch population, more than 3 million people, consider themselves amateur musicians.(7) Among university students the number of amateur musicians is possibly even higher; a Dutch study indicated that 33% of these university students played an instrument.(3)

The reported prevalences of PRMDs in amateur musicians vary greatly, depending on the study design and the population studied. Prevalences of up to 80% have been reported among amateur musicians.(8–12) These numbers seem to outline the prevalence of musculoskeletal complaints in the open population, for example in the Netherlands a year prevalence of 53.4% is reported in a survey in the open population.(13) However, no study directly comparing prevalences has been performed to our knowledge.(2,14,15) Female gender has been associated with a higher prevalence of playing-related musculoskeletal disorders (PRMDs) among amateur musicians.(2,11,12) Playing load is another confirmed risk factor among amateur musicians.(8,9,11) A recent cohort study reported a nearly threefold increase in prevalence following a sudden increase in playing time.(8)

However, literature studying the health of the amateur musician is scarce.(8) Several associated factors for PRMDs in professional musicians have not yet been studied in amateur musicians. Among these factors are instrument type, tobacco and alcohol consumption, exercise, playing experience and warming up, and perceived physical burden.(1,16,17) Also several biomechanical factors possibly influence the occurrence of PRMDs in musicians; asymmetric static playing posture, weight of the instrument and elevation of the arms possibly play a role in the development and maintenance of PRMDs.(14,16,18) Each instrument thereby has its own potential risk factors due to differences in playing technique.(19) Within the general population, additional to the music-specific risk factors, other determinants such as age, comorbidity and physical demands were found to be risk factors for musculoskeletal complaints.(20)

Therefore, this study aimed to explore the extent and prevalence of musculoskeletal health problems among amateur musicians. The first objective was to evaluate the

prevalence of PRMDs in amateur musicians.(21) The second objective was to identify factors associated with a higher risk of PRMDs.

MATERIALS AND METHODS

DESIGN

A cross-sectional study was performed among university student amateur musicians. Amateur musicians in this study are defined as all musicians who do not currently study at a music academy or have obtained a music academy degree. The timeframe for inclusion was set between February and May 2015 because we wanted to exclude PRMDs related to an increase in playing load related to the start of the orchestra season (September - October) and upcoming performances (November-December, June-July), as an increase in playing load is a known risk factor for PRMDs in amateur musicians.(8)

PARTICIPANTS

We approached 17 Dutch student orchestras all across the Netherlands for participation in the study. Two orchestras declined and four orchestras were not able to participate within the desired timeframe. Thus, we visited 11 student orchestras (LMK, KAG, SH, WB) during their weekly rehearsals and invited all the musicians who were present to participate in our study. A student orchestra in the Netherlands is an orchestra, mainly consisting of university students, for whom making music is a leisure activity. In other words, these students generally do not study music. However, some orchestra members attended or attend a music academy (fulltime or part-time professional musical education); they were excluded from participation in this study. A certain playing level is required to play in a Dutch student orchestra, as musicians have to play an audition (play for a committee who decides whether the musician has the desired playing capacities) before admission to the orchestra. In all orchestras a classical, symphonic program is played during the study period. The study protocol was reviewed by the regional ethical committee; (METC Zuid-West Holland, registration number 14-086) who decided the Medical Research Act did not apply. According to the Dutch Code of conduct for the use of data in health research, participants were presented with an opt-out and written informed consent was not collected as data were analysed anonymously.

OUTCOME MEASURES

The paper-based questionnaire used in this study has been described in PLOS in detail by Kok et al..(8) In brief, the questionnaire includes sociodemographic characteristics, such as gender, age and lifestyle habits, and music-related questions including instrument and playing experience. The part of the questionnaire focusing on PRMDs is an adaptation of the Nordic Musculoskeletal Questionnaire (NMQ).(22) We used Zaza's definition of PRMDs: 'pain and other symptoms that are chronic, beyond your control, and that interfere with the ability to play your instrument at the usual level'.(21) This definition of PRMDs was explicitly mentioned to the participants. Participants were asked if they had experienced such PRMDs during the past week, four weeks, three months and year and to identify the location of these PRMDs using the body map of the NMQ. The body map of the NMQ included the following anatomic localizations: mouth/jaw; neck; shoulder left; shoulder right; upper back; elbow left; elbow right; lower back; hand/wrist left; hand/wrist right; hip/upper leg left; hip/upper left right; knee left; knee right; foot/ankle left; foot/ankle right. To assess the degree of impact on musical activity, the music module of the DASH (Disabilities of Arm, Shoulder and Hand) was included in the questionnaire. This music module of the DASH consists of four questions evaluating the impact of the complaints on the ability to play the instrument during the last seven days (*Supplemental table 2)*. Each item was scored on a 5-point Likert scale; 1 representing the best and 5 the worst score on each question The response scores of each item were summed and transferred to a total score ranging from 0 (no disability) to 100 (completely disabled). The total score was calculated by adding the assigned values (1-5) for each response; divide this number by four, subtract one and multiply this number by 25.(23) In case of a missing value on one or more of the DASH questions, the subject was excluded from the DASH analysis.

The following anatomic regions for PRMDs were distinguished: head, mouth/jaw, neck, upper back, lower back, shoulders (left and right), elbows (left and right), hands/wrists (left and right), hips/thighs (left and right), knees (left and right), and feet/ankles (left and right). Instruments were classified following the traditional subdivisions; the category string instruments included the bowed string instruments violin, viola, cello and double-bass. The category woodwind instruments included the instruments flute, bassoon, clarinet, oboe, and saxophone. In the category brass instruments the horn, tuba, trumpet, trombone and euphonium were included. Percussion, piano and harp were classified as "other". All responses were entered anonymously into a database, with a unique identifier

for each questionnaire to preserve the link between database and paper. All answers were entered into the database as literally as possible. If a range was given, this was changed, in consensus (KAG, SH, LMK), to the lowest number for data entry.

DATA ANALYSIS

Baseline variables were represented as medians and quartiles 1 and 3 for continuous variables and as a number with a percentage for categorical variables. A prevalence was calculated for each anatomic region at each time point. This prevalence was also aggregated as prevalence of any complaint at certain points in time and as prevalence of any complaint at any point in time. Associations between patient characteristics, type of musical instruments, playing characteristics and outcome were explored using logistic regression modelling. Outcome was defined as any PRMD at any point in time. Possible risk factors were selected using literature search and expert knowledge. We considered age, alcohol use, BMI, experience, hand dominance, type of instrument, practice, sex, exercise and doing a warming up. We fitted two models. The first model was corrected for age and sex, as these variables are generally considered clinically relevant. Based on literature, in addition we included alcohol use, BMI, experience, hand dominance, type of instrument, practice, exercise and doing a warming up into the full model. The level of significance was set to 0.05. All analyses were performed using R (version 3.2.2) in the RStudio environment. (version 0.99.463)

RESULTS

The questionnaires were completed by 383 participants from 11 student orchestras across the Netherlands. After exclusion of 26 conservatory students, who were not considered amateur musicians, data of 357 participants were included in the analysis. The participants (28.9% male) were on average 22.4 years old (range 15.5-80.8). All baseline characteristics can be found in *Table 1*. Most participants played a string instrument (52.1%). A baseline table divided by instrument group can be found in *Supplemental Table 1*. The majority of the string instrumentalists and woodwinds were female (79.6% and 77.1% respectively), while the majority of the brass and other instrumentalists were male (64.4% and 62.5%, respectively).

PREVALENCE OF PRMDS

The prevalence of PRMDs in this population was 26.9% in the past week, 33.6% in the past four weeks, 37.3% in the past three months and 67.8% in the last year. String instrumentalists reported the highest number of PRMDs, and the year prevalence in this group was 74.2%. The prevalences of each instrument group are presented in *Table 2.*

Table 1: Baseline characteristics of the amateur musicians included in this study (n=357)

Age (years)		22.4 (20.6-24.7)
Sport (hours/week)		2.0 (1.0-3.0)
Alcohol (units/week)		4.0 (2.0-7.0)
BMI (kg/m2)		21.5 (20.0-23.2)
Instrument experience (years)		13.0 (10.0-16.0)
Practice (hours/week)		5.0 (3.8-7.0)
Sex	Female	248 (69.5)
	Male	103 (28.9)
	Missing	6 (1.7)
Smoking	No	318 (89.1)
	Yes	37 (10.4)
	Missing	2 (0.6)
Hand dominance	Right-handed	309 (86.6)
	Left-handed	47 (13.2)
	Missing	1 (0.3)
Warming up	No	189 (52.9)
	Yes	165 (46.2)
	Missing	3 (0.84)
Warming up duration (minutes)		5.0 (5.0-10.0)
Instrument group	String	186 (52.1)
	Woodwind	96 (26.9)
	Brass	59 (16.5)
	Other	16 (4.5)

Numbers are medians with (Q1-Q3) for continuous variables, and numbers with percentages for categorical variables

Table 2: Prevalence of PRMDs in amateur musicians by instrument group (n=357**)**

	Total (n=357)	**String (n=186)**	**Woodwind (n=96)**	**Brass (n=59)**	**Other (n=16)**
One week prevalence	26.9%	32.8%	21.9%	20.3%	12.5%
Four week prevalence	33.6%	36.6%	33.3%	28.8%	18.8%
Three months prevalence	37.3%	41.9%	36.5%	28.8%	18.8%
One year prevalence	67.8%	74.2%	63.5%	57.6%	56.2%

DASH

Of the subjects with PRMDs during the last week, 94 out 96 subjects completed all questions of the DASH. The score of the music module of the DASH was 18.8 (6.3-31.2) (median and interquartile range). String instrumentalists and instrumentalists in the group 'other' with PRMDs during the last week reported the highest DASH scores (18.9 (6.3 - 34.2) and 25.0 (15.6 - 34.3) respectively). The results of the individual questions of the music module of the DASH are displayed in *Supplemental Table 2.*

Table 3: Distribution of PRMDs over various instrumental groups (one-year prevalence)

	Strings (n=186)	**Woodwind (n=96)**	**Brass (n=59)**	**Other (n=16)**
Head	6 (3.2%)	4 (4.2%)	2 (3.4%)	0
Mouth / jaw	20 (10.8%)	20 (20.8%)	12 (20.3%)	0
Neck	69 (37.1%)	24 (25.0%)	9 (15.3%)	2 (12.5%)
Shoulder(s)	110 (59.1%)	35 (36.5%)	17 (28.8%)	7 (43.8%)
Shoulder left	97 (52.2%)	24 (25.0%)	12 (20.3%)	5 (31.2%)
Shoulder right	61 (32.8%)	29 (30.2%)	13 (22.0%)	5 (31.2%)
Upper back	60 (32.3%)	15 (15.6%)	6 (10.2%)	1 (6.2%)
Lower back	44 (23.7%)	12 (12.5%)	9 (15.3%)	2 (12.5%)
Elbow(s)	5 (2.7%)	2 (2.1%)	1 (1.7%)	1 (6.2%)
Elbow left	4 (2.2%)	0	1 (1.7%)	1 (6.2%)
Elbow right	2 (1.1%)	2 (2.1%)	1 (1.7%)	0
Hand(s) / wrist(s)	49 (26.3%)	25 (26.0%)	6 (10.2%)	4 (25.0%)
Hand / wrist left	34 (18.3%)	7 (7.3%)	4 (6.8%)	2 (12.5%)
Hand / wrist right	29 (15.6%)	23 (24.0%)	4 (6.8%)	3 (18.8%)
Hip(s) / upper leg(s)	2 (1.1%)	1 (1.0%)	0	0
Hip / upper leg left	2 (1.1%)	0	0	0
Hip / upper leg right	1 (0.5%)	1 (1.0%)	0	0
Knee(s)	3 (1.6%)	0	0	0
Knee left	2 (1.1%)	0	0	0
Knee right	1 (0.5%)	0	0	0
Foot / feet / ankle(s)	0	0	0	0
Foot / ankle left	0	0	0	0
Foot / ankle right	0	0	0	0

LOCATION OF PRMDS

Figures 1 to 3 show the body distribution of PRMDs in the different instrument groups. *Table 3* presents the corresponding year prevalences for each body region in each instrument group are shown. Of the string instrumentalists, 52.2% reported left shoulder PRMDs during the past year. In this group, 59.4% of the violinists and violists and 36.2%

of the cellists and double-bass players reported left shoulder PRMDs during the last year. Also, neck and back problems were reported more frequently among string instrumentalists. Among woodwind instrumentalists the right hand was more often affected than the left (24.0% versus 7.3%). This difference was found in all the instrumental groups of the woodwind section.

RISK FACTORS FOR PRMDS

Our logistic regression model showed that younger age (OR 0.94 (0.90-0.97)), higher BMI (OR 1.10 (1.00-1.21)) and female sex (OR 2.90 (1.78-4.77)) were independently associated with a higher prevalence of PRMDs. The age effect remained present after exclusion of participants aged 35 and older (n=12) (OR 0.84 (0.77-0.92)). *Table 4* shows the results of the sex- and age-corrected model, as well as the fully adjusted model.

Hand dominance was not significantly associated in our regression model with the prevalence of PRMDs in the complete group of musicians. However, left-handed brass instrumentalists reported a higher number of PRMDs than their right-handed colleagues. The prevalences related to hand dominance are presented in the *Supplemental Table 3.*

Table 4: PRMDs in amateur musicians (n= 357); logistic regression modelling

	Model adjusted for age and gender	**Full model**
	OR (95% CI)	**OR (95% CI)**
Age	0.94 (0.90-0.97)	0.93 (0.88-0.98)
Alcohol	0.99 (0.94-1.04)	0.97 (0.92-1.03)
BMI	1.10 (1.00-1.21)	1.14 (1.03-1.27)
Hand dominance (right-handedness)	0.84 (0.41-1.66)	0.78 (0.35-1.64)
Playing experience	0.99 (0.94-1.04)	0.97 (0.92-1.03)
Brass instrument (vs string)	0.69 (0.35-1.39)	0.54 (0.24-1.22)
Other instrument (vs string)	0.79 (0.26-2.63)	0.65 (0.20-2.28)
Woodwind instrument (vs string)	0.54 (0.31-0.96)	0.37 (0.20-0.70)
Practice (weekly playing load)	0.96 (0.90-1.04)	0.92 (0.85-1.00)
Female sex	2.90 (1.78-4.77)	2.28 (1.25-4.17)
Sport	1.01 (0.91-1.13)	1.02 (0.91-1.15)
Warming up (No)	0.95 (0.59-1.53)	0.71 (0.39-1.26)

Numbers are odds ratios (95% CI)

DISCUSSION

This study aimed to explore the extent and prevalence of the musculoskeletal health problems among amateur musicians. The year prevalence of PRMDs among amateur musicians in this study was 67.8%. Female sex, younger age, higher BMI and instrument group were independently associated with a higher prevalence of PRMDs. The left shoulder was affected frequently among violinists and violists, whereas the right hand and wrist were frequently affected in woodwind instrumentalists. This study is the first in the literature reporting on musculoskeletal health in a large group of amateur musicians. The reported prevalences in this study are in line with the scarce literature about PRMDs among amateur musicians.(8–11) Moreover, our prevalence PRMDs in amateur musicians are very comparable to the prevalences of PRMDs in high-level amateur musicians playing in two renowned Dutch national student orchestras, compared to our study population playing in local student orchestras.(8) Furthermore, the results of our study suggest that playing experience does not influence the occurrence of PRMDs in student amateur musicians.

For this study we choose to evaluate PRMDs by using an adapted version of the NMQ. This has several reasons; at first because it eases comparison to other studies evaluating PRMDs in musicians, as most studies assessing musculoskeletal health of musicians evaluate PRMDs instead of all musculoskeletal complaints.(1,8,11,16,24–26) By using the NMQ clarifying body diagrams are used; above this questionnaire is validated. We did however not revalidate our adapted version as only minor changes were made to the original questionnaire. By using the music module of the DASH we were able to evaluate the impact of the PRMDs, a valuable addition to the prevalence data.

The year prevalence of PRMDs in amateur musicians is comparable to the year-prevalence of PRMDs in professional musicians, as reported in a recent review (41-93%)(1) Also the other prevalences (e.g. week, month, 3-months) are comparable to the prevalence rates of professional musicians, although it should be mentioned that the range of these prevalences in the review is broad.(1) In this study, female sex and instrument group are independently associated with PRMDs among amateur musicians. These gender differences are in line with the literature on professional musicians, in which female musicians report more PRMDs.(1,2) Also the anatomic distribution of PRMDs is comparable to professional musicians.(1) However, when comparing literature on

amateur and professional musicians, one should realize that study protocols and definitions of complaints are heterogenous.(1)

The results of our study suggest that playing experience does not influence the occurrence of PRMDs in student amateur musicians. Although a sudden increase of playing load influences the occurrence of PRMDs(8), average playing load does not seem to be related to PRMDs, a finding consistent with the literature on amateur musicians.(14) Practicing more therefore does not seem to reduce or increase PRMDs; there are many possible other variables however which can confound this outcome, for example technical playing level and playing capabilities and difficulty of the played repertoire.

A surprising and significant finding in this study is the higher prevalence of PRMDs at a younger age. This finding cannot be explained by less playing experience, which we also included in our model. Furthermore, this effect did not disappear when we excluded participants aged 35 and older from the analysis. A possible explanation for this age dependent difference in this study could be the change in health behaviour in the younger students(27,28), which potentially could influence PRMDs. Healthcare providers therefore should be aware of the high prevalence of PRMDs in this younger population. As the effect of age is, however, minor (OR 0.94), future research should re-evaluate whether PRMDs actually are age-dependent.

Another remarkable finding in this study is the higher prevalence of PRMDs in left-handed brass instrumentalists compared to their right-handed colleagues. Although there are only eight left-handed brass instrumentalists included in this study, it is a striking difference between the two groups. Some brass instruments, for example the French Horn, are mainly played left-handed, which could potentially influence this difference. However, other studies evaluating the effect of handedness did not show differences between right- and lefthanded musicians.(29,30) Therefore, future studies among brass instrumentalists could be conducted aiming to clarify this issue of handedness.

As up to 20% of the general population consider themselves amateur musicians(7), PRMDs in this specific group have meaningful consequences. First, these PRMDs may interfere with other activities in daily life, such as work, and thus may have financial consequences, even though making music is not the source of income for amateur musicians. Second, PRMDs can affect the amount of pleasure that playing an instrument

generally conveys to the musician, thereby counteracting the mental health benefits. It is therefore surprising that literature on PRMDs in amateur musicians is so scarce. When we compare research on musculoskeletal complaints due to playing a musical instrument with research on those due to sports activities at the amateur level, there are considerable differences, mainly related to knowledge on the origin and treatment of these musculoskeletal complaints.(31–33) The field of performing arts medicine is clearly underdeveloped compared to sports medicine, which comprises extensive research not only on prevalences and risk factors, but also on preventive measures to reduce the number of PRMDs, both in professionals and in amateurs.(34)

No norm scores are available for using the DASH music module to reflect the impact and significance of PRMDs in musicians while playing a musical instrument. Moreover for the optional modules of the DASH the minimally clinically relevant differences are unknown. The results of the music module of the DASH are comparable with these results in a cohort of high-level amateur musicians playing in national orchestras, in which a DASH score (music module) of 14 is reported.(8) This DASH results therefore implicate that the PRMDs of the subjects do influence their playing behaviour, however, the impact of these PRMDs is confined. The relatively low DASH scores suggest that the severity of the evaluated PRMDs was generally limited.

One of the limitations in this study is the possible selection bias. In general, participants who experience PRMDs are more willing to complete a health-related questionnaire. To prevent selection bias as much as possible, the researchers who visited the orchestras explained the aims of the study and emphasized the importance of completing the questionnaire, regardless of the presence of PRMDs.

Overall, the current study analyses a specific group of amateur musicians. Amateur musician may comprise a wide range of age groups, as well as different musical activities. There is a clear difference in playing technique and playing habits between musical styles (for example classical versus pop music). In addition, the playing time and experience of amateur musicians vary greatly, which was reflected in our study population. The current study was performed in young amateur instrumentalists, the majority of whom had passed an audition before joining their orchestra, implicating a minimum required level of playing. Thus, our data cannot be extrapolated to all amateur musicians, who may not possess the desired skills to pass such an audition. In addition, vocalists were not included

in this study, as we aimed to evaluate the occurrence of PRMDs among instrumentalist musicians. A second limitation concerns the evaluation of sports. As we did not evaluate its intensity or exact physical activity, the reported activities might not be comparable, thereby influencing the regression analysis. Another limitation of this study concerns the musicians who play more than one instrument. In the present study, we chose to analyse data regarding the main instrument, as indicated by the musician. In theory, the PRMDs they reported could have been related to their second instrument. However, for all participants who indicated that they played two instruments, these instruments were within the same instrument category, therefore the effect on our results was most probably small. The instruments in this study were grouped according to posture and instrument. The grouping of instruments is another possible limitation as each group constitutes of different instruments, with differences in playing posture and technique, and therefore differences in musculoskeletal load. However, separately reporting prevalences for each instrument would not be reliable due to the relatively small sizes of these groups. The cross-sectional design of the study prohibits any conclusions regarding the causality of the observed risk factors that were associated with increased PRMDs. Moreover, as we studied amateur musicians, their PRMDs could also have originated from other activities in their daily lives. As most of them were students, for example excessive use of computers or reading textbooks in a wrong posture could have resulted in musculoskeletal complaints that interfere with playing their musical instrument. Our definition of PRMDs aimed to catch all musculoskeletal complaints that interfere with playing, and as such it does not state the source of the complaints.

One of the major strengths of this study is that it reports on the largest population of amateur musicians in literature. Due to this large study group, information on the prevalence of PRMDs and associated factors could be assessed relatively reliably. Moreover, this study was the first to systematically evaluate a collection of potential risk factors among amateur musicians. As the literature on amateur musicians is scarce, the current study fills a knowledge gap in medical science regarding musculoskeletal problems in the general population.

Future research among amateur musicians should aim to evaluate the occurrence and risk factors of PRMDs in other groups of amateur musicians. For example, older amateur musicians and non-classical musicians could be evaluated. This knowledge could serve as a guide for developing suitable preventive measures, for example physical training and

educational programs, to prevent the development, longer duration and severity of PRMDs in musicians.

Summarizing, in this study among a large group of amateur musicians playing in student orchestras, 67.8% of the instrumentalists reported PRMDs during the past year. The occurrence of these PRMDs was associated with female sex, younger age, higher BMI and playing a string instrument.

ACKNOWLEDGMENTS

The authors thank Wadim de Boon for his contribution to the design of the study and the data-collection. We thank Thomas Groenewegen for his contribution to the data entry. We also thank the board and the members of CREA orkest (Amsterdam), Delfts Studenten Muziek Gezelschap Krashna Musika (Delft), Groninger Studenten Muziekgezelschap Bragi (Groningen), Groninger Studentenorkest Mira (Groningen), Leids Studenten Koor en Orkest Collegium Musicum (Leiden), Rotterdams Studenten Orkest (Rotterdam), Studenten Harmonie Orkest Twente (Enschede), Studentenorkest De Ontzetting (Wageningen), UniversiteitsOrkest Maastricht (Maastricht), Utrechtsch Studenten Concert (Utrecht), Utrechts Studenten Koor en Orkest (Utrecht), and VU Orkest (Amsterdam) for their participation in this study.

REFERENCES

1. Kok LM, Huisstede BMA, Voorn VMA, Schoones JW, Nelissen RGHH. The occurrence of musculoskeletal complaints among professional musicians: a systematic review. Int Arch Occup Environ Health. 2016;89(3).

2. Kok LM, Huisstede BMA, Nelissen RGHH. Musculoskeletal complaints in male and female instrumental musicians. In: Legato M, editor. Principles of gender-specific medicine. 3rd ed. Academic Press; 2017.

3. Kok LM, Vlieland TPV, Fiocco M, Nelissen RG. A comparative study on the prevalence of musculoskeletal complaints among musicians and non-musicians. BMC Musculoskelet Disord. 2013;14.

4. Kok LM, Nelissen RGHH, Huisstede BMA. Prevalence and consequences of arm, neck, and/or shoulder complaints among music academy students: A comparative study. MPPA. 2015;30(3).

5. Zaza C. Playing-related musculoskeletal disorders in musicians: a systematic review of incidence and prevalence. CMAJ. 1998 Apr 21;158(0820–3946 (Print)):1019–25.

6. Wiel, A. van de RABM. Medische problemen bij musici. Ned Tijdschr Geneeskd. 2010;154(A1143):1–5.

7. Volz L, Deekman A, Heimans H. Factsheet Amateurkunst. Utrecht; 2014.

8. Kok LM, Haitjema S, Groenewegen KA, Rietveld ABM. The influence of a sudden increase in playing time on playing-related musculoskeletal complaints in high-level amateur musicians in a longitudinalcohort study. PLoS One. 2016;11(9).

9. Newmark J, RJ L. Practice doesn't necessarily make perfect: incidence of overuse syndromes in amateur instrumentalists. MPPA. 1987;2(4):142–4.

10. Dawson WJ. Upper extremity difficulties in the dedicated amateur instrumentalist. MPPA. 2001;16(4):152–6.

11. Buckley T, Manchester R. Overuse injuries in non-classical recreational instrumentalists. MPPA. 2006;21(2):80–7.

12. Sadeghi S, Kazemi B, Shooshtari SM, Bidari A, Jafari P. A high prevalence of cumulative trauma disorders in Iranian instrumentalists. BMCMusculoskeletDisord. 2004 Oct 14;5(1471–2474 (Electronic)):35.

13. Picavet HS, Schouten JS. Musculoskeletal pain in the Netherlands: prevalences, consequences and risk groups, the DMC(3)-study. Pain. 2003 Mar;102(0304–3959 (Print)):167–78.

14. Kok LM, Huisstede BM, Douglas TJ, Nelissen RG. Association of Arm Position and Playing Time with Prevalence of Complaints of the Arm, Neck, and/or Shoulder (CANS) in Amateur Musicians: A Cross-Sectional Pilot Study Among University Students. MPPA. 2017 Mar 1;32(1):8–12.

15. Huisstede BM, Wijnhoven HA, Bierma-Zeinstra SM, Koes BW, Verhaar JA, Picavet S. - Prevalence and characteristics of complaints of the arm, neck, and/or shoulder (CANS) in the open population. - Clin J Pain2008 Mar-Apr;24(3)253-9. (0749-8047 (Print)).

16. Kaufman-Cohen Y, Ratzon NZ. Correlation between risk factors and musculoskeletal disorders among classical musicians. OccupMed(Lond). 2011 Mar;61(1471–8405 (Electronic)):90–5.

17. Wu SJ. Occupational risk factors for musculoskeletal disorders in musicians: A systematic review. MPPA. 2007;22(2):43–51.

18. Edling CW, Fjellman-Wiklund A. Musculoskeletal Disorders and Asymmetric Playing Postures of the Upper Extremity and Back in Music Teachers A Pilot Study. MPPA. 2009;24(3):113–8.

19. Sataloff RT, Brandfonbrener AG, Lederman RJ. Performing arts medicine. Vol. 3rd. Science & Medicine; 2013.

20. Roquelaure Y, Ha C, Rouillon C, Fouquet N, Leclerc A, Descatha A, et al. Risk factors for upper-extremity musculoskeletal disorders in the working population. Arthritis Rheum. 2009 Oct 15;61(0004–3591 (Print)):1425–34.

21. Zaza C, Charles C, Muszynski A. The meaning of playing-related musculoskeletal disorders to classical musicians. SocSciMed. 1998 Dec;47(0277–9536 (Print)):2013–23.

22. Kuorinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sorensen F, Andersson G, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. ApplErgon. 1987 Sep;18(0003–6870 (Print)):233–7.

23. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). AmJIndMed. 1996 Jun;29(0271–3586 (Print)):602–8.

24. Engquist K, Orbaek P, Jakobsson K. Musculoskeletal pain and impact on performance in orchestra musicians and actors. MPPA. 2004;19(2):55–61.

25. Middlestadt SE, Fishbein M. The prevalence of severe musculoskeletal problems among male and female symphony orchestra string players. MPPA. 1989 Mar;4(1):41–8.

26. Ackermann B, Driscoll T, Kenny DT. Musculoskeletal pain and injury in professional orchestral musicians in Australia. MPPA. 2012 Dec;27(0885–1158 (Print)):181–7.

27. Keller S, Maddock JE, Hannöver W, Thyrian JR, Basler H-D. Multiple health risk behaviors in German first year university students. Prev Med (Baltim). 2008 Mar;46(3):189–95.

28. Hicks T, Heastie S. High school to college transition: A profile of the stressors, physical and psychological health issues that affect the first-year on-campus college student. J Cult Divers. 2008;

29. Kopiez R, Jabusch H, Galley N. No disadvantage for left-handed musicians: the relationship between handedness, perceived constraints and performance-related skills in string players and pianists. Psychol. 2012;

30. Christman S. Handedness in Musicians: Bimanual Constraints on Performance. Brain Cogn. 1993 Jul;22(2):266–72.

31. van der Horst N, Smits D-W, Petersen J, Goedhart EA, Backx FJG. The Preventive Effect of the Nordic Hamstring Exercise on Hamstring Injuries in Amateur Soccer Players. Am J Sports Med. 2015 Jun 20;43(6):1316–23.

32. Bizzini M, Junge A, Dvorak J. Implementation of the FIFA 11+ football warm up program: how to approach and convince the Football associations to invest in prevention. Br J Sport Med. 2013;

33. van Mechelen W, Hlobil H, Kemper HCG. Incidence, Severity, Aetiology and Prevention of Sports Injuries. Sport Med. 1992 Aug;14(2):82–99.

34. Leppanen M, Aaltonen S, Parkkari J, Heinonen A, Kujala UM. Interventions to prevent sports related injuries: a systematic review and meta-analysis of randomised controlled trials. Sport Med. 2014 Apr;44(1179–2035 (Electronic)):473–86.

Supplemental table 1: Musicians' characteristics by instrument group (overall study population n=357)

		Strings (n=186)	**Woodwind (n=96)**	**Brass (n=59)**	**Other (n=16)**
Age (years)		22.4 (20.7-24.6)	22.1 (20.3-24.3)	22.7 (20.8-25.2)	22.4 (20.8-25.8)
Sport (hours/week)		2.0 (0.5-3.0)	2.0 (1.0-3.0)	1.2 (1.0-2.8)	1.2 (0.0-2.0)
Alcohol (units/week)		3.0 (1.0-6.0)	3.0 (1.8-5.0)	6.0 (3.0-10.0)	10.0 (4.0-15.2)
BMI (kg/m^2)		21.2 (19.8-23.1)	21.8 (20.1-23.4)	21.6 (20.1-23.4)	22.0 (19.6-24.1)
Instrument experience (years)		14.0 (12.0-16.0)	12.0 (9.8-15.0)	11.0 (9.0-15.0)	13.0 (9.8-18.0)
Practice (hours/week)		5.0 (4.0-8.0)	4.0 (3.0-5.2)	5.0 (3.0-7.0)	4.0 (3.0-5.0%)
Sex	Male	34 (18.3%)	21 (21.9%)	38 (64.4%)	10 (62.5%)
	Female	148 (79.6%)	74 (77.1%)	21 (35.6%)	5 (31.3%)
	Missing	4 (2.2%)	1 (1.0%)	0	1 (6.3%)
Smoking	No	158 (85.0%)	86 (89.6%)	58 (98.3%)	16 (100.0%)
	Yes	26 (14.0%)	10 (10.4%)	1 (1.7%)	0
	Missing	2 (1.1%)	0	0	0
Hand dominance	Right-handed	164 (88.2%)	82 (85.4%)	51 (86.4%)	12 (75.0%)
	Left-handed	21 (11.3%)	14 (14.6%)	8 (13.6%)	4 (25.0%)
	Missing	1 (0.5%)	0	0	0
Warming up	No	62 (33.3%)	48 (50.0%)	53 (89.8%)	2 (12.5%)
	Yes	122 (65.6%)	47 (40.0%)	6 (10.2%)	14 (87.5%)
	Missing	2 (1.1%)	1 (1.0%)	0	0
Warming up duration (minutes)		10.0 (5.0-10.0)	5.0 (2.0-10.0)	5.0 (3.5-10.0)	10.0 (10.0-10.0)
Instruments		Violin 94 (50.5%)	Flute 26 (27.1%)	Horn 20 (33.9%)	Harp 1 (6.3%)
		Viola 34 (18.3%)	Oboe 9 (9.4%)	Trombone 30 (50.9%)	Piano 1 (6.3%)
		Cello 48 (25.8%)	Clarinet 28 (29.2%)	Bass trombone 3 (5.1%)	Timpani 1 (6.3%)
		Double bass 10 (5.4%)	Bass clarinet 2 (2.1%)	Tuba 4 (6.8%)	Percussion 13 (81.3%)
			Bassoon 9 (9.4%)	Euphonium 2 (3.4%)	
			Alto saxophone 17.7 (9.4%)		
			Baritone saxophone 1 (1.0%)		

Numbers are medians with (Q1-Q3) for continuous variables, and numbers with percentages for categorical variables

Supplemental table 2: DASH performing arts module; results per individual question of subjects with complaints during the last week) (n=94)

	1 (n)	2 (n)	3 (n)	4 (n)	5 (n)
Did you have any difficulty using your usual technique for playing your instrument?	59	26	9	0	0
Did you have any difficulty playing your musical instrument because of arm, shoulder or hand pain?	25	45	21	3	0
Did you have any difficulty playing your musical instrument as well as you would like?	38	36	15	4	1
Did you have any difficulty spending your usual amount of time practicing or playing your instrument?	43	20	18	12	1

Score of the performing arts module on 5-point Likert scale; 1 representing the best and 5 the worst score on each question

Supplemental table 3: Prevalence of PRMDs in each instrument group by hand dominance

	Strings right-handed (n=164)	Strings left-handed (n=21)	Wind right-handed (n=82)	Wind left-handed (n=14)	Brass right-handed (n=51)	Brass_ left-handed (n=8)	Other right-handed (n=12)	Other left-handed (n=4)
One-week prevalence	32.9%	28.6%	19.5%	35.7%	15.7%	50.0%	16.7%	0.0%
4-weeks prevalence	36.0%	38.1%	32.9%	35.7%	27.5%	37.5%	25.0%	0.0%
3-months prevalence	42.1%	38.1%	39.0%	21.4%	25.5%	50.0%	16.7%	25.0%
One-year prevalence	73.8%	76.2%	64.6%	57.1%	54.9%	75.0%	58.3%	50.0%

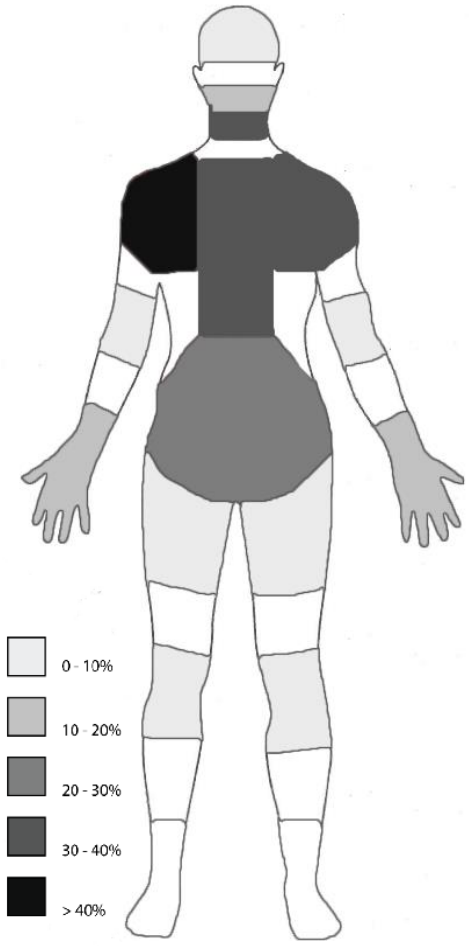

Figure 1: Localization of complaints in string instrumentalists (year prevalence)

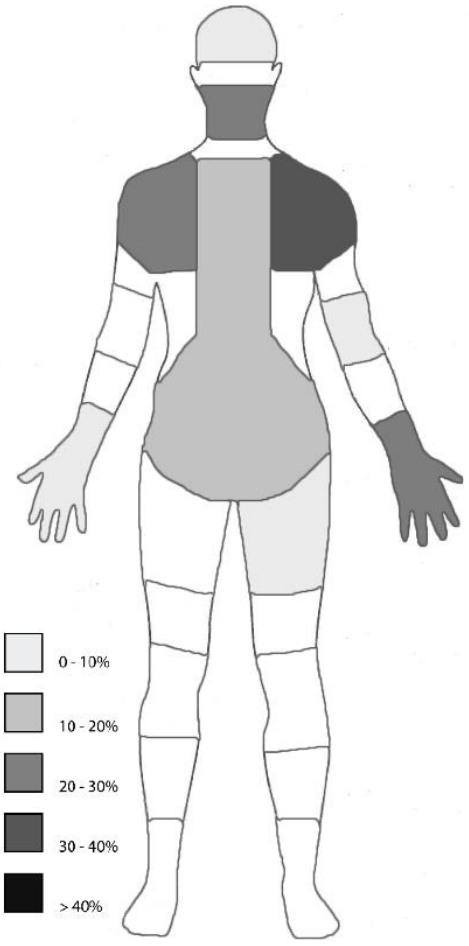

Figure 2: Localization of complaints in wind instrumentalists (year prevalence)

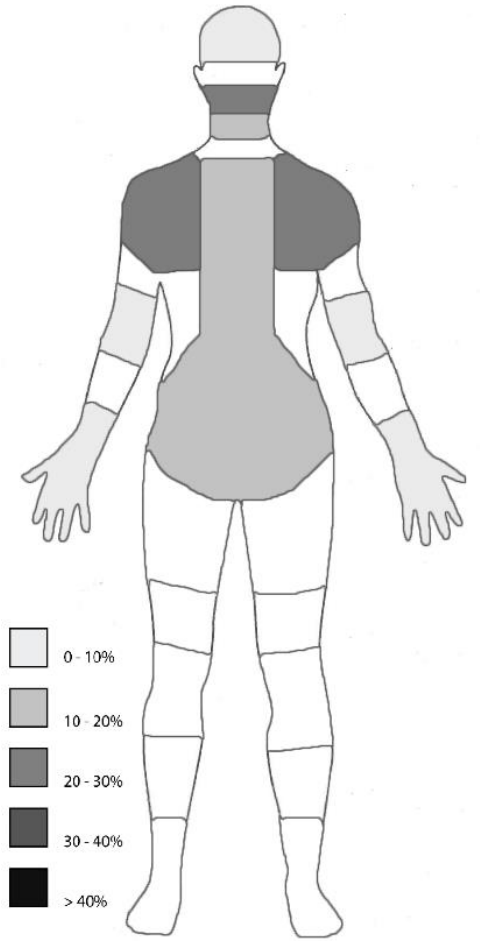

Figure 3: Localization of complaints in brass instrumentalists (year prevalence)

CHAPTER 5

Association of arm position and playing time with prevalence of complaints of arm, neck and/or shoulder (CANS) in amateur musicians

A cross-sectional pilot study among university students

LAURA M. KOK

BIONKA M.A. HUISSTEDE

TACO J. DOUGLAS

ROB G.H.H. NELISSEN

MPPA 2017 Mar;32(1):8-12

ABSTRACT

Objective Next to known risk factors for musculoskeletal complaints in the general population, playing an instrument is an additional risk factor for these complaints. In this study the prevalence of musculoskeletal complaints in student amateur musicians, and the relation with playing posture and playing time is evaluated.

Methods A cross-sectional web-based survey among amateur musicians studying at a Dutch university.

Results 162 amateur musicians were included in this pilot study (response rate 17.6%). 46.9% of these amateur musicians played with elevated arm position. CANS was not significantly related to arm position, except for complaints in the left shoulder in musicians playing with an elevated left arm compared to musicians playing with a neutral left arm position (OR 6.7, CI 95% 2.2-20.8) The number of hours playing per week did not significantly contribute to CANS (OR 1.0, CI 95% 0.95-1.17).

Conclusion The occurrence of CANS in student amateur musicians was not significantly associated with arm position, except for musicians playing with an elevated left arm ,which reported more complaints of the left shoulder. Playing time was not related to CANS in this group of university students playing an instrument on an amateur level.

INTRODUCTION

Professional musicians are at risk for musculoskeletal complaints. Up to 93% of the professional musicians experienced musculoskeletal complaints which interfered with playing at some time during their career.(1–3) The impact of these complaints on the professional musician is significant, thereby seriously influencing physical, psychological, social and financial aspects of daily life.(4–6)

Several risk factors are known for upper extremity and neck complaints in the general population; among them are an asymmetrical working posture and elevated arm position.(7–9) Musicians are exposed to several of these risk factors that may result in musculoskeletal complaints, depending on the played instrument. Other known risk factors for musculoskeletal complaints among professional musicians include sex, perceived work environment, playing time and the weight of the instrument.(10)

Despite a rapidly growing literature on the epidemiology of health issues of professional and student musicians, studies focusing on musculoskeletal complaints of amateur musicians are scarce. Given the fact that 20% of the western European population is amateur musician(11), scientific knowledge concerning this subject should be increased.

The acquired knowledge in professional musicians cannot be simply extrapolated to amateur musicians for several reasons. In contrast to amateur musicians, professional musicians are financially dependent on the capability to play the instrument. Also, the average playing time is higher among professional musicians compared to amateurs. Besides, due to the strict selection process during the educational period, selection is possibly influenced by the physical fitness of the musician, creating a health-related selection bias.

Upper extremity musculoskeletal complaints can be described by using the CANS (Complaints of Arm, Neck, and/or Shoulder) model.(12) In this model, complaints due to systemic disease or acute trauma are excluded. The term CANS was introduced following a multidisciplinary consensus project on the definition and classification of upper extremity and neck complaints. The advantage of its introduction in the field of performing arts medicine is the possibility to compare musicians with non-musicians.(13) Uniformity in language and definition of musculoskeletal complaints is of advantage in both the clinical and scientific context.

Elevated arm position is a known risk factor for musculoskeletal complaints in the general working population. Some studies indicate that musicians playing in an asymmetrical and/or elevated arm position may be more likely to have upper body musculoskeletal symptoms.(14–16) In the single study focusing on elevation as a risk factor for musculoskeletal complaints in musicians, performed by Nyman et al., a cut-off value of 40 degrees of elevation while playing is described, classified by the authors using photographs of experienced instrumentalists.(15) This cut-off value of 40 degrees was originally chosen following a study showing an impaired blood flow in the supraspinatus at this level of elevation.(17) As asymmetrical left- and/or right-sided elevation in the instrumental musician was not distinguished in this former study by Nyman et al., arm position was reclassified in the present study, maintaining the original 40 degrees of elevation but taking asymmetrical playing position into account.

Another suggested risk factor for the development of musculoskeletal complaints among musicians is playing time. However, unanimity concerning this subject in the scientific literature is lacking.(2,11,18,19) Therefore this study aims to evaluate the association between the occurrence of CANS in amateur musicians and two possible risk factors; arm position and playing time.

STUDY POPULATION AND METHODS

DESIGN

For this study describing amateur musicians, data from the control group of a formerly published study were used.(20) This former control group consisted of 503 students (response rate 17.6%) of the medical faculty of Leiden University; of them all (n=162) amateur musicians were included in the present study as follows: All students were asked to fill in an online questionnaire between February and May 2011, subjects who indicated playing a musical instrument, without attending a music academy (present or past) and without indicating themselves to be a professional musician, were defined to be amateur musician. Those subjects who were under 18 and above 30 years of age were excluded. The Medical Ethical Committee of the Leiden University Medical Center approved the protocol.

QUESTIONNAIRE

The online questionnaire included questions on socio-demographic variables, general health, playing time and musculoskeletal complaints. The baseline questionnaire evaluated socio-demographic variables (age, gender, anthropometric data and principal handedness) and general health variables (medical history, medication, intoxications and sports). Also playing time (years of active practicing and playing time in hours per week) and the mostly played instrument were questioned. In the original study musculoskeletal complaints were categorized in six body regions.(20) For the present study on CANS, data on complaints of the upper extremity not caused by trauma or systemic disease were used.

OUTCOME MEASURES

Outcome measures in this study were the occurrence of current CANS and CANS during the past 12 months in amateur musicians playing in neutral or elevated arm position. The relationship between CANS during the past 12 months and the average number of hours per week devoted to playing the main instrument was evaluated. The results were expressed as an OR and its 95% confidence interval (CI).

ARM POSITION

The participants were categorized into exposure groups according to their arm position; playing postures were classified as either none, one or both arms elevated. The arm position was defined as elevated when: ≥ 40° abduction and/or ≥ 40° forward flexion while playing. All other positions were classified as neutral. This classification and cut-off point of 40 degrees was formerly used by Nyman et al.(15), however adapted for this study in order to distinct left- and right sided elevation. Two researchers (TD and LMK) independently defined the arm position of the instrument groups, afterwards this categorization was compared between the two researchers. Discrepancies were solved by discussion. Initial agreement between the two researchers concerning the arm position was present in 42 of the 44 scored arm positions (95%). The initial disagreement between the researchers concerned both the right and left arm of the guitar players.

DATA ANALYSIS

The t-test, Chi-square test and Mann-Whitney U test were used to compare outcomes of amateur musicians playing their instrument in neutral arm position with amateur musicians playing their instrument in an elevated arm position. Multiple logistic

regression analysis was used to model playing time and arm position as predictors of the presence of CANS. The following variables were modeled in this regression analysis: Age, gender and BMI, next to arm position and playing time. The significance level for all tests was set to $p<0.05$.

RESULTS

The online questionnaire was sent to 2870 medical students and was returned by 503 students, of whom 162 played a musical instrument. Those 162 student amateur musicians were included in this study, of whom 16 (9.9%) played a bowed string instrument, 39 (24.1%) played a plucked string instrument, 26 (16.0%) played a woodwind instrument, 8 (4.9%) played a brass instrument, 5 (3.1%) played percussion and 68 (42.0%) were keyboard players. Thirty-three amateur musicians reported current CANS (20.4%), and 76 amateur musicians reported CANS during the past 12 months (46.9%).

ARM POSITION

Of all amateur musicians 46.9% (n=76) played an instrument using elevated arm position (23 both arms in elevated position, 1 elevated left arm only, 52 elevated right arm only). Those playing with elevated arm position were comparable to those playing in neutral arm position with respect to age, gender, BMI, hand preference, practice time and sports *(Table 1).*

Table 1 Baseline characteristics of amateur musicians by arm position

	Neutral arm position (n=86)	**Elevated arm position (n=76)**	**Difference (p)**
Age (years) *	21.8 (2.7)	21.7(2.4)	0.93[a]
Gender (% female)	67 (77.9%)	53 (69.7%)	0.24[b]
Body Mass index (kg/m2) *	21.2 (2.0)	21.8(2.3)	0.06[c]
Right-handedness	74 (86.0%)	64 (84.2%)	0.74[b]
Playing-time (hours per week) *	2.6 (3.0)	3.3 (3.2)	0.06[a]
Sports (hours per week)	2.8 (2.5)	3.3 (3.2)	0.90[a]

** Data expressed as mean (SD)*
[a] Mann Whitney U Test
[b] Chi square test
[c] T-test

Among musicians playing with an elevated left arm the prevalence of left shoulder pain was higher (29.2%) compared to musicians playing with a neutral arm position (5.8%) (OR

6.69, CI 95% 2.15-20.78). All other sites of complaints were not found to be statistically significant related to arm position *(Table 2).* Current CANS in amateur musicians playing in neutral position was 24.4% compared to 15.8% in amateur musicians playing in elevated position (OR 0.41, 95% CI 0.22-1.05). The 12-months prevalence in those playing in a neutral arm position was 45.3%, compared to 48.7% in subjects playing with elevated arm position (OR 1.14, 95% CI 0.61-2.12). The most prevalent site of CANS in amateur musicians was the neck, followed by the shoulders and wrists. The distribution of CANS by body-region did not differ significantly between the two arm positions *(Table 3).*

Table 2: Musculoskeletal complaints during the last twelve months among amateur musicians specified by arm-position and localization

	Hand	**Wrist**	**Elbow**	**Shoulder**	**Neck**	**CANS**
Neutral arm position (n=86) (%)	7 (8.1)	9 (10.5)	1 (1.2)	12 (14.0)	23 (26.7)	39 (45.3)
Elevated arm position (n=76) (%)	8 (10.5)	7 (9.2)	1 (1.3)	15 (19.7)	19 (25.0)	37 (48.7)
Difference (p) *	0.60	0.79	0.93	0.32	0.80	0.67

**Chi-square test*

Table 3: Arm position and site and number of musculoskeletal complaints during the last twelve months among amateur musicians

			Arm position					
			Left			**Right**		
			Neutral n=138 (%)	**Elevated n=24 (%)**	**OR (95% CI)**	**Neutral n=87 (%)**	**Elevated n=75 (%)**	**OR (95% CI)**
Site of complaints		Neck	38 (27.5)	4 (16.7)	0.53 (0.17-1.64)	23 (26.4)	19 (25.3)	0.94 (0.47-1.91)
	LEFT	Hand	5 (3.6)	3 (12.5)	3.80 (0.85-17.09)	5 (5.7)	3 (4.0)	0.68 (0.16-2.96)
		Wrist	5 (3.6)	0	-	5 (5.7)	0	-
		Elbow	1 (0.7)	1 (4.2)	5.96 (0.36-98.62)	1 (1.1)	1 (1.3)	1.16 (0.07-18.91)
		Shoulder	8 (5.8)	7 (29.2)	6.69 (2.15-20.78)	5 (5.7)	10 (13.3)	2.52 (0.82-7.75)
	RIGHT	Hand	7 (5.1)	2 (8.3)	1.70 (0.33-8.73)	4 (4.6)	5 (6.7)	1.48 (0.04-5.73)
		Wrist	9 (6.5)	4 (16.7)	2.87 (0.81-10.19)	6 (6.9)	7 (9.3)	1.39 (0.45-4.33)
		Elbow	0	0	-	0	0	-
		Shoulder	13 (9.4)	3 (12.5)	1.37 (0.36-5.23)	10 (11.5)	6 (8.0)	0.67 (0.23-1.94)

Note: Total number of included arms n=324 (respondents n=162)
** Chi-square test*

PLAYING TIME

In the study population the mean numbers of hours per week spend playing the instrument was 2.9 (range 0-21) Multiple logistic regression analysis was used to model

playing time as predictor of the presence of CANS. The number of hours per week devoted to playing an instrument was not found to contribute to the presence of CANS in a statistically significant way (OR 1.0 CI 95% 0.95-1.17, p=0.36).

DISCUSSION

The prevalence of CANS during the past 12 months in amateur musicians in this study is higher compared to the occurrence of CANS in the general population (46.9% versus 36.8%).(21) However, CANS in student amateur musicians in this study is considerably less prevalent compared to CANS in music academy students, among which a 12-months prevalence of 80.7% is reported.(22) This higher prevalence in professional musicians might be caused by occupational factors, like the inability to rest in presence of symptoms. The financial dependency on playing the instrument is hypothesized to be a contributing factor for this difference, as professional players most probably will not take a rest in presence of complaints. This financial dependency is logically absent among amateur musicians. Furthermore, amateur musicians play less hours a week compared to professional musicians. Next to the social and occupational differences, there is a difference in psychological factors between amateur and professional musicians. High demands and public exposure, related to performance anxiety, are factors which differ between amateur and professional musicians.(23)

If the instrument was played with the left arm in an elevated position (>40 degrees) a greater number of complaints of the left shoulder was present. A hypothesis for this finding might be the decreased blood flow of the shoulder muscles when the arm is elevated (16,24,25), although a higher biomechanical joint reaction force at the shoulder in this position, causing higher muscle strain is more probable. Furthermore, side dominance resulting in both better muscle strength and lesser fatigue on the right side could possibly protect against CANS in the right shoulder.(26) A relation is described between the presence of overall muscle fatigue and presence of pain causing coordination impairment with subsequent musculoskeletal complaints.(27) However, in the present study playing time was not found to be a predictor of CANS in amateur musicians. As pain and the ability to play are inextricably linked, one can argue that reported practice time is affected by the presence of CANS. This interaction hampers identification of playing time as an independent risk factor of CANS. As average playing

time per week was assessed and evaluated retrospective, recall bias may have affected results in the present study.

Another explanation for the complaints in the left shoulder is the basic forward flexed and externally rotated left shoulder position in violists and violinists.(28,29) The shoulder and neck rests influence the position of the instrument and therefore the range of motion and muscular activity of the shoulder.(30,31) As there is a known relationship between muscular activity and pain in violists and violinists(32), the tuning of the shoulder and chin rest is a possible amendable factor in prevention and treatment of musculoskeletal complaints in this group of musicians.

This pilot study has some limitations which should be kept in mind while interpreting the results. The first important limitation is the low response rate of this study (17.6%). The reason for this low response rate is the fact that the invitation for the questionnaire was sent by e-mail only twice, without the possibility to send a reminder in another form (i.e. telephone interview). Therefore, we do not have information on the non-responders in our study. As the non-respondents are in the majority, this low response rate could have seriously bias our results. However, it was unknown to our participants that we studied the association between CANS and the two hypothesized associated factors playing time and arm positioning. Therefore, this study is of added value for the knowledge on risk factors for CANS among amateur musicians despite its relevant low response rate.

This pilot study was performed among medical students, a very specific group of young, highly educated amateur musicians with special interests to health. Extrapolation of the outcomes of this study to amateur musicians in general should be done with caution. This pilot study merely explores CANS and relevant associated factors in amateur musicians, aiming to guide future research in this field. Thereby a broader group of amateur musicians should be studied, and bias minimized. For optimally evaluating the risk factor playing time a prospective designed study should be performed.

Another critical remark concerning the current study is the fact that the data were collected using self-reporting questionnaires without physical examination. One could debate that physical examination of the (amateur) musician is necessary to exclude any systemic illness which could affect the musculoskeletal system during playing an instrument. However, the a priori chance of the presence of an unknown systemic illness

at this early age is negligible. If any, this may have introduced an overestimation of the true prevalence of CANS in amateur musicians.

The classification of elevated arm position in this study is suboptimal, as not the individual musician was measured and arm position objectified. By separately classifying the arm position the researchers initially agreed in 95%, indicating at least a reliable inter-observer validity. In an optimal performed study, the arm position should be captured for each individual with physical objective measures. This critical note is thereby a suggestion for future research studying the relationship between musculoskeletal complaints and arm positioning.

CONCLUSION

The overall prevalence of CANS in student amateur musicians in this study was not significantly associated with arm position, except for musicians playing with an elevated left arm who reported more complaints of the left shoulder compared to musicians playing with a neutral arm position. This implies that research evaluating the optimal posture while playing a musical instrument may be of importance in the prevention, therapy and rehabilitation of CANS. The number of hours per week devoted to playing an instrument was not related to the prevalence of CANS. The results of this study should be interpreted with caution, and in order draw firm conclusions regarding this topic, future studies are needed in which musculoskeletal complaints and risk factors among a broader group of amateur musicians will be evaluated.

REFERENCES

1. Kok LM, Huisstede BMA, Voorn VMA, Schoones JW, Nelissen RGHH. The occurrence of musculoskeletal complaints among professional musicians: a systematic review. Int Arch Occup Environ Health. 2016;89(3).
2. Ackermann B, Driscoll T, Kenny DT. Musculoskeletal pain and injury in professional orchestral musicians in Australia. MPPA. 2012 Dec;27(0885–1158 (Print)):181–7.
3. Davies J, Mangion S. Predictors of pain and other muscoloskeletal symptoms among professional instrumental musicians - Elucidating specific effects. MPPA. 2002;17(4):155–68.
4. Zaza C, Charles C, Muszynski A. The meaning of playing-related musculoskeletal disorders to classical musicians. SocSciMed. 1998 Dec;47(0277–9536 (Print)):2013–23.
5. Spahn C, Ell N, Seidenglanz K. Psychosomatic aspects of occupational diseases in musicians: Cross-section study of hand surgery patients in talk therapy. Psychother Psychosom Medizinische Psychol. 2001;51(2):116.
6. Kok LM, Vlieland TPMV, Fiocco M, Kaptein AA, Nelissen RGHH. Musicians' illness perceptions of musculoskeletal complaints. Clin Rheumatol. 2013;32(4).
7. Hanvold TN, Waersted M, Mengshoel AM, Bjertness E, Veiersted KB. Work with prolonged arm elevation as a risk factor for shoulder pain: a longitudinal study among young adults. ApplErgon. 2015 Mar;47(1872–9126 (Electronic)):43–51.
8. Svendsen SW, Bonde JP, Mathiassen SE, Stengaard-Pedersen K, Frich LH. Work related shoulder disorders: quantitative exposure-response relations with reference to arm posture. OccupEnvironMed. 2004 Oct;61(1470–7926 (Electronic)):844–53.
9. Pope DP, Silman AJ, Cherry NM, Pritchard C, Macfarlane GJ. Association of occupational physical demands and psychosocial working environment with disabling shoulder pain. AnnRheumDis. 2001 Sep;60(0003–4967 (Print)):852–8.
10. Kaufman-Cohen Y, Ratzon NZ. Correlation between risk factors and musculoskeletal disorders among classical musicians. OccupMed(Lond). 2011 Mar;61(1471–8405 (Electronic)):90–5.
11. Volz L, Deekman A, Heimans H. Factsheet Amateurkunst. Utrecht; 2014.
12. Huisstede BM, Miedema HS, Verhagen AP, Koes BW, Verhaar JA. Multidisciplinary consensus on the terminology and classification of complaints of the arm, neck and/or shoulder. OccupEnvironMed. 2007 May;64(1470–7926 (Electronic)):313–9.
13. Kok LM, Nelissen RGHH, Huisstede BMA. Prevalence and consequences of arm, neck, and/or shoulder complaints among music academy students: A comparative study. MPPA. 2015;30(3).
14. Wahlstrom Edling C, Fjellman-Wiklund A, Edling CW, Fjellman-Wiklund A. Musculoskeletal Disorders and Asymmetric Playing Postures of the Upper Extremity and Back in Music Teachers A Pilot Study. MPPA. 2009;24(3):113–8.
15. Nyman T, Wiktorin C, Mulder M, Johansson YL. Work postures and neck-shoulder pain among orchestra musicians. Am J Ind Med. 2007;50(5):370–6.

16. Lonsdale K, Laakso EL, Tomlinson V. Contributing factors, prevention, and management of playing-related musculoskeletal disorders among flute players internationally. MPPA. 2014 Sep;29(3):155–62.

17. Jarvholm U, Palmerud G, Herberts P, Hogfors C, Kadefors R. Intramuscular pressure and electromyography in the supraspinatus muscle at shoulder abduction. ClinOrthopRelat Res. 1989 Aug;(0009–921X (Print)):102–9.

18. Yoshimura E, Fjellman-Wiklund A, Paul PM, Aerts C, Chesky K. Risk Factors for Playing-related Pain among Piano Teachers. MPPA. 2008;23(3):107–13.

19. Newmark J, RJ L. Practice doesn't necessarily make perfect: incidence of overuse syndromes in amateur instrumentalists. MPPA. 1987;2(4):142–4.

20. Kok LM, Vlieland TPV, Fiocco M, Nelissen RG. A comparative study on the prevalence of musculoskeletal complaints among musicians and non-musicians. BMC Musculoskelet Disord. 2013;14.

21. Huisstede BM, Wijnhoven HA, Bierma-Zeinstra SM, Koes BW, Verhaar JA, Picavet S. - Prevalence and characteristics of complaints of the arm, neck, and/or shoulder (CANS) in the open population. - Clin J Pain2008 Mar-Apr;24(3)253-9. (0749-8047 (Print)).

22. Kok LM, Nelissen RG, Huisstede BM. The striking prevalence and alarming consequences of Complaints of Arm, Neck and/or Shoulder among music academy students - a comparative study. MPPA. 2015 Jan 9;30(3):163–8.

23. Vervainioti A, Alexopoulos EC. Job-Related Stressors of Classical Instrumental Musicians: A Systematic Qualitative Review. MPPA. 2015 Dec;30(0885–1158 (Print)):197–202.

24. Palmerud G, Forsman M, Sporrong H, Herberts P, Kadefors R. Intramuscular pressure of the infra- and supraspinatus muscles in relation to hand load and arm posture. EurJ ApplPhysiol. 2000 Oct;83(1439–6319 (Print)):223–30.

25. Jensen BR, Sjogaard G, Bornmyr S, Arborelius M, Jorgensen K. Intramuscular laser-Doppler flowmetry in the supraspinatus muscle during isometric contractions. EurJ ApplPhysiol OccupPhysiol. 1995;71(0301–5548 (Print)):373–8.

26. Westrick RB, Duffey ML, Cameron KL, Gerber JP, Owens BD. Isometric shoulder strength reference values for physically active collegiate males and females. Sports Health. 2013 Jan;5(1941–7381 (Print)):17–21.

27. Fry HJH, Hallett M, Mastroianni T, Dang N, Dambrosia J. Incoordination in pianists with overuse syndrome. Neurology. 1998;51(2):512–9.

28. Shan G, Visentin P. A quantitative three-dimensional analysis of arm kinematics in violin performance. MPPA. 2003 Jan 3;18(1):3–10.

29. Tubiana R, Chamagne P, Brockman R. Fundamental positions for instrumental musicians. MPPA. 1989;4(2):73–6.

30. Levy CE, Lee WA, Brandfonbrener AG, Press J, Levy AE. Electromyographic Analysis of Muscular-Activity in the Upper Extremity Generated by Supporting A Violin with and Without A Shoulder Rest. MPPA. 1992;7(4):103–9.

31. Rabufetti M, Converti RM, Boccardi S, Ferrarin M. Tuning of the violin-performer interface. MPPA. 2007 Jan 6;22(2):58–66.

32. Berque P, Gray H. The influence of neck-shoulder pain on trapezius muscle activity among professional violin and viola players: An electromyographic study. MPPA. 2002;17(2):68–75.

Appendix: Consensus-sheet of arm position by instrument

Instrument	Arm position
Violin	Elevated (two-sided)
Viola	Elevated (two-sided)
Cello	Elevated (left)
Double bass	Elevated (left)
Piano/keyboard	Neutral
Guitar/Bass guitar/Mandolin	Elevated (right)
Bassoon	Neutral
Oboe/Alt Oboe	Neutral
Clarinet	Neutral
Harp	Elevated (two-sided)
Flute/Piccolo	Elevated (right)
Recorder	Neutral
Trombone	Elevated (two-sided)
Trumpet/Bugle	Elevated (two-sided)
Saxophone	Neutral
Pan Flute	Neutral
Percussion	Neutral
Tuba	Neutral
Kazoo	Neutral
Accordion	Neutral
Organ	Neutral
French horn	Neutral

Chapter 6

The influence of a sudden increase in playing time on playing-related musculoskeletal complaints in high-level amateur musicians in a longitudinal cohort study

Laura M. Kok

Saskia Haitjema

Karlijn A. Groenewegen

A. Boni M. Rietveld

PLoS One. 2016 Sep 22;11(9):e0163472

ABSTRACT

Background Several studies in the domain of professional musicians describe the relation between playing time and the occurrence of musculoskeletal complaints in professional musicians. To date, no longitudinal cohort study into this relationship has been performed and no amateur musicians were studied. Therefore, the aim of this study is to examine the causal relationship between a sudden increase in playing time among amateur musicians on the occurrence of musculoskeletal complaints in a prospective cohort study.

Methods All members of two national Dutch Students Orchestras were asked to participate in the study. These project-based orchestras, consisting of high-level amateurs, followed a nine hour rehearsing schedule for ten consecutive days. On the first day (t_0) and after one week (t_1) the subjects were asked to complete a paper-based questionnaire including sociodemographic characteristics, music-related questions, questions regarding playing-related musculoskeletal complaints and the music module of the disabilities of arm, shoulder and hand questionnaire.

Results The NSO consisted of 85 and the NESKO of 41 members during the study period. 59 subjects completed the questionnaire at both timepoints (response rate 47%). 9 subjects were excluded for being a music academy student, leaving 50 subjects (mean age 22.1, 72% female) suitable for analysis. During the rehearsal week, the prevalence of at least one playing-related musculoskeletal complaint increased from 28% to 80%. The most frequently affected areas were the neck, upper and lower back, hand/and or wrists and shoulders. The DASH music module score increased from 14 at t_0 to 23 at t_1.

Conclusion A point prevalence of 28% at the start of the study that increased remarkably to 80% within a one-week period. Future research should evaluate other risk factors for musculoskeletal complaints in amateur musicians. These risk factors should be the base for the development of preventive measures.

INTRODUCTION

Nearly 20% of the Dutch population considers itself amateur musician(1), and in the USA there are over 62 million active amateur musicians.(2) Whereas the knowledge of health problems among professional musicians is growing(3), little is known about the health effect of playing a music instrument on an amateur level.(4) For example, the prevalence rates of musculoskeletal complaints among children and adolescents, music academy students and professional musicians are increasingly studied(5), whereas amateur musicians seem to be underrepresented. This is remarkable as most musicians are amateur musicians and therefore a possible health problem in this group is clearly relevant in terms of public health.

Several studies in the domain of professional musicians describe the association between playing time and the occurrence of musculoskeletal complaints. These studies, all with a cross-sectional design, report conflicting results. Ackermann et al. evaluated professional orchestra musicians with musculoskeletal complaints.(6) These musicians self-reported insufficient rest (81%), long practice sessions (82%) and a sudden increase in playing time (76%) as causative factors for their complaints. In another study among professional orchestra musicians a positive correlation was found between the average of playing hours in an orchestra and playing-related musculoskeletal complaints.(7) Conversely, in a cross-sectional study among piano teachers, playing time was inversely related with musculoskeletal complaints.(8) To date, no longitudinal cohort study has been performed among amateur musicians. Therefore, the aim of this study is to examine the causal association between a sudden increase in playing time among amateur musicians on the occurrence of musculoskeletal complaints in a prospective cohort study.

METHODS

STUDY DESIGN AND SUBJECTS

We conducted a prospective cohort study, in which all members of the Dutch student orchestra (Nederlands Studenten Orkest; NSO) and Dutch student chamber orchestra (Nederlands Studenten Kamerorkest; NESKO) were invited to participate. The NSO and NESKO are project-based student orchestras, consisting of high level amateur musicians. Both orchestras hold an audition to select the best amateur student players from all over

the Netherlands. Therefore passing this audition with good result is an inclusion criterium. Once a year, nine-hour rehearsals are scheduled on ten consecutive days, followed by one to two weeks of daily concerts. At the first day (t=0) and after one week (t=1) during the rehearsal period in February 2015 (NSO) and May 2015 (NESKO) the subjects were asked to complete a questionnaire. As our study focused on amateur musicians, participants attending professional musical education were excluded. The study protocol was approved by the regional ethical committee; (METC Zuid-West Holland, registration number 14–086). No consent was collected as data were analysed anonymously.

QUESTIONNAIRE

The paper-based questionnaire included sociodemographic characteristics and music-related baseline questions. We asked participants for their gender, date of birth, weight, height, lifestyle habits (smoking, alcohol and exercise) and whether they were left- or right-handed. Then we asked them about their instrument and playing experience. The part of the questionnaire focusing on playing-related musculoskeletal complaints was an adaptation of the Nordic Musculoskeletal Questionnaire (NMQ). The definition by Zaza of playing-related musculoskeletal complaints was used(9); 'pain and other symptoms, that are chronic, beyond your control, and that interfere with the ability to play your instrument at the usual level'. Participants were asked if they had any complaints during the past week, and were subsequently asked to identify where these complaints were located using the body map of the NMQ. The following anatomic regions were distinguished: head, mouth/jaw, neck, upper back, lower back, shoulders (left and right), elbows (left and right), hands/wrists (left and right), hips/thighs (left and right), knees (left and right), feet/ankles (left and right). Finally to assess the impact on daily living, the music module of the DASH was included.(10)

DATA PROCESSING

All questionnaires were entered into a database, with a unique identifier for each questionnaire to keep the link between database and paper. All answers were entered into the database as close as possible to the information written down. If a range was given, this was changed to the lowest number during data-cleaning. Due to logistical constraints, we were unable to give each participant two questionnaires with identifiers at the start of the study. Therefore, the questionnaires from time 0 and time 1 were matched by a unique identifier comprising the participant's orchestra and birth date.

Therefore subjects who completed only one of the two questionnaires were excluded. Questionnaires with illegible or incomplete birthdates were also excluded.

DATA ANALYSIS

Baseline variables were represented as medians and quartiles 1 and 3 for continuous variables and as a number with a percentage for categorical variables. For each complaint, proportion of those reporting it at time 0 and time 1 was calculated. Subsequently, the absolute and proportional increase or decrease was calculated. As we were dealing with paired data, McNemar's test was used to test for significance in the difference in prevalence of complaints between time 0 and time 1. To compare the DASH-module between time 0 and time 1, we used a paired t-test. For all statistical tests, a two-sided p-value of < 0.05 was considered significant. All analyses were performed using R (version 3.2.2) in the RStudio environment (version 0.99.463).

RESULTS

The NSO consisted of 85 and the NESKO of 41 members during the study period. 59 subjects completed the questionnaire at both the first and second measuring moments, a response rate of 47%. 9 subjects were excluded for being a music academy students, leaving 50 subjects suitable for analysis.

In *Figure 1* a flowchart of the inclusion process is presented. The baseline characteristics of the included subjects are displayed in *Table 1.* The average age in the orchestras was 22.1 years (Q1-Q3 21.2–23.7), 72% of the study subjects were female. The orchestras consist of experienced amateur players, this is reflected in a median experience with the instrument of 13.5 years (Q1-Q3 11.2–15.0). The majority of players did warm-up before commencing rehearsals: 60%. The majority (84%) of respondents played a string instrument.

PLAYING-RELATED MUSCULOSKELETAL COMPLAINTS

At the start of the rehearsal period (t_0) 28% of the musicians experienced at least one playing-related musculoskeletal complaint. At t_1 this percentage had increased to 80%. There was one individual reporting complaints at the start of the study, but not after one week. Of those reporting no complaints at t_0 (n = 36), 27 (75%) developed at least one

complaint. The reported playing-related musculoskeletal complaints at specific locations at t_0 and t_1 are displayed in *Table 2.* The most frequently affected areas are the neck, back and shoulders.

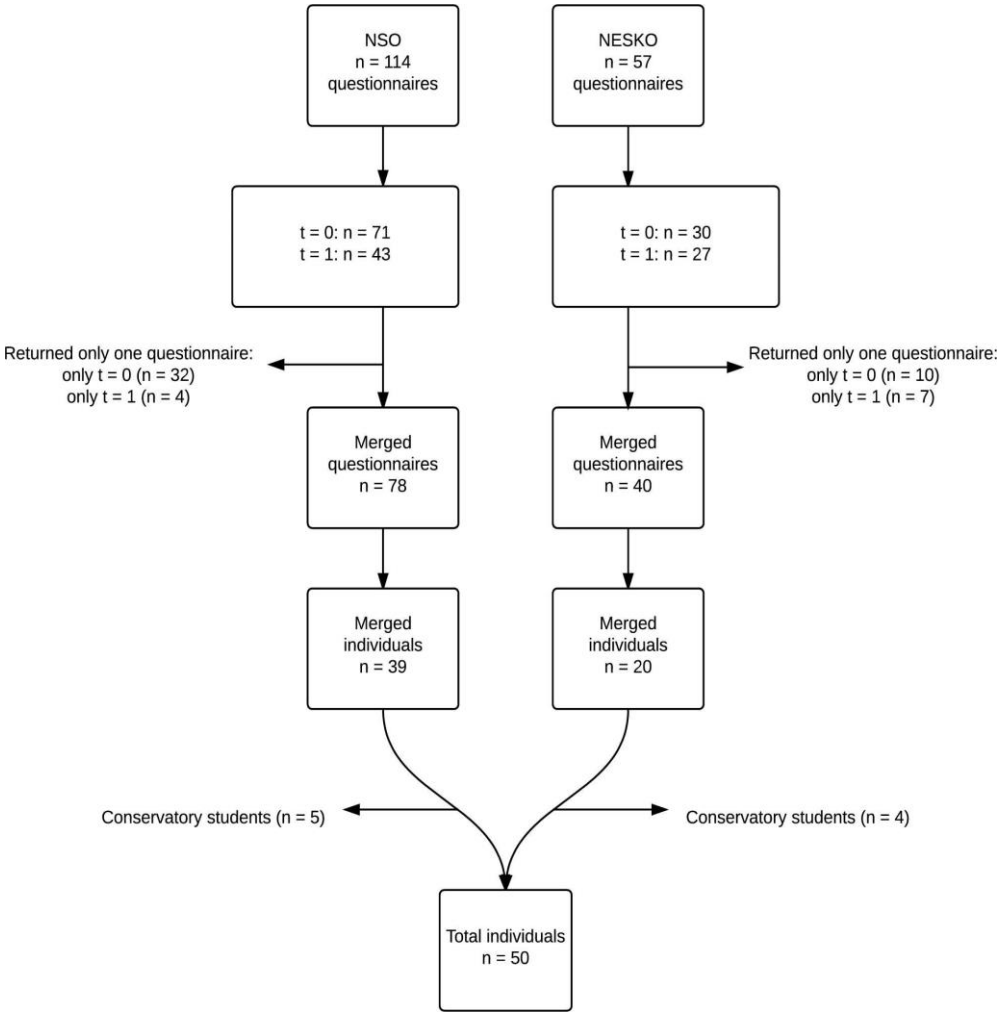

Figure 1: Flowchart of the inclusion process

DASH MUSIC MODULE

The score of the DASH module ranges between 0 (best score) and 100 (worst score). The score of the DASH music module in our study population was 14 at t_0, compared to 23 at t_1 ($p < 0.001$).

Table 1: Description of the cohort

Demographic information	Age (years)		22.1 (21.2–23.7)	
	Sex	Female	36 (72.0%)	
		Male	14 (28.0%)	
	Smoking	No	40 (80.0%)	
		Yes	10 (20.0%)	
Information related to playing	Exercise (hours/week)		2.0 (1.0–3.0)	
	Alcohol (units/week)		6.0 (3.0–10.0)	
	Warm-up duration (minutes)		10.0 (5.0–10.0)	
	Experience current instrument (years)		13.5 (11.2–15.0)	
	Dexterity	Right-handed	46 (92.0%)	
		Left-handed	4 (8.0%)	
	Warm-up	Yes	30 (60.0%)	
		No	20 (40.0%)	
Instrument	String-instrument	Total	43 (86.0%)	
		Violin		24 (55.8%)
		Viola		8 (18.6%)
		Cello		8 (18.65)
		Double bass		3 (7.0%)
	Wind-instrument	Total	5 (10.0%)	
		Trumpet		1 (20.0%)
		Horn		2 (40.0%)
		Oboe		1 (20.0%)
		Flute		1 (20.0%)
	Percussion	Total	2 (4.0)	

Numbers represent median (Q1-Q3) for continuous variables and n (%) for categorical variables

Table 2: Complaints in the last week at t_0 and t_1

	t_0	t_1	Difference	p-value
No complaint	17 (34.0%)	9 (18.0%)	-8 (-16.0%)	0.080
Head	1 (2.0%)	4 (8.0%)	+3 (+6.0%)	0.371
Mouth/Jaw	2 (4.0%)	4 (8.0%)	+2 (+4.0%)	0.617
Neck	6 (12.0%)	29 (58.0%)	+23 (+46.0%)	<0.001
Upper back	7 (14.0%)	23 (46.0%)	+16 (+32.0%)	<0.001
Lower back	4 (8.0%)	16 (32.0%)	+12 (+24.0%)	0.001
Shoulders	9 (18.0%)	31 (62.0%)	+22 (+44.0%)	<0.001
Shoulder (left)	9 (18.0%)	29 (58.0%)	+20 (+40.0%)	<0.001
Shoulder (right)	5 (10.0%)	19 (38.0%)	+14 (+28.0%)	<0.001
Elbows	0 (0.0%)	5 (10.0%)	+5 (+10.0%)	0.074
Elbow (left)	0 (0.0%)	4 (8.0%)	+4 (+8.0%)	0.134
Elbow (right)	0 (0.0%)	2 (4.0%)	+2 (+4.0%)	0.480
Hands/wrists	3 (6.0%)	21 (42.0%)	+18 (+36.0%)	<0.001
Hand/wrist (left)	2 (4.0%)	10 (20.0%)	+8 (+16.0%)	0.027
Hand/wrist (right)	1 (2.0%)	13 (26.0%)	+12 (+24.0%)	0.001
Hips/upper legs	0 (0.0%)	2 (4.0%)	+2 (+4.0%)	0.480
Hip/upper leg (left)	0 (0.0%)	2 (4.0%)	+2 (+4.0%)	0.480
Hip/upper leg (right)	0 (0.0%)	1 (2.0%)	+1 (+2.0%)	1.000
Knees	0 (0.0%)	1 (2.0%)	+1 (+2.0%)	1.000
Knee (left)	0 (0.0%)	1 (2.0%)	+1 (+2.0%)	1.000
Knee (right)	0 (0.0%)	0 (0.0%)	+0 (+0.0%)	NA
Feet/ankles	0 (0.0%)	0 (0.0%)	+0 (+0.0%)	NA
Foot/ankle (left)	0 (0.0%)	0 (0.0%)	+0 (+0.0%)	NA
Foot/ankle (right)	0 (0.0%)	0 (0.0%)	+0 (+0.0%)	NA

DISCUSSION

We studied the effect of a sudden large increase in playing time on musculoskeletal complaints in high-level amateur classical musicians. In our study-population, the prevalence of playing-related musculoskeletal complaints was 28% at baseline. After one week of intensive rehearsals, this percentage had increased to 80%. Probably the most obvious explanation for the sharp increase in reported complaints is the sudden increase in playing time. Amateurs, including high-level amateurs, are not used to playing for long

hours during consecutive days. Although we did not study the exact causal factors, we hypothesize that amateur musicians possess less technical strategies to cope with a sudden increase in playing time compared to professional musicians. This is for example reflected by the fact that not all musicians in our population performed warming-up exercises. Our population further differs from professionals as during this natural experiment, players also experienced lack of sleep and (for some) higher than normal alcohol consumption. These might play a role as aggravating factors in the development of playing-related musculoskeletal complaints.(11)

Almost all complaints in our population were reported in the upper body, most notably the neck and shoulders. This distribution of localizations of complaints has been described before. In a systematic review of studies describing the occurrence of musculoskeletal complaints among professional musicians, neck, shoulders and back were the most prevalent complaints.(3)

The sudden increase in musculoskeletal complaints at a music camp has been described before in folk musicians, yet in a less extreme environment. Buckley and Manchester reported a point prevalence of 44% at the end of a music camp for amateur folk-instrumentalists, and an incidence of 31% of overuse injury during the camp.(12) Interestingly, as these folk instrumentalists played on average less hours a day (3.7 hours a day in the Buckley study vs 9 hours a day in our population) the increase in prevalence was also less extreme (25% increase in the Buckley study versus a 52% increase in our population). This contributes to the hypothesis that there is a gradual association between the amount of increase in playing burden and the resulting playing-related musculoskeletal complaints. It should be realized that the participants in this study already are a fine selection of high level amateur musicians. Therefore, the healthy worker effect is applicable to this study: subjects with serious musculoskeletal complaints are more likely to drop out before reaching the acquired level or will at least reconsider taking part in such an intensive project.

Despite the fact that these rehearsal weeks can be considered an extreme form of exercise, both due to the extensive duration of practice and due to the high level of performance aspired by the orchestras, this does not mean that these findings are only relevant for this very select population and therefore cannot be generalized. Although we studied two groups highly educated, Caucasian, classical musicians, many of them

women, almost all musicians are amateurs. In addition almost all musical activities undertaken in a group show large variation in the amount of playing time as orchestras preparing for concerts plan extra rehearsal evenings and rehearsal time spikes during rehearsal weekends. Moreover, the consequences of developing a playing-related musculoskeletal complaints are most likely not confined to playing the instrument, as the distribution of complaints points towards locations that are also frequently used in daily life (e.g. back pain while sitting in a chair, wrist pain with repetitive hand motions like typing). This could lead to loss of productivity at work. However, despite the influence of the complaints on playing capacity, it is unknown what the impact of these complaints on other daily activities.

This study has some limitations. First of all, our definition of playing-related musculoskeletal complaints does not strictly exclude complaints that are not caused by playing the instrument. This could lead to information bias, where complaints of another cause were misclassified as playing-related musculoskeletal complaints. However, we did stress (both in the oral instructions and on the questionnaire itself)the definition of playing-related musculoskeletal complaints as stated by Zaza.(9) Furthermore, the prevalence of for lower extremity complaints was very low among our amateur musicians. This despite the fact that lower extremity complaints are more frequently reported compared to upper extremity complaints in the open population.(13)

Playing-related musculoskeletal complaints very probably do not have one causal factor, but are more likely a multifactorial issue. The effect of a sudden increase in playing time could be modified by other contributing factors like poor posture while playing, technique and lack of sleep. Above the 'tour-life', being away from home can influence the complaints. In addition, although part of the questionnaire we used was derived from the Nordic Musculoskeletal questionnaire, in its adapted form it was not revalidated. The DASH music module on the impact and significance of complaints while playing a musical instrument does not have norm scores for musicians. This should be taken into account while interpreting our results. When looking at the available information on this subpart of the DASH questionnaire, our t_0 DASH score was somewhat higher compared to the general US population aged 19–34 (5.12).(14,15) As expected, the t_1 DASH score in this study is more than one SD higher compared to the norm population. However, for the optional modules of the DASH the minimally clinically relevant differences are unknown. The clinical impact and of the above reported musculoskeletal complaints are supported

by the fact that five musicians had to reduce their playing activity during the rehearsal period.

A second limitation is that while we aspired to have each participant fill out the questionnaire twice (once at study start and once at study end), this was not realized due to logistical constraints and people not handing in their questionnaire. We did have 47% participants with two questionnaires, however there were 42 subjects with only the first and 11 with only the second. However, we do not think the filling out the questionnaire only once was related to the presence of playing-related musculoskeletal complaints. As such, it led to a decrease in our included sample size, but not to a (large) distortion of results.

Main strength of the study is the use of an existing event to study this scarcely studied population of classical amateur musicians. This gives the unique opportunity to study the association between a sudden increase in playing time and the development of playing-related musculoskeletal complaints and acquisition of a large sample size. We are the first to show that a sudden increase in playing time in high-level amateur classical musicians leads to complaints that inhibit an enjoyable leisure activity and can have implications on work in daily life.

Our study therefore stresses the need for implementing preventive measures for amateur musicians going on a music camp. Such preventive measures can take place both before and during the camp, for example by gradually increasing playing-time. Other possible preventive measures include advice on posture, and provision of quality furniture. Several studies show positive health outcomes as the result of an exercise and/or educational health program.(16–19) Future studies should aim at improving dedicated preventive health programs for musicians. Optimal scientific quality should be pursued in these studies. Above, other risk factors for musculoskeletal complaints in amateur musicians should be evaluated in future research. These risk factors should be the base for the development of preventive measures.

ACKNOWLEDGMENTS

The authors thank Wadim de Boon for his contribution to the design of the study and the data-collection. We also thank the board and the members of the NSO and NESKO for

the collaboration in this study. We thank Thomas Groenewegen for his contribution to the data entry.

REFERENCES

1. Volz L, Deekman A, Heimans H. Factsheet Amateurkunst. Utrecht; 2014.
2. Dawson WJ. Upper extremity difficulties in the dedicated amateur instrumentalist. MPPA. 2001;16(4):152–6.
3. Kok LM, Huisstede BMA, Voorn VMA, Schoones JW, Nelissen RGHH. The occurrence of musculoskeletal complaints among professional musicians: a systematic review. Int Arch Occup Environ Health. 2016;89(3).
4. Newmark J, RJ L. Practice doesn't necessarily make perfect: incidence of overuse syndromes in amateur instrumentalists. MPPA. 1987;2(4):142–4.
5. Sataloff RT, Brandfonbrener AG, Lederman RJ. Performing arts medicine. Vol. 3rd. Science & Medicine; 2013.
6. Ackermann B, Driscoll T, Kenny DT. Musculoskeletal pain and injury in professional orchestral musicians in Australia. MPPA. 2012 Dec;27(0885–1158 (Print)):181–7.
7. Kaufman-Cohen Y, Ratzon NZ. Correlation between risk factors and musculoskeletal disorders among classical musicians. OccupMed(Lond). 2011 Mar;61(1471–8405 (Electronic)):90–5.
8. Yoshimura E, Fjellman-Wiklund A, Paul PM, Aerts C, Chesky K. Risk Factors for Playing-related Pain among Piano Teachers. MPPA. 2008;23(3):107–13.
9. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). AmJIndMed. 1996 Jun;29(0271–3586 (Print)):602–8.
10. Lautenbacher S, Kundermann B, Krieg JC. Sleep deprivation and pain perception. Sleep MedRev. 2006 Oct;10(1087–0792 (Print)):357–69.
11. Buckley T, Manchester R. Overuse injuries in non-classical recreational instrumentalists. MPPA. 2006;21(2):80–7.
12. Zaza C, Charles C, Muszynski A. The meaning of playing-related musculoskeletal disorders to classical musicians. SocSciMed. 1998 Dec;47(0277–9536 (Print)):2013–23.
13. Jordan KP, Kadam UT, Hayward R, Porcheret M, Young C, Croft P. Annual consultation prevalence of regional musculoskeletal problems in primary care: an observational study. BMCMusculoskeletDisord. 2010;11(1471–2474 (Electronic)):144.
14. Hunsaker FG, Cioffi DA, Amadio PC, Wright JG, Caughlin B. The American academy of orthopaedic surgeons outcomes instruments: normative values from the general population. JBone Jt SurgAm. 2002 Feb;84–A(0021–9355 (Print)):208–15.
15. The DASH and Quick DASH e-bulletin - fall 2012. 2012.
16. Chan C, Driscoll T, Ackermann B. Exercise DVD effect on musculoskeletal disorders in professional orchestral musicians. OccupMed(Lond). 2014 Jan;64(1471–8405 (Electronic)):23–30.
17. Chan C, Driscoll T, Ackermann BJ. Effect of a musicians' exercise intervention on performance-related musculoskeletal disorders. MedProblPerformArt. 2014 Dec;29(0885–1158 (Print)):181–8.

18. Wilke C, Priebus J, Biallas B, Frobose I. Motor Activity as a Way of Preventing Musculoskeletal Problems in String Musicians. MPPA. 2011;26(1):24–9.

19. Foxman I, Burgel BJ. Musician health and safety: Preventing playing-related musculoskeletal disorders. AAOHNJ. 2006 Jul;54(0891–0162 (Print)):309–16.

CHAPTER 7

Musculoskeletal complaints in male and female instrumental musicians

LAURA M. KOK

BIONKA M.A. HUISSTEDE

ROB G.H.H. NELISSEN

In: Principles of gender-specific medicine, third edition: Gender in the genomic era (Chapter 37). Elsevier Academic Press; 2017

ABSTRACT

Musculoskeletal illnesses are a major cause of disease burden worldwide. They are the main cause of years lived with disability. The prevalence of musculoskeletal complaints is higher among females compared to males. This gender difference is present in both the general and the working population.

The prevalence of musculoskeletal complaints among musicians is higher compared with the general working population. In addition, the number of complaints and the impact on functioning is rated as more severe by musicians. Female musicians report a higher prevalence of musculoskeletal complaints, especially in the regions which are already most affected among musicians – the neck, upper back and shoulders. Several other factors related to musculoskeletal complaints in musicians are discussed. Practical guidelines for healthcare providers as well as preventive and therapeutic options are discussed.

I. A HISTORICAL PERSPECTIVE OF MUSCULOSKELETAL COMPLAINTS IN MUSICIANS

Music plays an important role in human culture. In prehistoric times, simple flutes and percussion instruments were already in use. Professional musicians were known in the ancient Greek and Roman traditions, and continued to exist even through the dark Middle Ages, when these professional musicians were known as troubadours. With the development of classical music, starting with the Baroque period, the development of the professional musician continued, and instruments used were increasingly standardised depending on the music compositions played. The violin, for example, was developed in Cremona by the Stradivari and Guarneri families in the 16th century. The way these instruments were crafted in that era is still considered the gold standard for both violin makers and violinists. In addition to the high demands on the craftsmanship of music instrument makers, the compositions to be played by musicians became also more physical demanding and virtuosic in the centuries that followed.

Barnadino Ramazzini was the first to give an exquisite description in 1713 of the presence of occupational diseases in musicians. 'There is no exercise, though never so healthful and innocent, but what may produce great disorders, if it is used with intemperance'.(1) Despite the interest of some physicians for specific musician- related diseases, it took until the 1960s when the specialty of music medicine really started. In the 1980s the terminology 'Performing Arts Medicine' emerged, with dedicated journals and conferences.(1) However, compared to sports medicine, a gigantic gap of both scientific knowledge, as well as awareness exists, by both physicians as well as the performing artists themselves.

Playing-related complaints among performing artists, either psychological or medical, were considered taboo until an 1981 article in the New York Times extensively described hand difficulties among world famous pianists Gary Graffman and Leon Fleisher.(2) Both were treated at the Massachusetts General Hospital. As a result of the publicity following the article, many other musicians who had never sought 'conventional' medical care sought medical help.(1) The experience of the physicians at the Massachusetts General Hospital with this large number of musicians was published in the Journal of the American Medical Association(3), marking the start of the new field of performing arts medicine.

In the scientific literature the first large study examining the health of performing artists was published in 1988.(4,5) In this study among professional symphony orchestra musicians, 82% reported medical problems at some point in their careers, while 76% had experienced a problem that was severe and affecting their performing ability. Musculoskeletal problems accounted for the majority of their occupational health problems. Psychological problems and substance abuse (alcohol, drugs, cigarettes and beta blockers) were considered to be other severe health issues in this population.(4,5)

Performing arts medicine developed in the years following these publications. A rapidly growing number of manuscripts reported details of musicians' health. Since the early nineteen and eighties specialized clinics, a performing arts journal (Medical Problems of Performing Artists, MPPA) and a yearly international conference were organized, all of them discussing and promoting the health and tabulating the occurrence of musculoskeletal complaints in performing artists. However, despite its recent growth spurt, the specialty of performing arts medicine is still much less developed compared to the field of sports medicine.(1)

II. MUSCULOSKELETAL COMPLAINTS IN THE GENERAL POPULATION

Musculoskeletal conditions are highly prevalent in the general population, and although they are not life-threatening, they cause the patient considerable discomfort during daily activities. These conditions are the most common cause of long term severe chronic pain and physical disability. Musculoskeletal conditions are one of the major causes of disease burden, and the main cause of years lived with disability.(6–8) They also represent 25% of the total health costs in European countries.(8,9)

During our daily life we are exposed to several risk factors for musculoskeletal problems: Demanding physical work, high psychosocial work demands, excessive repetition, awkward postures, and heavy lifting are known work-related risk factors for musculoskeletal complaints.(10) Above all, our leisure activities are associated with musculoskeletal problems; although physical activity reduces the risk for chronic diseases and disabilities(11), certain sports as soccer, handball and other ball and contact sports are associated with a high incidence of musculoskeletal injuries, resulting in subsequent physical impairment.(12,13)

IIA GENDER DIFFERENCES IN MUSCULOSKELETAL COMPLAINTS IN THE GENERAL POPULATION

Gender differences concerning musculoskeletal complaints and pain have been reported in multiple studies.(14,15) Most studies report female gender as a risk factor for the development of symptoms in the general population.(9,16–18) Women report higher prevalence rates of musculoskeletal complaints. They report pain more frequently, and complain of more intense and longer lasting pain compared with men.(19) The prevalence of neck and upper extremity complaints is particularly increased in females.(20) Women also have higher rates of sick leave due to musculoskeletal complaints.(21)

The underlying mechanisms explaining these sex differences are not completely understood; however explanations can be roughly divided in two models.(22) In the first model a higher exposure to risk factors for musculoskeletal complaints is stated to be the cause for gender differences *(exposure model).* The second category is the *vulnerability model.* This model suggests that women are more vulnerable compared to men for the development of musculoskeletal complaints. These differences may be caused by hormones, different pain sensitivity, or differences in social and psychological factors. This hypothesis is supported by a large Dutch study, in which the differences in prevalence rates of musculoskeletal complaints could not be explained by a different distribution of general risk factors. However, some risk factors (overweight; older age; and pain catastrophizing) had a different impact on musculoskeletal complaints in men and women.(22)

The vulnerability model is also supported by results of laboratory studies; women have greater pain sensitivity than men, especially when pressure pain is applied.(15,23) Pressure pain thresholds have been found to be diminished in women compared to men, and some authors maintain that this is the main reason for the observed gender differences in musculoskeletal pain.(15) Emerging evidence suggests that genotype and pre-sensitized receptors for endogenous opioid play a causal role in these disparities between men and women.(24) Furthermore, a considerable body of literature implicates sex hormones as factors influencing pain sensitivity.(24,25) Psychosocial processes such as pain coping and early-life exposure to stress are also hypothesized to explain gender differences in pain perception, as are stereotypical gender-specific behavior in the expression of pain.(24)

Concerning work-related complaints, differences in workload and work environment, work environments designed to male norms, and differences in posture and muscle strength are implicated in the production of musculoskeletal complaints and the differences between men and women in the experience of pain. In addition to these physical differences, psychosocial risk factors, such as low work satisfaction, a lack of social support, high perceived workload, time pressure, low job control, perceived stress and high psychological job demands are hypothesized to explain the sex differences.(15,26) Also diagnostic and treatment differences are suggested as possible influencers.(15)

III. MUSCULOSKELETAL COMPLAINTS IN MUSICIANS

Musicians can be arbitrarily divided into two groups: professional musicians, for whom music making is their occupation and main source of income, and amateur musicians. Of course, this dichotomy is somewhat artificial. In most literature music academy students are also considered to be professional as they are also as dependent on their ability to play their instrument as other professional musicians. Despite the fact that the majority of musicians are amateur musicians, for whom playing an instrument is a leisure activity, the importance of music making for these amateur musicians should not be underestimated. Musculoskeletal complaints impact the ability to play the instrument at the accustomed level of skill and are therefore relevant health issues.

An important subject of discussion in the field of performing arts medicine is the severity of the complaints and their impact on the ability to maintain a consistent level of performance. Most researchers studying musculoskeletal complaints in musicians exclude minor or irrelevant complaints, although both are ill-defined.(27) Therefore, Zaza developed a definition for playing-related musculoskeletal complaints in collaboration with musicians themselves.(28) Playing-related musculoskeletal complaints according to Zaza are defined as: 'Personal, chronic and disabling health problems that affected the whole person physically, emotionally, occupationally and socially'.(29) Despite these efforts to define PRMDs however, the term PRMD is used nowadays in the literature of performing arts medicine without strictly adhering to this definition. While studying the literature of performing arts medicine this should be kept in mind, especially when comparing prevalence rates of playing-related musculoskeletal complaints among musicians.

It is important to realize that apart from the definition used and the resulting number of musculoskeletal complaints that are reported, these complaints do have a great impact on the performing musician. However, at present there is little research aimed at studying the severity, and the impact on both the professional and private life of the musician. In a study among music academy students compared to a control group, the musicians rated their more frequent occurring musculoskeletal complaints as more severe and with more impact on daily activities compared to controls.(30) In this study health care usage among music academy students was higher compared to the control group. In another study illness perceptions among musicians and a control group with musculoskeletal complaints, were addressed.(31) Again, relevant and remarkable differences were found between the two groups. The data indicate that, next to the difference in the nature of the disorder itself, there are differences in the impact and consequences of these musculoskeletal complaints in musicians that should be considered.

One of the challenges in the detection of musculoskeletal complaints is the denial of the disability by the musician him or herself, despite the fact they often do result in inability to perform at the required or accustomed level. In the competitive environment of the professional musician, most of them do not have a permanent job contract but rather work as free-lancers. Consequently, minor complaints can be ignored easily because they could immediately result in financial problems.(31) The influence of musculoskeletal complaints on their career is devastating; studies report up to half of affected musicians leaving their careers as a result of these complaints.(32) However, exact and reliable numbers are missing due to the lack of prospective studies. As is often the case, particularly in studies of professional musicians, selection bias in reporting is present, since some of the musicians with severe musculoskeletal complaints interfering with their ability to play their instrument, will quit their job. This kind of bias is referred to as the 'healthy player effect', comparable to the healthy worker phenomenon.(33) The training and selection period for musicians starts very early, usually at the age of 5-10, and musculoskeletal complaints are frequently reported among young and adolescent musicians.(34–36) Therefore, the impact of this phenomenon on the reported prevalence rates in the literature is already relevant even before the start of a professional career.

Most musculoskeletal complaints among musicians can be classified as non-specific.(1,37,38) Other terms for these complaints, like surmenage, overuse syndrome, RSI (repetitive strain injury), WRULD (work-related upper limb disorders) are used in the

literature. Recently the term CANS (complaints of arm, neck and/or shoulder) was developed, aiming at uniformity in definition and classification.(39) A number of specific musculoskeletal problems in musicians are discussed below.

IIIA Focal dystonia

Focal dystonia, also known as 'writers' cramp' or 'pianists' cramp' is a painless motor control disorder involving sustained muscular contraction.(40,41) This involuntary contraction can be seen as an abnormal posturing and twisting of muscles during motor activities as making music.(42) The hand musculature is especially affected in musicians, although also the face musculature can be affected in wind and brass instrumentalists.(43,44) The pathophysiology of focal dystonia is unclear. Some claim a model in which anatomical connections are present between the forearm flexor tendons, and dystonic movements are a compensatory mechanism to overcome these anatomic limitations.(45) Other current evidence suggests a close network between cortical and subcortical areas in the brain.(46) However, both genetic predisposition and trauma are proposed as possible risk factors. Focal dystonia is a clinical diagnosis, with a gradual onset. Symptoms, including involuntary movements, stiffness and cramping, almost exclusively occur while playing the instrument. Therefore, physical examination while playing the instrument is mandatory. Therapeutic options are limited; they focus on technical retraining.(47–49) Supplemental anticholinergics and botulinum toxin injections are described, with moderately positive results. Recent studies showed promising effects of deep brain stimulation; however, this treatment modality is still in an exploratory phase with no long-term results.(50) Therefore, focal dystonia is still a career-threatening diagnosis for the musician.

IIIB Nerve entrapment syndromes

Loss of strength, sensory abnormalities and pain can be symptoms of nerve entrapment syndromes. It is supposed that musicians are more susceptible to nerve entrapment syndromes compared to non-musicians. These nerve entrapment syndromes have a more profound effect on musicians, due to the specific and complex musculoskeletal requirements. Mild symptoms can seriously influence the capability to play the instrument at the accustomed level.(1)

The basic work-up and diagnosis of entrapment therapies is similar to that of non-musicians. The signs and symptoms depend on the site of the injury. Specific attention

should be paid to provocative maneuvers while playing the instrument, in addition to clinical neurologic testing. Tinels' signs at the wrist (median nerve), Guyons' canal (ulnar nerve), pronator insertion (median nerve), elbow (ulnar nerve), lateral epicondyle or arcade of Frohse (radial nerve) and the tricipital and bicipital sulcus (ulnar and median nerve) should be considered.(41) It is important to realize that electrodiagnostic studies often produce false negative results in musicians, because their symptoms are commonly intermittent and only present while playing.(40,51,52) Conservative treatment, consisting of modification in playing technique, splinting, medication and injection can provide relief for a substantial percentage of patients.(53) Surgical decompression can be considered in case of failure of conservative treatment.

IV. Gender differences

IVa. Male and female professional musicians

For professional musicians, music making is their occupation and source of income. Within the group of professional musicians different occupations can be distinguished, although most musicians have more than one occupation; the work of the performing artists consists of giving concerts, either in a group (i.e. orchestra, music band or chamber ensemble), or as a soloist. In this group of artists performance stress and anxiety play an important role. Besides, the actual hours of prolonged playing are generally higher compared to music teachers. The latter group can work at a music academy, but also as an independent music professional. This difference implicates the financial dependency of continuously performing players compared to teachers and is therefore a stimulus for the former to continue playing whether or not hindered by pain.

A specific group of professional musicians are the music academy students. It should be noted that the entrance exam of music academies is usually demanding, requiring an intensive preparation program before being admitted. That is the reason for considering music academy students professional musicians.(27) This is reflected by their high workload and psychological stress during their studies. (27,54–56)

A recent systematic review analyzed the presence of musculoskeletal complaints among professional instrumental musicians.(27) In this review a distinction was made between PRMDs and musculoskeletal complaints in general. As mentioned before, the term PRMD was introduced aiming to exclude minor and irrelevant musculoskeletal symptoms

experienced by musicians.(29) Reported point prevalence rates of musculoskeletal complaints in this systematic review vary from 57 to 68% for all musculoskeletal complaints, and from 9 to 68% for playing-related complaints. Non-playing-related complaints related twelve-month prevalence range between 86-89%, playing-related twelve-month prevalence range between 41-93%.(27) Also playing-related lifetime prevalences are reported to range between 62-93%.

As musculoskeletal complaints are highly prevalent in the general population, comparative studies are relevant in identifying the specific impact of these disorders among musicians. In a comparative study the prevalence of musculoskeletal complaints among music academy students was compared to a control group of students. The odds ratio for both the point- and year-prevalence of musculoskeletal complaints in music academy students versus the control group is 2.3.(57)

In a recent review differences between male and female professional musicians were studied.(27) Ten out of twelve included studies showed a higher prevalence of musculoskeletal complaints among women. Other research showed that in the regions which are already most affected among musicians – i.e. the neck, upper back and shoulders - the highest differences between men and women were reported.(58–60)

Two studies were at variance with most studies which reported higher prevalence of disability in women. The first study reported a higher prevalence rate of complaints in female than in male string players.(61) However, men included in this study were significantly more affected by complaints for all other instrument groups. Another study reported 'no significant differences' between 59 male and female orchestra musicians. However, specific data were not presented.(62)

IVB Male and female amateur musicians

As stated before, for amateur musicians making music is not their main occupation or source of income. Therefore being an amateur musician or making music on an amateur level can comprise a very wide spectrum of activities. There is not only a broader age range compared to professional musicians; the playing load varies greatly. Therefore a standard set of characteristics describing the amateur musician does not exist. This should be carefully taken in mind when interpreting the literature.

In general the amateur musician spends less time playing the instrument compared to the professional musician. The style and technique of playing the instrument can differ extensively for example between a classical trained acoustic guitar player and a hard-rock electrical guitarist. Also the level of education can differ greatly, varying from self-taught to weekly lessons, in addition to the hours spending on playing the instrument. The 'playing load' of amateur musicians is generally less compared to professional musicians. On the contrary, the playing technique is mostly of inferior quality. In addition, sudden increases in playing time, i.e. at a music camp, are relevant risk factors for the development of musculoskeletal complaints among amateur musicians.

Compared to professional musicians, little is known about the health effects of playing a musical instrument on an amateur level.(63–65) In a group of participants of a high level amateur chamber music course, aged 24-79, musculoskeletal complaints were studied.(63) The playing load during this course was increased for most musicians compared to the period before the course. 81% of the participants with an increased playing load developed new musculoskeletal complaints, and 63% of the subjects without significant increase in playing time developed complaints.

Gender differences among amateur musicians are reported in some studies(65,66);In a study among active amateur musicians at a fiddle camp, reported lifetime prevalence rates among instrumental musicians of 73% for female and 56% for male adult amateur musicians.(65) As is reported for professional musicians and the general population, female amateur musicians are more prone to musculoskeletal complaints. Another study among a small number of traditional Iranian amateur instrumentalists showed the same trend; the prevalence of musculoskeletal complaints was twice as high among female compared to the male participants.(66)

IVc. Male and female children and adolescents

Most musicians start playing their instrument at a young age. With the introduction of the Suzuki method, children aged three years could already start making instrumental music. The majority of studied children and adolescents playing a music instrument reported PMRDs.(36,67,68)

In an Australian study examining PMRDs at primary and secondary schools, 67% of the 731 respondents reported a lifetime prevalence of PMRDs, and 412 (56%) reported symptoms within the past month. Due to these musculoskeletal complaints 30% of the

respondents were unable to play their instrument as competently as they were used to due to these symptoms.(36,38) Again, females were more affected than men (OR 1.6).(68) In another study among adolescents the lifetime prevalence of PRMDs was 63% for girls compared to 49% for boys. These prevalence rates of PRMDs were markedly higher compared to their classmates who did not play an instrument. As non-instrumentalists per definition cannot report PRMDs, reporting bias is always present in studies in case the incidence of PRMDs was compared in musicians to a control group. These results should therefore be interpreted with caution.

The majority of studies examining children and adolescents playing an instrument described higher prevalence rates of complaints in females even in young children.(36,38,67–69) Again however, there is some disagreement in the literature: some authors found comparable prevalence rates in both male and female adolescents reporting lifetime prevalence rates of 35% PRMDs in females and 36% in males.(65)

Despite the contradictory results found in some studies, it can be concluded that just as is the case with adult amateur and professional musicians, female children and adolescents do have a higher risk for the development of musculoskeletal complaints when playing a music instrument.

V. OTHER DETERMINANTS OF MUSCULOSKELETAL COMPLAINTS IN MUSICIANS

Apart from female gender, which is by far the most studied and confirmed risk factor, several other risk factors and associations have been related to musculoskeletal complaints in musicians.(58,59,62,68–74) It should be mentioned that most of the evidence for these risk factors was collected by studies using a cross-sectional or cohort design. Therefore, bias at different levels will be present; among them are selection bias and confounding due to a larger group of female instrumentalists in most studies.(57) However, most of these studies reported similar results, describing a number of relevant determinants of musculoskeletal complaints among musicians.

Risk factors for musculoskeletal complaints can be analyzed following the biopsychosocial model, in which a combination of biomedical and psychosocial factors are incorporated.(75) Physical, occupational and psychological, as well as social and

behavioral factors influence work-related complaints.(75,76) Also within musicians this biopsychosocial model can be used to evaluate risk factors of musculoskeletal complaints.(59,77)

VA. INSTRUMENT

The choice for playing a certain instrument is often made at young age. Gender is an important factor in the choice of the instrument; boys' and girls' preferences are based on the gender stereotyped associations.(78) For example, violin and flute are mostly played by female musicians, where brass and percussion instruments are predominantly played by males. The impact of this choice is essential in the musical development of the child: the instrument choice dictates the ability to play with others in an orchestra or band, and is thus is associated with social experiences like the shared pleasure of music making. Also anatomical proportions like height and length of arms as well as the potential learning curve of the child, depending on the playing technique of the specific instrument, are major determinants for initial success for mastering the instrument. As adolescents grow physically and mentally, the extent to which he or she is "physically adapted" to the instrument influences not only the fun and success when playing, but will also determine career opportunities as a musician.(79)

It is known that the type of instrument is related to the occurrence of musculoskeletal complaints among musicians. Generally violinists, violists and pianists are mentioned as having the highest risk. However, a recent systematic review studying professional classically trained musicians did not confirm this 'common knowledge'.(71) Contrary to the expectations of the researchers, no specific instrument group had an evident higher prevalence rate of musculoskeletal complaints.(27) However, brass instrumentalists in this review were reported to have the lowest prevalence rates of musculoskeletal complaints.

Reported prevalence rates of musculoskeletal disorders in musicians showed high variability in reported outcomes between instrument groups.(27) This variability can be explained by different grouping of the instruments that were studied. For example, most studies group the violin, viola, cello and double bass in the category string instruments, while some studies also add harp and piano to this group. But within this group the playing technique and therefore the musculoskeletal load and potential overuse, varies greatly between these instruments (e.g. the double bass compared with the violin). The prevalence of musculoskeletal complaints among violinists is the highest among all

musicians.(5,27,80–82) However, due to (partially) grouping string instrumentalists, the results of these studies are hardly comparable.

Another complicating factor is the great variance of music styles. For example, a classically trained pianist differs from the jazz pianist or a keyboard player in a pop/rock band in several ways. Among jazz pianists there is a great variation both in quality and in development; the jazz repertoire is less developed and, moreover, there is no established tradition of that repertoire following a recognized progression for the jazz student, with increasing levels of technical difficulty and working toward the more challenging technical difficulty only when the playing technique and stamina have been properly developed. Accordingly, there is a higher demand on the musculoskeletal system, accentuated by the fact that. the non-classical pianist usually performs with amplified instruments and a drum set. Last, but not least, jazz jam sessions often encourage intense competition between musicians to demonstrate their mastery of instrumental technique. In these situations, the immature player can easily be encouraged to perform beyond his or her level of physical development.(74) Comparable differences are present among classical and non-classical guitarists and percussionists/drummers.(83,84) The outcomes of studies on classical musicians cannot easily be extrapolated to data on non-classical musicians. Finally, as discussed above, gender influences both instrument choice and prevalence rates for musculoskeletal complaints. Male/female disability ratios vary greatly between studies.

Following the knowledge we have on gender differences in both instrument choice and prevalence of musculoskeletal complaints, it is probable that in many studies gender is a confounder for instrument-related differences in disability prevalence rates. Therefore statistical correction for gender should be performed in reporting instrument-specific prevalence rates.

VB. ANATOMIC LOCALIZATION

Many studies reporting on playing-related musculoskeletal complaints among musicians use (an adapted version of) the Nordic Musculoskeletal Questionnaire (NMQ).(85) In this questionnaire a body map is used for the localization of the complaints. As this questionnaire studies work-related complaints in several time frames and in several localizations comprising the entire body, it is considered as a good instrument for analyzing musculoskeletal complaints among musicians. As it is also frequently used in

other occupational fields, it is very suitable for comparing musicians with other occupational groups. Unfortunately, the use of various non-validated adapted versions of the NMQ influenced the results. Ideally, an adaptation of the NMQ that is validated especially for musicians should be developed. In a review of professional classical trained musicians, the neck and shoulder region were found to be the most affected regions.(27) Musculoskeletal complaints of the elbows showed the lowest prevalence rates of upper extremity musculoskeletal complaints.(27)

When comparing musicians with a control group, there is a markedly higher prevalence of upper extremity and back problems.(57) However, lower extremity complaints are rarely reported among musicians compared to their controls. (57) A hypothesis for this difference is that musicians may avoid sports and other risky activities which could cause health problems with a direct effect on their playing capacity and therefore career opportunities.(57)

Vc Hypermobility

Several comorbidities are associated with playing-related musculoskeletal complaints among musicians. Hypermobility is one which has gained attention, as hypermobility may have beneficial as well as disadvantageous effects for musicians.(69,86,87) Larsson et al. found that violinists and flautists with hypermobility reported fewer musculoskeletal symptoms in the hand region compared to musicians without hypermobility. However hypermobility in joints where stability is required such as the shoulder, could contribute to inadequate control due to excessive range of motion and increased muscle tension needed to stabilize the instrument.(88)

Niccolo Paganini (1782-1840), the greatest violin virtuoso of all time, is *the* example of the beneficial effect of hypermobility when playing a violin. Paganini was known for his striking hypermobility, he was also suspected to suffer from Marfan disease, a genetic disorder of hypermobility.(89,90) However, his playing technique exceeded that of all his contemporaries, and even now his work is considered the most virtuosic violin repertoire. His hypermobility of the small hand joints lead to a greater hand span (three octaves), and therefore the possibility to play his own virtuosic repertoire.(89–91)

Interestingly, hypermobility has a higher prevalence in musicians compared to the general population.(71,92,93) Some studies report hypermobile joints in musicians who play certain instruments, while these musicians do not show any hypermobility in joints which

are not used for playing.(93) In a groups of flautists for example, especially the finger joints which were involved in weight bearing of the instrument were found to be hypermobile, while other joints were not generally hypermobile as measured by the Beighton scale.(93)

In most recent literature as well as in clinical practice hypermobility is considered an important risk factor for the development of musculoskeletal complaints among musicians.(38,69,94) Various orthoses are developed for musicians, especially hand- and wrist orthoses, in order to stabilize joints while playing the instrument to reduce the possibility of musculoskeletal injury.(69,95) Small adaptions of the instrument, for example adding a saddle splint to a flute can also aid in reducing or avoiding musculoskeletal complaints.(96) However, strengthening exercises should always the core of the therapeutic regimen in complaints related to hypermobility.

VD MENTAL ASPECTS

Next to disorders of the musculoskeletal system, psychosocial problems are often reported by musicians.(97) Especially music performance anxiety and symptoms of depression and anxiety as well as sleep disturbances are commonly reported psychosocial problems.(4) Symptoms of burn-out were reported by 14-19% of the orchestra musicians.(97) Low-control and high-demand work are known risk factor for developing work-related complaints; musicians scored higher on l both work-related-causal factors compared with the overall working population.(59) Compared to other professions, musicians scored higher than other professional groups in professional ambition and work satisfaction but lower for autonomy and control.(98,99) Above all, musicians display a requirement for high levels of perfection in their performance. Musicians strongly identify themselves with their career, which makes it difficult for musicians to maintain a healthy distance from the necessity of practicing daily.(97)

In a Danish study among orchestra musicians, the mental aspects of being a professional musician are compared in both genders.(59) Female musicians reported their psychosocial work environment more negatively and had more symptoms of stress compared to male musicians.(59) However, job satisfaction was higher among female musicians.(59)

Concerning musculoskeletal complaints, the coping mechanism of musicians is somewhat exceptional; many musicians believe that pain is inherent to the level of performance they

try to achieve.(100) Furthermore, injuries may be interpreted as presence of an inferior talent and thus as a failure as a performer.(101) In a study comparing music academy students with a control group, both suffering from musculoskeletal complaints, musicians report worse psychological responses to their musculoskeletal complaints.(31) This study showed considerable differences between the two groups with respect to the cognitive and emotional aspects of their complaints. Students at music academies anticipated more severe consequences from their disorders and were more concerned and emotionally more affected by their musculoskeletal complaints, compared to controls.(31) These results emphasize once more the severe impact of emotional factors as a consequence of musculoskeletal complaints on musicians.(100,101)

VI. PREVENTION

Several preventive training and educational programs have been proposed aiming to reduce musculoskeletal complaints among musicians. In order to increase musculoskeletal fitness and thereby reduce fatigue, exercises, yoga and sports are presented as possible interventions in order to reduce and prevent musculoskeletal complaints. Furthermore, education of musicians, mostly at music academies is proposed. However, till now, in our opinion, prevention of musculoskeletal complaints among musicians is an underdeveloped field. It is generally recognized that prevention of musculoskeletal complaints in musicians is important. However, the content of these programs and the way they should be presented to musicians, as well as the impact and effect of these programs are still a matter of debate and study.

A frequently discussed subject is the influence of sports on the occurrence of musculoskeletal complaints among musicians. In a survey among professional musicians it was found that these players thought that their injury rates would decrease with exercise.(102) However, several studies studying the effect of physical exercise and sports on musculoskeletal disorders in music students found no effect on reducing occupational musculoskeletal complaints in musicians, and some studies in the nineties even reported a higher number of musculoskeletal complaints as the result of sports activities.(103,104) It was therefore concluded that regular sports, especially those with a high injury risk may not be suitable for musicians. Therefore, because in general, health benefits on respiratory, cardiovascular and psychosocial health have been well known as a result of

physical activity(105), sport programs especially designed for musicians seem to be needed.

Some research in this area has already been performed. Since the 2000's a number of studies described the positive health effect of training programs on musicians. Most of these studies are performed at music academies. For example, in a study performed in Spanish music academy 90 students received a practical and theoretical course, focusing on warming up and posture. While for the students in the experimental group the frequency of their injuries decreased by 78%, there was no improvement in the students of the control group at the end of the experiment.(106) Ackermann et al. compared a six-week strength- and endurance training program for undergraduate music majors. Perceived exertion of playing was significantly better for those that had followed the programs consisting of endurance training compared to a program consisting of strength training.(107) However, in this study the influence of these programs on the occurrence of musculoskeletal complaints was not measured. In another study the health effect of an educational program including a theoretical combined with a practical approach was measured.(108) The relation between proprioception and motor control while playing the instrument or singing was a central and continuous theme of the course, which consisted of a weekly practical and theoretical lesson. In the practical session, exercises with and without the instrument were performed, with particular emphasis on posture, breathing, and movement. The exercises applied physiological knowledge to the practice of playing, embedding functionality with the instrument and on stage in total expressive behavior. As a result of the course playing-related symptoms, general symptom frequency, and emotional disturbances and anxiety level decreased; general coping with work as a musician and security in performance situations improved. Also another longitudinal study among music academy students, the health effect of a prevention program incorporating physical, psychosocial and behavioral aspects, showed a positive effect on students' performance and their attitude towards health.(109)

A preventive intervention program consisting of a ten week exercise program, of sixteen 35 minute sessions in Australian orchestra musicians showed an immediate significant positive effect on playing-related musculoskeletal complaints, but not thereafter.(110) However, overall playing capacity as rated by the musicians themselves was improved directly and six months after the intervention. The exercise program consisted of low-load activation of supporting musculature in the early stages, gradually advancing to

more difficult exercises (changing positioning and challenging proprioceptive systems) until finally exercises were modified into functional movement patterns with added resistance. In the intervention group a reduction in the frequency and severity of musculoskeletal complaints was reported. Furthermore, the program was associated with a reduction in perceived playing effort during private practice in both the short-term and at the 6-month follow-up. Musicians reported that the intervention was useful for learning strengthening techniques for musculature that supported instrument playing and increased ease of movement and posture. The same authors also report the effects of a comparable DVD-based exercise program for musicians, which also showed a reduction in a reduction of musculoskeletal complaints and severity in this group. Compared to a comparable face-to-face program directed by a physiotherapist, most musicians rated the DVD as the same or better.(111)

The preventive physical and mental exercise programs are promising in reducing musculoskeletal complaints. In particular, the DVD-based exercise program, which might be changed in streaming video programs, offers an easily accessible and affordable intervention with proven reduction of musculoskeletal complaints. These preventive techniques should be incorporated in the daily musical instrument practice. Future research should aim to improve the training program, and randomized controlled trials performed in order to minimize the risk of bias in the scientific literature concerning preventive measures in performing arts medicine.

Compared to the previous taboos on both physical training and acknowledging the presence of musculoskeletal complaints enormous progress has been made in this field of performing arts medicine. In the forthcoming years prevention programs should be optimized, but even more importantly, incorporated in musicians' routine. Health should become a standard in the school program at music academies. Employers (i.e. orchestra governance) also have a role in promoting the health and for that matter prevention of musculoskeletal injuries and complaints of their employees, the musicians. Close collaboration between these institutes and musculoskeletal health professionals, including orthopaedic surgeons, specialized sports physicians, and physical therapists, should is a prerequisite for prevention.

VII. THERAPEUTIC MANAGEMENT – A PRACTICAL APPROACH

Performing arts medicine can be compared to sports medicine in many ways. Both complaints and treatment options are strongly dependent on the activities of the individual. However, in contrasts to sports medicine, only a few physicians and surgeons are trained in the treatment of musicians. This is despite the fact that specialized knowledge of the performing artist including the features of his instrument is essential for satisfactory outcomes of the treatment.

In a study among performing artists visiting health care providers, 58% of the patients reported that physicians with more knowledge about performing arts medicine are needed.(112) In particular, knowledge about acute and chronic musculoskeletal problems in musicians, injury prevention as well as how to help the injured performer return quickly to full functional capacity in case of a disorder were mentioned as desirable areas for improvement.(112)

The parallel with sports medicine can again be drawn, but an important difference should be stressed. Professional sportsmen have a career which is clearly age-limited and depending on the sport. Professional sportsmen generally retire before their fourth decade, where most professional musicians work at least until their seventh decade. This influences the necessity of longevity of the musculoskeletal health of the performing artist. Short-term solutions for complaints – i.e. corticosteroid injections - with possible negative long-term outcomes should be avoided in the musician.

Despite the growing number of physicians and surgeons dedicated to the health of musicians, at present, most musicians with musculoskeletal complaints will be treated by general health care providers. Below some essential factors for these complaints in musicians are discussed, which can be kept in mind during treatment.

VIIA MEDICAL HISTORY AND DRUGS

Next to the general medical history it is essential to gain information about the playing habits of the musician. What instrument does the patient play, what kind of music style(i.e. classical, rock, jazz) does he or she have? What is the average practice time? Is there a recent increase or change in playing habits? A change in program, increase in playing time or volume, an approaching audition or stressful concerts are known risk factors for playing-related complaints.(77,113,114) What is the occupation of the patient; what

employment does he or she have? Many musicians are self-employed and not being able to play will result in loss of income. Playing and practicing habits, including warming up and taking breaks should be discussed. Above all, following the biopsychosocial model, psychological stress factors and coping mechanisms should be reviewed.

Medication should be tabulated, including the use of beta blockers or other drugs to diminish the symptoms of performance anxiety. Performance anxiety is generally more frequently reported among female compared to male musicians. Reported prevalence rates for performance anxiety range from 24 to 70%.(4,115) Among adolescents the prevalence of performance anxiety is comparable to that of adult musicians.(115) It is well known that among musicians, performance anxiety and especially the use of medication suppressing the symptoms is a taboo. This taboo concerning the use of i.e. beta-blocking agents should be specifically addressed and carefully questioned. The more the musicians are educated on this subject, the more they admit the extent of the problem.(115) This education is therefore an essential part of the treatment of the musician.

Moreover, the use of other substances should be noted. In a study among professional musicians, 10-16% indicated that the use of alcohol or drugs influenced their performance in a negative way during the previous year.(116) In general, non-classical musicians are more likely to report widespread drug use compared with classical musicians.(117)

VIIB PHYSICAL EXAMINATION

A general physical examination should be performed, focusing on the presenting complaint and underlying pathology. In addition to this general examination, musicians should bring their instrument to the consulting room. Only in this way playing posture and - technique can be examined. As a health care provider, basic knowledge of playing technique should be a requisite for a successful physical examination while dealing with playing-related musculoskeletal complaints.

Posture is a major risk factor for developing musculoskeletal complaints which interfere with the ability to play the instrument.(118) Instruments are developed in order to produce optimal tonal quality, ergonomic considerations are subservient. Many instruments require asymmetrical postures, which are often sustained during long time periods.(119) This high static load is mentioned as a causal factor for the development of musculoskeletal complaints. To consider the optimal posture for a musician, the playing

requirements for the instrument and the movement options available to the performer must be considered.(1) This examination should ideally be performed while the musician is standing and sitting, and both while playing and at rest.

VIID CONSERVATIVE THERAPEUTIC MODALITIES

Most musicians present with overuse injuries as the result of repetitive movements or static loads as the result of playing the instrument.(1) Therapeutic management options consist therefore primarily of physiotherapy, combined with anti-inflammatory medication.(1) Treatment with (repeated) steroid injections aiming to relieve inflammation should be performed with caution due to the risk of damage to tendons and subcutaneous tissues. As it is usually impossible to change the instrument itself, ergonomic interventions are, in general, focused on equipment and set-up. For example, for violin and viola players, shoulder and chin rests can be optimized and changed according to the individual requirements. Especially in individuals with symptomatic hypermobility the use of a splint can be considered. Another important therapeutic tool is education. For example, prescribing rest to musicians is a subject of discussion. Despite the fact that complete rest is often beneficial in relieving the symptoms, most musicians do not want to stop playing even temporarily as they are afraid of losing skills and income. However, controlled playing i.e. according to a new schedule in order to reducing load, or relative rest is often an option to consider for the musician. Returning a musician to 'healthy' playing should be graduated in duration, intensity and frequency.(1) This process should optimally be accompanied by therapists, in order to gradually increase playing loads.

VIIE OPERATIVE THERAPEUTIC MODALITIES

Surgery is rarely indicated in treating musculoskeletal complaints among musicians. In a review of 825 musicians presenting upper limb symptoms to a specialized musicians' clinic in London, only 4% were considered as candidates for surgery.(120) However, for some conditions, especially nerve compression syndromes, Dupuytren disease, and stenosing tenosynovitis, additional options must be discussed when conservative treatment fails.(121) When selecting the treatment modality one can adhere to multidisciplinary guidelines for the specific condition developed for the general population.(122–126) However, the function needed to play the instrument should be taken into account.(1,121) If the situation clearly demands a surgical approach, and

surgery is performed with careful planning, precision and skill, and a rehabilitation program is initiated early, good results can be expected.(120)

As is the case with sports medicine, the musician often requires a comprehensive specialized rehabilitation program. Treatment by specialized health professionals like orthopaedic surgeons, rehabilitation physicians and physiotherapists are essential for treatment and preventive programs. A multidisciplinary approach, as proposed in the biopsychosocial model will give satisfactory result of not only treatment at long-term, but also in long-lasting effects of preventive programs for musicians.

VIII. CONCLUSION

The prevalence of musculoskeletal complaints among musicians is high. Gender is the most reported risk factor associated with musculoskeletal complaints among musicians. Female musicians reported more musculoskeletal complaints. This finding was consistent in all groups of musicians; professional, amateur, children and adolescent musicians. Women reported more complaints in the regions which are most commonly affected, i.e. the neck, upper back and shoulders.

The prevalence of musculoskeletal complaints among musicians was higher compared with the general working population. Above, both the number of complaints and their impact on functioning were rated as more severe by musicians when compared to controls. Other important risk factors for the development of musculoskeletal complaints among musicians were the type of instrument played, hypermobility and psychological elements.

Healthcare for musicians should optimally be performed by dedicated healthcare providers. Preventive training programs showing promising results, should be further developed and incorporated in music academies. Treatment of musculoskeletal complaints among musicians should aim at long-term benefits; they often constitute of conservative treatment modalities like physiotherapy. Operative treatment is rarely indicated.

REFERENCES

1. Sataloff RT, Brandfonbrener AG, Lederman RJ. Performing arts medicine. Vol. 3rd. Science & Medicine; 2013.
2. DunningJ. When a pianist's fingers fail to obey. NY Times. 1981 Jun 14;
3. Hochberg FH, Leffert RD, Heller MD, Merriman L. Hand difficulties among musicians. JAMA. 1983 Apr 8;249(0098–7484 (Print)):1869–72.
4. Fishbein M, Middlestadt SE, Ottati V, Straus S, Ellis A. Medical problems among ICSOM musicians: overview of a national survey. MPPA. 1988;3(1):1–8.
5. Middlestadt SE, Fishbein M. The prevalence of severe musculoskeletal problems among male and female symphony orchestra string players. MPPA. 1989 Mar;4(1):41–8.
6. Vos T, Barber RM, Collaborators GB of DS 2013. Global, regional, and national incidence, prevalence, and years lived with disability for 301 acute and chronic diseases and injuries in 188 countries, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet. 2015 Aug 22;386(1474–547X (Electronic)):743–800.
7. Brooks PM. The burden of musculoskeletal disease--a global perspective. ClinRheumatol. 2006 Nov;25(0770–3198 (Print)):778–81.
8. Woolf AD, Pfleger B. Burden of major musculoskeletal conditions. BullWorld Heal Organ. 2003;81(0042–9686 (Print)):646–56.
9. Picavet HS, Schouten JS. Musculoskeletal pain in the Netherlands: prevalences, consequences and risk groups, the DMC(3)-study. Pain. 2003 Mar;102(0304–3959 (Print)):167–78.
10. da Costa BR, Vieira ER. - Risk factors for work-related musculoskeletal disorders: A systematic review of recent longitudinal studies. - Am J Ind Med2010 Mar;53(3)285-323. (1097-0274 (Electronic)).
11. Haskell WL, Lee IM, Pate RR, Powell KE, Blair SN, Franklin BA, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. Circulation. 2007 Aug 28;116(1524–4539 (Electronic)):1081–93.
12. Schneider S, Seither B, Tonges S, Schmitt H. Sports injuries: population based representative data on incidence, diagnosis, sequelae, and high risk groups. BrJ Sport Med. 2006 Apr;40(1473–0480 (Electronic)):334–9.
13. Almeida SA, Williams KM, Shaffer RA, Brodine SK. Epidemiological patterns of musculoskeletal injuries and physical training. MedSciSports Exerc. 1999 Aug;31(0195–9131 (Print)):1176–82.
14. Feleus A, Bierma-Zeinstra SM, Miedema HS, Bernsen RM, Verhaar JA, Koes BW. Incidence of non-traumatic complaints of arm, neck and shoulder in general practice. ManTher. 2008 Oct;13(1532–2769 (Electronic)):426–33.
15. Rollman GB, Lautenbacher S. Sex differences in musculoskeletal pain. ClinJPain. 2001 Mar;17(0749–8047 (Print)):20–4.
16. Treaster DE, Burr D. Gender differences in prevalence of upper extremity musculoskeletal

disorders. Ergonomics. 2004 Apr 15;47(0014–0139 (Print)):495–526.

17. de Zwart BC, Frings-Dresen MH, Kilbom A. Gender differences in upper extremity musculoskeletal complaints in the working population. Int ArchOccupEnvironHealth. 2001 Jan;74(0340–0131 (Print)):21–30.

18. Huisstede BM, Wijnhoven HA, Bierma-Zeinstra SM, Koes BW, Verhaar JA, Picavet S. - Prevalence and characteristics of complaints of the arm, neck, and/or shoulder (CANS) in the open population. - Clin J Pain2008 Mar-Apr;24(3)253-9. (0749-8047 (Print)).

19. Unruh AM. Gender variations in clinical pain experience. Pain. 1996 May;65(0304–3959 (Print)):123–67.

20. Hooftman WE, van Poppel MN, van der Beek AJ, Bongers PM, van MW. Gender differences in the relations between work-related physical and psychosocial risk factors and musculoskeletal complaints. ScandJ Work EnvironHealth. 2004 Aug;30(0355–3140 (Print)):261–78.

21. Leijon M, Hensing G, Alexanderson K. Gender trends in sick-listing with musculoskeletal symptoms in a Swedish county during a period of rapid increase in sickness absence. ScandJSocMed. 1998 Sep;26(0300–8037 (Print)):204–13.

22. Wijnhoven HA, de Vet HC, Picavet HS. Explaining sex differences in chronic musculoskeletal pain in a general population. Pain. 2006 Sep;124(1872–6623 (Electronic)):158–66.

23. Riley III JL, Robinson ME, Wise EA, Myers CD, Fillingim RB. Sex differences in the perception of noxious experimental stimuli: a meta-analysis. Pain. 1998 Feb;74(0304–3959 (Print)):181–7.

24. Bartley EJ, Fillingim RB. Sex differences in pain: a brief review of clinical and experimental findings. BrJAnaesth. 2013 Jul;111(1471–6771 (Electronic)):52–8.

25. Lawson KP, Nag S, Thompson AD, Mokha SS. Sex-specificity and estrogen-dependence of kappa opioid receptor-mediated antinociception and antihyperalgesia. Pain. 2010 Dec;151(1872–6623 (Electronic)):806–15.

26. Fredriksson K, Alfredsson L, Koster M, Thorbjornsson CB, Toomingas A, Torgen M, et al. Risk factors for neck and upper limb disorders: results from 24 years of follow up. OccupEnvironMed. 1999 Jan;56(1351–0711 (Print)):59–66.

27. Kok LM, Huisstede BMA, Voorn VMA, Schoones JW, Nelissen RGHH. The occurrence of musculoskeletal complaints among professional musicians: a systematic review. Int Arch Occup Environ Health. 2016;89(3).

28. Zaza C. Playing-related musculoskeletal disorders in musicians: a systematic review of incidence and prevalence. CMAJ. 1998 Apr 21;158(0820–3946 (Print)):1019–25.

29. Zaza C, Charles C, Muszynski A. The meaning of playing-related musculoskeletal disorders to classical musicians. SocSciMed. 1998 Dec;47(0277–9536 (Print)):2013–23.

30. Kok LM, Nelissen RG, Huisstede BM. The striking prevalence and alarming consequences of Complaints of Arm, Neck and/or Shoulder among music academy students - a comparative study. MPPA. 2015 Jan 9;30(3):163–8.

31. Kok LM, Vlieland TPMV, Fiocco M, Kaptein AA, Nelissen RGHH. Musicians' illness perceptions of musculoskeletal complaints. Clin Rheumatol. 2013;32(4).

32. Heinan M. A review of the unique injuries sustained by musicians. JAAPA. 2008 Apr;21(1547–1896 (Print)):45–46,48,50.

33. Shah D. Healthy worker effect phenomenon. Indian JOccupEnvironMed. 2009 Aug;13(1998–3670 (Electronic)):77–9.

34. Fry HJH, Ross P, Rutherford M. Music-Related Overuse in Secondary-Schools. MPPA. 1988;3(4):133–4.

35. Fry HJH, Rowley GL. Music Related Upper Limb Pain in Schoolchildren. Ann Rheum Dis. 1989;48(12):998–1002.

36. Ranelli S, Straker L, Smith A. Prevalence of Playing-related Musculoskeletal Symptoms and Disorders in Children Learning Instrumental Music. MPPA. 2008;23(4):178–85.

37. Brandfonbrener AG. Musculoskeletal problems of instrumental musicians. Hand Clin. 2003;19(2):231–+.

38. Hoppmann RA. Instrumental musicians' hazards. OccupMed. 2001 Oct;16(0885–114X (Print)):619–61v.

39. Huisstede BM, Miedema HS, Verhagen AP, Koes BW, Verhaar JA. Multidisciplinary consensus on the terminology and classification of complaints of the arm, neck and/or shoulder. OccupEnvironMed. 2007 May;64(1470–7926 (Electronic)):313–9.

40. Rosenbaum AJ, Vanderzanden J, Morse AS, Uhl RL. Injuries complicating musical practice and performance: the hand surgeon's approach to the musician-patient. JHand SurgAm. 2012 Jun;37(1531–6564 (Electronic)):1269–72.

41. Pascarelli EF, Hsu YP. Understanding work-related upper extremity disorders: clinical findings in 485 computer users, musicians, and others. J OccupRehabil. 2001 Mar;11(1053–0487 (Print)):1–21.

42. Altenmuller E. Neurological Disorders in Musicians: Musicians' Dystonia. Eur J Neurol. 2011;18:645.

43. Haslinger B, Altenmueller E, Castrop F, Zimmer C, Dresel C. Musicians with embouchure dystonia show primary sensorimotor overactivity. Mov Disord. 2009;24:S89–S89.

44. Schuele S, Lederman RJ. Focal dystonia in woodwind instrumentalists: Long-term outcome. MPPA. 2003;18(1):15–20.

45. Leijnse JN, Hallett M, Sonneveld GJ. A multifactorial conceptual model of peripheral neuromusculoskeletal predisposing factors in task-specific focal hand dystonia in musicians: etiologic and therapeutic implications. BiolCybern. 2015 Feb;109(1432–0770 (Electronic)):109–23.

46. Liuzzi D, Gigante AF, Leo A, Defazio G. The anatomical basis of upper limb dystonia: lesson from secondary cases. NeurolSci. 2016 May 12;(1590–3478 (Electronic)).

47. Berque P, Gray H, Harkness C, McFadyen A. A Combination of Constraint-induced Therapy and Motor Control Retraining in the Treatment of Focal Hand Dystonia in Musicians. MPPA. 2010;25(4):149–61.

48. Chamagne P. Functional dystonia in musicians: rehabilitation. Hand Clin. 2003;19(2):309–+.

49. Tubiana R. Prolonged neuromuscular rehabilitation for musician's focal dystonia. MPPA. 2003;18(4):166–9.

50. Subramanian I, Tagliati M, Alterman R. Preliminary results of pallidal deep brain stimulation in a cellist with focal task-specific dystonia: A case study. Mov Disord. 2006;21:S378–S378.

51. Amadio PC. Management of nerve compression syndrome in musicians. Hand Clin. 2003;19(2):279–+.

52. Lockwood AH. Medical problems of musicians. NEnglJMed. 1989 Jan 26;320(0028–4793 (Print)):221–7.

53. RJ L. Entrapment neuropathies in instrumental musicians. MPPA. 1993 Jan 6;8(2):35–40.

54. Hagglund KL. A comparison of the physical and mental practices of music students from the New England Conservatory and Boston University Music School. MPPA. 1996;11(3):99–107.

55. Wristen BG, Fountain SE. Relationships Between Depression, Anxiety, and Pain in a Group of University Music Students. MPPA. 2013;28(3):152–8.

56. White JW, Hayes MH, Jamieson GG, Pilowsky I, Faris IB. A 4-Year Prospective-Study of the Overuse Syndrome Among Music Students - the Results of Analysis of Psychological Profiles. Aust N Z J Surg. 1991;61(7):525.

57. Kok LM, Vlieland TPV, Fiocco M, Nelissen RG. A comparative study on the prevalence of musculoskeletal complaints among musicians and non-musicians. BMC Musculoskelet Disord. 2013;14.

58. Leaver R, Harris EC, Palmer KT. Musculoskeletal pain in elite professional musicians from British symphony orchestras. Occup Med. 2011 Dec;61(1471–8405 (Electronic)):549–55.

59. Paarup HM, Baelum J, Holm JW, Manniche C, Wedderkopp N. Prevalence and consequences of musculoskeletal symptoms in symphony orchestra musicians vary by gender: a cross-sectional study. BMCMusculoskeletDisord. 2011 Oct 7;12(1471–2474 (Electronic)):223.

60. Roach KE, Martinez MA, Anderson N. Musculoskeletal pain in student instrumentalists: a comparison with the general student population. MPPA. 1994 Dec;9(4):125–30.

61. Davies C. Musculoskeletal pain from repetitive strain in musicians: Insights into an alternative approach. MPPA. 2002;17(1):42–9.

62. Kaufman-Cohen Y, Ratzon NZ. Correlation between risk factors and musculoskeletal disorders among classical musicians. OccupMed(Lond). 2011 Mar;61(1471–8405 (Electronic)):90–5.

63. Kok LM, Haitjema S, Groenewegen KA, Rietveld ABM. The influence of a sudden increase in playing time on playing-related musculoskeletal complaints in high-level amateur musicians in a longitudinalcohort study. PLoS One. 2016;11(9).

64. Newmark J, RJ L. Practice doesn't necessarily make perfect: incidence of overuse syndromes in amateur instrumentalists. MPPA. 1987;2(4):142–4.

65. Dawson WJ. Upper extremity difficulties in the dedicated amateur instrumentalist. MPPA. 2001;16(4):152–6.

66. Buckley T, Manchester R. Overuse injuries in non-classical recreational instrumentalists. MPPA.

2006;21(2):80–7.

67. Sadeghi S, Kazemi B, Shooshtari SM, Bidari A, Jafari P. A high prevalence of cumulative trauma disorders in Iranian instrumentalists. BMCMusculoskeletDisord. 2004 Oct 14;5(1471–2474 (Electronic)):35.

68. Ranelli S, Straker L, Smith A. Playing-related Musculoskeletal Problems in Children Learning Instrumental Music: The Association Between Problem Location and Gender, Age, and Music Exposure Factors. MPPA. 2011;26(3):123–39.

69. Ranelli S, Straker L, Smith A. Soreness during non-music activities is associated with playing-related musculoskeletal problems: an observational study of 731 child and adolescent instrumentalists. JPhysiother. 2014 Jun;60(1836–9561 (Electronic)):102–8.

70. Vinci S, Smith A, Ranelli S. Selected Physical Characteristics and Playing-Related Musculoskeletal Problems in Adolescent String Instrumentalists. MedProblPerformArt. 2015 Sep;30(0885–1158 (Print)):143–51.

71. Brandfonbrener AG. Joint laxity and arm pain in a large clinical sample of musicians. MPPA. 2002;17(3):113–5.

72. Wu SJ. Occupational risk factors for musculoskeletal disorders in musicians: A systematic review. MPPA. 2007;22(2):43–51.

73. Yoshimura E, Fjellman-Wiklund A, Paul PM, Aerts C, Chesky K. Risk Factors for Playing-related Pain among Piano Teachers. MPPA. 2008;23(3):107–13.

74. Wood GC. Prevalence, risk factors, and effects of performance-related medical disorders (PRMD) among tertiary-trained jazz pianists in Australia and the United States. MPPA. 2014 Mar;29(1):37–45.

75. Engel GL. The clinical application of the biopsychosocial model. AmJPsychiatry. 1980 May;137(0002–953X (Print)):535–44.

76. Bongers PM, Ijmker S, van den Heuvel S, Blatter BM. Epidemiology of work related neck and upper limb problems: psychosocial and personal risk factors (part I) and effective interventions from a bio behavioural perspective (part II). JOccupRehabil. 2006 Sep;16(1053–0487 (Print)):279–302.

77. Fjellman-Wiklund A, Brulin C, Sundelin G. Physical and psychosocial work-related risk factors associated with neck-shoulder discomfort in male and female music teachers. MPPA. 2003;18(1):33–41.

78. O'neill S, Boultona MJ. boys' and girls' preferences for musical instruments: a function of gender? Psychol Music. 1996;24(2):171–83.

79. Wych GMF. Gender and instrument associations, sterotypes, and stratification: a literature review. Appl Res Music Educ. 2012;30(2):22–31.

80. Steinmetz A, Scheffer I, Esmer E, Delank KS, Peroz I. Frequency, severity and predictors of playing-related musculoskeletal pain in professional orchestral musicians in Germany. Clin Rheumatol. 2015 May;34(5):965–73.

81. Fotiadis DG, Fotiadou EG, Kokaridas DG, Mylonas AC. Prevalence of musculoskeletal disorders in

professional symphony orchestra musicians in Greece: a pilot study concerning age, gender, and instrument-specific results. MPPA. 2013 Jun;28(2):91–5.

82. Ackermann B, Driscoll T, Kenny DT. Musculoskeletal pain and injury in professional orchestral musicians in Australia. MPPA. 2012 Dec;27(0885–1158 (Print)):181–7.

83. Fjellman-Wiklund A, Chesky K. Musculoskeletal and general health problems of acoustic guitar, electric guitar, electric bass, and banjo players. MPPA. 2006;21(4):169–76.

84. Marques DN, Rosset-Llobet J, Marques F, Gurgel IGD, Augusto LGS, Nunes Marques D, et al. Flamenco guitar as a risk factor for overuse syndrome. MPPA. 2003 Mar;18(1):11–4.

85. Kuorinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sorensen F, Andersson G, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. ApplErgon. 1987 Sep;18(0003–6870 (Print)):233–7.

86. Larsson LG, Baum J, Mudholkar GS, Kollia GD. Nature and Impact of Musculoskeletal Problems in A Population of Musicians. MPPA. 1993;8(3):73–6.

87. AG B. Joint laxity in instrumental musicians. MPPA. 1990;5(3):117–9.

88. Larsson LG, Baum J, Mudholkar GS, Kollia GD. Benefits and disadvantages of joint hypermobility among musicians. NEnglJMed. 1993 Oct 7;329(0028–4793 (Print)):1079–82.

89. Schoenfeld MR. Nicolo Paganini. Musical magician and Marfan mutant? JAMA. 1978 Jan 2;239(0098–7484 (Print)):40–2.

90. Sperati G, Felisati D. Nicolo Paganini (1782-1840). Acta OtorhinolaryngolItal. 2005 Apr;25(0392–100X (Print)):125–8.

91. Miranda CM, Navarrete TL, Zuniga NG. Niccolo Paganini: medical aspects of his life and work. RevMedChil. 2008 Jul;136(0034–9887 (Print)):930–6.

92. Brandfonbrener AG. Joint laxity and arm pain in musicians. MPPA. 2000;15(2):72–4.

93. Artigues-Cano I, Bird HA. Hypermobility and proprioception in the finger joints of flautists. JClinRheumatol. 2014 Jun;20(1536–7355 (Electronic)):203–8.

94. Quarrier NF. Is hypermobility syndrome (HMS) a contributing factor for chronic unspecific wrist pain in a musician? If so, how is it evaluated and managed? Work J Prev Assess Rehabil. 2011;40(3):325–33.

95. Patrone NA, Hoppman RA, Whaley J, Schmidt R. Digital Nerve Compression in A Violinist with Benign Hypermobility - A Case-Study. MPPA. 1989;4(2):91–4.

96. Patrone NA, Hoppman RA, Whaley J, Chauncey B. Benign hypermobility in a flutist: a case study. MPPA. 1998 Jan 12;3(4):158–61.

97. Voltmer E, Zander M, Fischer JE, Kudielka BM, Richter B, C. S. Physical and mental health of different types of orchestra musicians compared to other professions. MPPA. 2012;27(1):9–14.

98. Voltmer E, Schauer I, Schroder H, C. S. Musicians and Physicians - A comparison of psychosocial strain patterns and resources. MPPA. 2008;23(4):164–8.

99. Kivimaki M, Jokinen M. Job perceptions and well-being among symphony orchestra musicians: a comparison with other occupational groups. MPPA. 1994;9(3):73–6.

100. Amadio PC, Russotti GM. Evaluation and treatment of hand and wrist disorders in musicians. Hand Clin. 1990 Aug;6(0749–0712 (Print)):405–16.

101. Brandfonbrener AG. Special issues in the medical assessment of musicians. PhysMedRehabilClinNAm. 2006 Nov;17(1047–9651 (Print)):747–53, v.

102. Yeung E, Chang W, Pan F, Sau P, Tsui M, Yu B, et al. A survey of playing-related musculoskeletal problems among professional orchestral musicians in Hong Kong. MPPA. 1999;14(1):43–7.

103. Zetterberg C, Backlund H, J. K, Werner HOL. Musculoskeletal problmes among male and female music students. MPPA. 1998 Dec;13(4):160–6.

104. Dawson WJ. Hand and upper extremity trauma in high-level instrumentalists: epidemiology and outcomes. Work. 1996;7(1051–9815 (Print)):81–7.

105. Johannsen NM, Swift DL, Lavie CJ, Earnest CP, Blair SN, Church TS. Combined Aerobic and Resistance Training Effects on Glucose Homeostasis, Fitness, and Other Major Health Indices: A Review of Current Guidelines. Sport Med. 2016 May 3;(1179–2035 (Electronic)).

106. T.M. L, Farias MJ. Strategies to promote health and prevent musculoskeletal injuries in students from the high conservatory of music of Salamanca, Spain. MPPA. 2013 Jun;28(2):100–6.

107. Ackermann B, Adams R, E. M. Strength or endurance training for undergraduate music majors at a university? MPPA. 2002;17(1):33–41.

108. Spahn C, Hildebrandt H, Seidenglanz K. Effectiveness of a prophylactic course to prevent playing-related health problems of music students. MPPA. 2001;16:24–31.

109. Zander MF, Voltmer E, Spahn C. Health promotion and prevention in higher music education: results of a longitudinal study. MedProblPerformArt. 2010 Jun;25(0885–1158 (Print)):54–65.

110. Chan C, Driscoll T, Ackermann BJ. Effect of a musicians' exercise intervention on performance-related musculoskeletal disorders. MedProblPerformArt. 2014 Dec;29(0885–1158 (Print)):181–8.

111. Chan C, Driscoll T, Ackermann B. Exercise DVD effect on musculoskeletal disorders in professional orchestral musicians. OccupMed(Lond). 2014 Jan;64(1471–8405 (Electronic)):23–30.

112. Chandler PA, Foster B. Health care services to performing artists: what do the artists think? MPPA. 1999;14(3):133–7.

113. Furuya S, Nakahara H, Aoki T, Kinoshita H. Prevalence and causal factors of playing-related musculoskeletal disorders of the upper extremity and trunk among Japanese pianists and piano students. MPPA. 2006;21(3):112–7.

114. Lonsdale K, Laakso EL, Tomlinson V. Contributing factors, prevention, and management of playing-related musculoskeletal disorders among flute players internationally. MPPA. 2014 Sep;29(3):155–62.

115. Brugues AO. Music performance anxiety - part 1. a review of its epidemiology. MPPA. 2011;26(2):102–5.

116. Raeburn SD, Hipple J, Delaney CP, Chesky K. Surveying popular musicians' health status using convenience samples. MPPA. 2003;18(3):113–9.

117. Chesky K, Hipple J. Musicians' perceptions of widespread drug use among musicians. MPPA.

1999;14(4):187–95.

118. Davies J, Mangion S. Predictors of pain and other muscoloskeletal symptoms among professional instrumental musicians - Elucidating specific effects. MPPA. 2002;17(4):155–68.

119. Tubiana R, Chamagne P, Brockman R. Fundamental positions for instrumental musicians. MPPA. 1989;4(2):73–6.

120. Winspur I, Wynn Parry CB. Musicians' Hands. MPPA. 2000;15(1):31–4.

121. Dawson WJ. The role of surgery in treating upper extremity problems in musicians. MPPA. 1992;7(2):59–62.

122. Huisstede BM, Coert JH, Friden J, Hoogvliet P. Consensus on a multidisciplinary treatment guideline for de Quervain disease: results from the European HANDGUIDE study. PhysTher. 2014 Aug;94(1538–6724 (Electronic)):1095–110.

123. Huisstede BM, Hoogvliet P, Coert JH, Friden J. Dupuytren disease: European hand surgeons, hand therapists, and physical medicine and rehabilitation physicians agree on a multidisciplinary treatment guideline: results from the HANDGUIDE study. PlastReconstrSurg. 2013 Dec;132(1529–4242 (Electronic)):964e–976e.

124. Hoogvliet P, Coert JH, Friden J, Huisstede BM. How to treat Guyon's canal syndrome? Results from the European HANDGUIDE study: a multidisciplinary treatment guideline. BrJSports Med. 2013 Nov;47(1473–0480 (Electronic)):1063–70.

125. Huisstede BM, Hoogvliet P, Coert JH, Friden J. Multidisciplinary consensus guideline for managing trigger finger: results from the European HANDGUIDE Study. PhysTher. 2014 Oct;94(1538–6724 (Electronic)):1421–33.

126. Huisstede BM, Friden J, Coert JH, Hoogvliet P. Carpal tunnel syndrome: hand surgeons, hand therapists, and physical medicine and rehabilitation physicians agree on a multidisciplinary treatment guideline-results from the European HANDGUIDE Study. ArchPhysMedRehabil. 2014 Dec;95(1532–821X (Electronic)):2253–63.

PART 2

IMPACT &

ILLNESS PERCEPTIONS

CHAPTER 8

Prevalence and consequences of arm, neck, and/or shoulder complaints among music academy students:

A Comparative Study

LAURA M. KOK

ROB G.H.H. NELISSEN

BIONKA M.A. HUISSTEDE

MPPA 2015 Sep;30(3):163-8

ABSTRACT

Objective CANS (Complaints of Arm, Neck, and/or Shoulder not caused by a systemic disease or acute trauma) are a recognized problem in specific occupational groups such as musicians. This study aimed to compare the prevalence, characteristics, and consequences of CANS between music academy students and a control group of peer-age medical students.

Methods A cross-sectional study among music academy students and medical students. Data were collected using a web-based questionnaire on musculoskeletal conditions of the upper extremity in the two cohorts.

Results Students of three music academies (n=345) and one medical university (n=2,870) received the questionnaire, of which 25% (n=87) and 18% (n=503) responded, respectively. The 12-month prevalence of CANS was nearly twice as high among music academy students as the control group (80.7% vs 41.5%, $p<0.001$). Music academy students reported 2.6 times the point prevalence as medical students (47.0% vs 18.2%, $p<0.001$). Chronic CANS was present in 36.1% of the music students, compared to 10.3% of the medical students ($p<0.001$). Music academy students presented more complaints per anatomic localization and a higher number of involved anatomic localizations. Music students rated the influence of CANS on daily functioning as more severe (5.0 vs 3.1, $p<0.001$). Of all subjects with CANS during the last year, more music academy students (46.3%) visited a healthcare professional compared to medical students (29.8%, $p=0.013$).

Conclusion The prevalence of CANS is higher in music academy students compared to medical students. This emphasizes the necessity of effective (preventive) interventions in these high-demanding professionals.

INTRODUCTION

Musculoskeletal problems among musicians are frequent, with reported 12-month prevalences among music academy students and professional musicians ranging from 39% to 90%(1–8), while these numbers vary between 2% and 60% in the general working population.(9,10) These prevalence estimates are often focused on the occurrence of musculoskeletal complaints in the whole body.(2–5,11) However, playing an instrument mainly involves overuse at the upper extremity and neck area. The latter is in accordance with studies showing a high prevalence of musculoskeletal complaints among musicians at the upper extremities, neck, and mouth.(11,12) Since some studies showed that nearly half of professional musicians discontinued practicing their instrument at home during 1 year due to musculoskeletal complaints, evaluation is necessary.(2)

The extent of upper extremity musculoskeletal complaints can be described within the CANS (Complaints of Arm, Neck, and/or Shoulder) model.(13) In the CANS model, complaints due to systemic disease or acute trauma are excluded. This model was developed to support and compare scientific research and to increase multidisciplinary cooperation, using a Delphi consensus strategy. One of the advantages of using this model is the possibility of comparing different populations. Systematically describing the scope of CANS experienced by musicians is not only an important step in recognizing the extent of the problem in that specific group in comparison to other professions, but it will also give clues for addressing preventive interventions. Thus, the primary aim of this study was to evaluate the prevalence of CANS among music academy students compared to a control group of medical students; secondly, the impact of CANS symptoms experienced by music academy students compared to medical students was evaluated.

METHODS

STUDY DESIGN

A cross-sectional study on musculoskeletal conditions of the upper extremity in music academy students was performed. A group of medical school students was considered as a control group. Data were collected from a web-based questionnaire among 3,215 students of three music academies and one medical university in the Netherlands, extensively described in a previous article.(11) Data were collected between February and May 2011. All Dutch-speaking students of three music academies (n=345)—the Royal

Conservatoire, The Hague; CODARTS University for the Arts, Rotterdam; the Amsterdam School of the Arts, Amsterdam, with a classical instrument as main subject (singers and conductors were excluded)—received an invitation, as did medical students (studying to be physicians) from Leiden University (n=2,870). The student registries of the four centers were used to select the subjects. Exclusion criteria were age below 18 years and above 30 years. All eligible students received an e-mail with an invitation to complete the web-based questionnaire. A reminder e-mail was send 3 weeks after the first e-mail. The Leiden University Medical Ethical Committee approved the protocol (11/003b).

QUESTIONNAIRE

The electronic questionnaire included items on sociodemographic characteristics, general health and musculoskeletal complaints (age, gender, height, weight, right/left-hand dominance), study-year (bachelor year 1– 4, master year 1–2), instrument playing (average time playing per week and years of experience) and study (music academy student/medical student), and main instrument. For students playing an instrument, information on the number of years already spent playing the instrument and the average number of hours per week devoted to practice were collected. In addition, the questionnaire included questions concerning smoking, alcohol, sports, and comorbidities.

The existence of musculoskeletal complaints during the last year, current musculoskeletal complaints, and chronic musculoskeletal complaints (complaints during at least 3 months) were scored for six anatomic regions: 1) elbow, wrist, and hand; 2) neck, shoulder, and upper back; 3) lower back; 4) hips and knees; 5) ankles and feet; 6) jaw and mouth. Since this study focused on CANS, only the upper extremity data were used. The body region "elbows, wrists, and hands" was subdivided in six localizations (elbow left and right, wrist left and right, and hand left and right). The region "neck, shoulders, and upper back" was subdivided in four localizations (shoulders left and right, neck and upper back). For all complaints, information was collected concerning the type of the complaint (pain, loss of gross motor skills, loss of fine motor skills, power loss, loss of control, cramp, loss of speed, loss of endurance, swelling, redness, other), the duration of the complaint, cause of the complaint according to the subject, the effect on daily life functioning (scored on a scale from 0–10), and medical consultation (general practitioner, specialist, physiotherapist, alternative medicine). Also the cause(s) of the complaint according to the musicians were questioned (e.g., trauma, repetitive use, etc.).

Statistical Analysis

Statistical analyses were performed with SPSS 20.0 (IBM SPSS, Armonk, NY, USA). Mean and standard deviation (SD) were calculated for each continuous normally distributed variable. Median and range were computed in case of a non-normal distribution. Comparisons of gender, study, smoking, hand preference, and healthcare usage between music academy and medical students were done using chi-square and t-tests.

Prevalence estimates for CANS were calculated by adding all subjects with at least one complaint in one of the six relevant anatomic regions. In case of complaints at multiple sites (e.g., elbow and shoulder), the complaint with the longest duration and the most severe score on daily functioning was used to calculate duration and severity of CANS. Following the definition of CANS complaints due to acute trauma (using the question on causality) and systemic disease (using the questions on causality and comorbidity) were excluded. The following non-exclusive prevalence estimates were calculated: point prevalence of CANS (defined as current CANS); 12-month prevalence of CANS (defined as CANS during the last 12 months); and chronic CANS (defined as CANS present at the time of completing the questionnaire and present for at least 3 months).(13) Prevalence rates, symptoms, occurrence of complaints at multiple sites, and healthcare usage were compared using chi-square tests. The occurrence of complaints at multiple sites was compared using t-tests.

RESULTS

A total of 590 students completed the questionnaire: 87 music academy students (25%) and 503 (18%) medical students. After exclusion of subjects exceeding the age limits, 577 students were included: 83 from the music academies and 494 from the medical school. *Table 1* illustrates the characteristics of the responders.

Prevalence

The 12-month prevalence of CANS among music academy students was nearly twice as high as in medical students (80.7% vs 41.5%, $p<0.001$, *Table 2).* The point-prevalence of CANS was 2.6 times higher in music academy students than in medical students (47.0% vs 18.2%, $p<0.001$, *Table 2).* Differences between both groups were highest for those with chronic CANS. Chronic CANS was more than 3 times as frequent in music academy students (36.1%) as in medical students (10.3%, $p<0.001$).

SYMPTOMS

For those with CANS at present, during the last 12 months, or with chronic CANS, *Table 2* reports the symptoms (e.g., pain, loss of gross motor skills, and presence of muscle cramp). Within both the music academy and medical students groups, at least 90% of the subjects reported pain. However, music academy students presented more severe symptoms compared to medical students; music students with CANS reported more joint swelling ($p=0.042$) and more motor skill problems (fine motor skills $p=0.024$, loss of speed $p<0.001$, loss of control $p=0.012$, cramp $p=0.046$, power loss $p=0.043$, and loss of endurance $p<0.001$) than medical students.

LOCALIZATION OF CANS

The localizations of CANS among music academy and medical students are presented in *Table 3*. The neck was the most frequently affected area, with 46% and 27% of the music academy students and medical students reporting complaints of the neck ($p=0.001$). Among all subjects with CANS during the last 12 months, a higher percentage of music academy students compared to medical students report complaints of the shoulders. The right shoulder was affected in 30% and 9% ($p<0.001$) and the left shoulder in 28% and 7% ($p<0.001$) of the music and medical students, respectively.

Table 1: Sociodemographic characteristics of the study populations

		Music Academy Students (n=83)	**Medical Students (n=494)**	**p-value**
Age		21.5 (SD 2.2)	22.1 (SD 2.6)	0.062
Gender	Male	22 (26.2%)	120 (24.3%)	0.843
	Female	62 (73.8%)	374 (75.7%)	
Grade	Bachelor	72 (86.7%)	248 (50.2%)	<0.001
	Master	11 (13.3%)	246 (49.8%)	
Smoking		10 (11.9%)	26 (5.3%)	0.019
Sport (hrs/wk)		2.2 (SD 2.4)	3.0 (SD 2.8)	0.005
Alcohol consumption (glasses/wk)		3.9 (SD 4.5)	5.5 (SD 6.9)	0.090
Body mass index (kg/m^2)		21.2 (SD 3.0)	22.0 (SD 2.5)	0.001
Practice time (hrs/wk)		20.7 (SD 8.7)		
Experience (no. of playing years)		13.0 (SD 3.3)		
Hand preference	Right	71 (85.5%)	43 (87.7%)	0.593
	Left	12 (14.5%)	61 (12.3%)	

Table 2: Characteristics and duration in music academy and medical students with CANS

			12-months-prevalence of CANS			Point prevalence of CANS			Chronic CANS		
			Music Academy Students (n=83)	**Medical Students (n=494)**	**p**	**Music Academy Students (n=83)**	**Medical Students (n=494)**	**p**	**Music Academy Students (n=83)**	**Medical Students (n=494)**	**p**
Prevalence of CANS			80.7%	41.5%	0.001	47.0%	18.2%	<0.001	36.1%	10.3%	<0.001
Influence of CANS on functioning (VAS 0-10) (SD)			5.0 (2.8)	3.1 (2.4)	<0.001	5.0 (2.7)	3.7 (2.4)	0.013	5.4 (2.6)	4.4 (2.3)	0.122
Symptoms	Pain		91.0%	91.2%	0.965	92.3%	91.1%	0.329	90.4%	90.2%	0.623
	Motor problems	Gross motor skills	23.9%	25.4%	0.807	25.6%	23.3%	0.823	30.0%	35.3%	0.897
		Fine motor skills	10.4%	3.4%	0.024	2.6%	1.1%	0.013	13.3%	2.0%	0.701
		Loss of speed	13.4%	1.0%	<0.001	5.1%	0	0.001	20.0%	0	0.062
		Loss of control	7.5%	1.5%	0.012	5.1%	1.1%	0.164	13.3%	0	0.062
		Cramp	35.8%	23.4%	0.046	25.6%	23.3%	0.016	40.0%	35.3%	0.422
		Power loss	14.9%	6.8%	0.043	7.7%	1.1%	0.365	23.3%	5.9%	0.107
		Loss of endurance	29.9%	5.4%	<0.001	23.1%	6.7%	0.001	36.7%	9.8%	0.021
	Other	Swelling	10.4%	3.9%	0.042	10.3%	0	0.455	20.0%	0	0.007
		Redness	3.0%	2.9%	0.980	2.6%	0	0.181	3.3%	2.0%	0.190
		Other	0	5.4%	0.053	0	5.6%	0.644	0	13.7%	0.371

Table 3: Affected anatomic localizations in music academy and medical students with CANS during the last twelve months

		Number of music academy students with CANS during the last twelve months (n=67)	Number of medical students with CANS during the last twelve months (n=205)	p
Hand	Right	13 (16%)	21 (4%)	0.005
	Left	7 (8%)	16 (3%)	0.123
Wrist	Right	13 (16%)	30 (6%)	<0.001
	Left	6 (7%)	17 (3%)	0.001
Elbow	Right	1 (1%)	4 (1%)	0.541
	Left	5 (6%)	6 (1%)	0.012
Shoulder	Right	25 (30%)	42 (9%)	<0.001
	Left	23 (28%)	32 (7%)	<0.001
Neck		38 (46%)	135 (27%)	0.001

NUMBER OF INVOLVED ANATOMIC LOCALIZATIONS

More music academy students reported CANS in a higher number of anatomic localizations: 32.8% of the music academy students reported complaints in one, 38.8% in two, and 28.4% in three or more anatomic localizations. In medical students, 58.8% reported complaints in one, 31.7% in two, and 9.8% in three or more localizations. *Table 4* shows the number of anatomic localizations in which complaints were reported in those reporting CANS during the last 12 months.

IMPACT ON FUNCTIONING

Music academy students rated the impact of CANS on activities of daily living as more severe than did medical students (VAS 5.0 vs 3.1; p<0.001, *Table 2).*

Table 4: Overlap of complaints in anatomic localizations in subjects with CANS during the last year

	1 anatomic site	2 anatomic sites	3 anatomic sites	4 anatomic sites	5 anatomic sites	6 anatomic sites	7 anatomic sites
Music academy students (n=67)	22 (32.8%)	26 (38.8%)	13 (19.4%)	5 (7.5%)	0	1 (1.5%)	0
Medical Students (n= 205)	120 (58.5%)	65 (31.7%)	17 (8.3%)	2 (1.0%)	0	0	1 (0.5%)

Table 5: Health care usage of music academy and medical students with CANS

	CANS during the last year			Current CANS			Chronic CANS		
	Music academy students (n=67)	**Medical students (n=205)**	**p**	**Music academy students (n=39)**	**Medical students (n=90)**	**p**	**Music academy students (n=30)**	**Medical students (n=51)**	**p**
Any medical care	46.3%	29.8%	0.013	53.8%	52.2%	0.865	63.3%	66.7%	0.761
General practitioner	14.9%	12.7%	0.638	15.4%	23.3%	0.308	16.7%	31.4%	0.145
Specialist	16.4%	4.4%	0.001	20.5%	8.9%	0.066	26.7%	7.8%	0.021
Physiotherapist	34.3%	18.5%	0.007	41.0%	34.4%	0.476	53.3%	49.0%	0.708
Alternative medicine	16.4%	3.4%	<0.001	23.1%	6.7%	0.008	26.7%	9.8%	0.046

HEALTH CARE USAGE

Of all students reporting CANS during the last 12 months, significantly more music academy students than the medical students visited a healthcare professional (46.3% vs 29.8%, p=0.013, *Table 5).*

GENDER AND SCHOOL GRADE

Among the music academy students, a higher prevalence of CANS was present among female students compared to male students (84% vs 71%, p=0.212, *Table 6).* A higher prevalence of CANS was reported among bachelor students than master students (85% vs 55%, p=0.018, *Table 6).*

Table 6: Gender specific occurrence of CANS (12 month prevalence) among music academy students

	CANS (n=67)	**No CANS (n=16)**	**p**
Male (n=21)	15 (71.4%)	6 (28.6%)	p=0.212
Female (n=62)	52 (83.9%)	10 (16.1%)	

Table 7: Grade specific occurrence of CANS (12 month prevalence) among music academy students

	CANS (n=67)	**No CANS (n=16)**	**p**
Bachelor (n=72)	61 (84.7%)	11 (15.3%)	p=0.018
Master (n=11)	6 (54.5%)	5 (45.4%)	

DISCUSSION

This study showed high prevalence rates of CANS among music academy students, which were two to three times higher than in medical students. Prevalence rates of CANS in music academy students were 80.7% for 12-month prevalence of CANS, 47.0% for point prevalence, and 36.1% for prevalence of chronic CANS. Furthermore, music academy students with CANS presented with a higher number of symptoms for each of the anatomic localizations. Complaints were present at a higher number of anatomic localizations among music academy students than in medical students, and they rated the influence of CANS on daily functioning as more severe compared to the control group of medical students. Music academy students also reported more healthcare use compared to medical students due to these musculoskeletal complaints.

In this study we choose not to account work-relatedness, although we focused on a specific occupational group. The reason for this was that the advantage of using the definition of CANS, a universal term allowing adequate comparison of results, would thereby be lost. Also the term playing-related musculoskeletal complaints (PRMDs)(14) was not used in the present study, due to the limitation to work/music-related complaints in that definition. Furthermore, PRMDs would not have been scored properly in the non-musicians control group, which would make comparison of these groups impossible.

Computer office workers are one of the occupational groups known to have a high risk of upper extremity musculoskeletal complaints. Research on CANS among computer office workers showed 1-year prevalences between 54% and 64%.(9,15,16) This prevalence is higher than the prevalence in the general Dutch population (36.8%).(17) However, this prevalence of CANS among computer office workers is still low compared to the 12-month prevalence in our music academy students (80.7%), underscoring even more the high prevalence of CANS in this specific group of students. Thus, focusing on preventive measures to counteract the occurrence of these musculoskeletal complaints is of importance.

An unexpected outcome of this study was the use of healthcare of music academy students compared with medical students with CANS. Previous research showed a culture among musicians acknowledging musculoskeletal pain as "a normal consequence of playing" and in which talking about these complaints is considered a taboo, the latter

potentially causing a healthcare-avoiding behaviour.(14,18) This was in contrast to our findings, since we found more healthcare use among Dutch music academy students than in medical students. These results are comparable to a Danish study(2) which also showed a high healthcare use among musicians (64%); on the contrary, in the USA, healthcare use among musicians is reported at only 21%.(19) Musicians in general have low economic resources and often no permanent contract, with consequently no healthcare insurance for these complaints in a US-based system.(7) The differences found between the above-mentioned studies and countries may be caused by financial reasons due to national differences in both accessibility of healthcare systems as well as funding of healthcare use, which are both easily accessible and rather cheap in the Netherlands.

LIMITATIONS

The present study has some limitations. First, the response rate was low, which can be due to the fact that the invitation for the questionnaire was sent by e-mail (instead of telephone/mail), and only one reminder was send to the participants. Second, selection bias may be present as a consequence of this low response rate and may have resulted in an over- or underestimation of the results. In general it has been found, that those who sought medical care are more likely to respond to a postal survey(20), and thus an overestimation of musculoskeletal complaints might be present in this study.

Third, selection bias may be present by the use of medical students as a control group. It is unknown whether medical students with CANS will under- or over-report their complaints compared to those with CANS in the general population. The "medical students disease," hypochondria, might result in a higher amount of health-care use; on the other hand, medical students can easily access medical literature and informally consult a physician, which might result in a less "official" healthcare usage.(21) The largest study measuring the prevalence of CANS in the general population reported a 1-year prevalence of 36.8%.(17) This prevalence, in a population aged over 25 yrs of age, is comparable to our outcome data among medical students (41.5%). Also, the overall healthcare usage due to CANS between these studies is comparable: 59% in our control population compared to 58% in the study of Huisstede et al.(17) This comparability of the control group with a study performed in the general population underlines the representativeness of our control group.

There is a lack of literature comparing musicians with non-musicians.(4,11,12,22) Comparative research has a higher level of evidence compared to a non-controlled cross-sectional study. This study has, despite the presence of bias by using medical students, an important additional value to the existing literature on musculoskeletal problems among musicians.

Future research on musculoskeletal complaints among musicians should aim at two important domains: 1) prevention, and 2) treatment of specific and non-specific CANS. One of the options for prevention could be a prevention training program; In all types of professional sports, there are specific strength training programs, in addition to the technical sport-specific training, which have proved to reduce the risk of injuries, also in non-contact sports.(23) A comparable preventive training program should be developed for musicians; a study on a physical training program for musicians or music academy students with a focus on the upper extremity would be very interesting. Khalsa and Cope(24), for example, studied the effect of yoga training on a small group of music students, which seemed to relieve performance anxiety but not musculoskeletal problems. Recently, in Australia, a trial was started to study the effects of a training program on orchestral musicians.(25) In addition to physical efforts preventing musculoskeletal complaints, the mental aspects also should be addressed.(26) These studies are examples of the next steps in preventing musculoskeletal complaints among musicians. However, much work has to be done, especially among music academy students, in which musculoskeletal problems are highly prevalent and changes in health habits and attitude can be made.

A second important future study domain should focus on describing the occurrence, clinical presentation, and treatment options and outcomes of specific syndromes and diseases among musicians. For example, studies describing the presentation of "normal diseases" such as neuropathy of the median or ulnar nerve among musicians(27,28) should focus on specific complaints among musicians that are probably different compared to the general population. Also, the outcome of regular and musicians specific conservative treatment options (e.g., adaptive instruments, playing technique) and operative treatment options should be evaluated in order to optimize healthcare for musicians.(29) This could lead to a field of knowledge, comparable to sports medicine, in which the choice of treatment for musicians possibly differs compared to non-musicians.

The results of this study may help to give directions to both of the above-mentioned study domains.

CONCLUSION

In conclusion, this study emphasized the striking prevalence rates and serious consequences on daily functioning and healthcare usage of CANS among music academy students. Awareness of this health condition among this specific profession is a first step, which may be helpful to develop preventive intervention programs aimed at reducing the extent and consequences of CANS among music academy students and musicians.

REFERENCES

1. Zaza C, Farewell VT. Musicians' playing-related musculoskeletal disorders: an examination of risk factors. Am J Ind Med. 1997 Sep;32(3):292–300.
2. Paarup HM, Baelum J, Holm JW, Manniche C, Wedderkopp N. Prevalence and consequences of musculoskeletal symptoms in symphony orchestra musicians vary by gender: a cross-sectional study. BMCMusculoskeletDisord. 2011 Oct 7;12(1471–2474 (Electronic)):223.
3. Kaufman-Cohen Y, Ratzon NZ. Correlation between risk factors and musculoskeletal disorders among classical musicians. OccupMed(Lond). 2011 Mar;61(1471–8405 (Electronic)):90–5.
4. Zaza C. Playing-related musculoskeletal disorders in musicians: a systematic review of incidence and prevalence. CMAJ. 1998 Apr 21;158(0820–3946 (Print)):1019–25.
5. Engquist K, Orbaek P, Jakobsson K. Musculoskeletal pain and impact on performance in orchestra musicians and actors. MPPA. 2004;19(2):55–61.
6. Brandfonbrener AG. History of Playing-related Pain in 330 University Freshman Music Students. MPPA. 2009;24(1):30–6.
7. Guptill C, Zaza C, Paul S. An occupational study of physical playing-related injuries in college music students. MPPA. 2000;15(2):86–90.
8. Nawrocka A, Mynarski W., A. P-D, M. G, W. G. Musculoskeletal pain among polish music school students. MPPA. 2014 Jan 6;29(2):64–9.
9. Ranasinghe P, Perera YS, Lamabadusuriya DA, Kulatunga S, Jayawardana N, Rajapakse S, et al. Work related complaints of neck, shoulder and arm among computer office workers: a cross-sectional evaluation of prevalence and risk factors in a developing country. Environ Health. 2011 Aug 4;10(1):70.
10. Huisstede BM, Bierma-Zeinstra SM, Koes BW, Verhaar JA. Incidence and prevalence of upper-extremity musculoskeletal disorders. A systematic appraisal of the literature. BMCMusculoskeletDisord. 2006 Dec 31;7(1471–2474 (Electronic)):7.
11. Kok LM, Vlieland TPV, Fiocco M, Nelissen RG. A comparative study on the prevalence of musculoskeletal complaints among musicians and non-musicians. BMC Musculoskelet Disord. 2013;14.
12. Roach KE, Martinez MA, Anderson N. Musculoskeletal pain in student instrumentalists: a comparison with the general student population. MPPA. 1994 Dec;9(4):125–30.
13. Huisstede BM, Miedema HS, Verhagen AP, Koes BW, Verhaar JA. Multidisciplinary consensus on the terminology and classification of complaints of the arm, neck and/or shoulder. OccupEnvironMed. 2007 May;64(1470–7926 (Electronic)):313–9.
14. Zaza C, Charles C, Muszynski A. The meaning of playing-related musculoskeletal disorders to classical musicians. SocSciMed. 1998 Dec;47(0277–9536 (Print)):2013–23.
15. Ranasinghe P, Perera YS, Lamabadusuriya DA, Kulatunga S, Jayawardana N, Rajapakse S, et al. Work-related complaints of arm, neck and shoulder among computer office workers in an Asian country: prevalence and validation of a risk-factor questionnaire. BMCMusculoskeletDisord.

2011;12(1471–2474 (Electronic)):68.

16. Eltayeb S, Staal JB, Kennes J, Lamberts PH, de Bie RA. Prevalence of complaints of arm, neck and shoulder among computer office workers and psychometric evaluation of a risk factor questionnaire. BMCMusculoskeletDisord. 2007;8(1471–2474 (Electronic)):68.

17. Huisstede BM, Wijnhoven HA, Bierma-Zeinstra SM, Koes BW, Verhaar JA, Picavet S. - Prevalence and characteristics of complaints of the arm, neck, and/or shoulder (CANS) in the open population. - Clin J Pain2008 Mar-Apr;24(3)253-9. (0749-8047 (Print)).

18. Bragge P, Bialocerkowski A, McMeeken J. Understanding playing-related musculoskeletal disorders in elite pianists: A grounded theory study. MPPA. 2006;21(2):71–9.

19. Pratt RR, Jessop SG, Niemann BK. Performance-related disorders among music majors at Brigham Young University. Int J Arts Med. 2012;1(1):7–20.

20. Etter JF, Perneger T V. Analysis of non-response bias in a mailed health survey. J ClinEpidemiol. 1997 Oct;50(0895–4356 (Print)):1123–8.

21. Ross S, von FM, Cleland J. Medical students' illness-related cognitions. Med Educ. 2011 Dec;45(1365–2923 (Electronic)):1241–50.

22. Fry HJH. Prevalence of Overuse (Injury) Syndrome in Australian Music Schools. Br J Ind Med. 1987;44(1):35–40.

23. Abernethy L, Bleakley C. Strategies to prevent injury in adolescent sport: a systematic review. BrJ Sport Med. 2007 Oct;41(1473–0480 (Electronic)):627–38.

24. Khalsa SB, Cope S. Effects of a yoga lifestyle intervention on performance-related characteristics of musicians: a preliminary study. Med Sci Monit. 2006 Aug;12(1234–1010 (Print)):CR325-CR331.

25. Chan C, Driscoll T, Ackermann B. Development of a specific exercise programme for professional orchestral musicians. InjPrev. 2012 Dec 4;19(1475–5785 (Electronic)):257–63.

26. C. S, M. N, Zander M. Long-term analysis of health status and preentive behavior in music students across an entire university program. MPPA. 2014 Jan 3;29(1):8–15.

27. S.W. S, N.R. K, L.B. G, D.R. S, J.h. M, D.G. G. Median and Ulnar Neuropathies in U.S. Army Medical Command Band Members. MPPA. 2013 Jan 12;28(4):188–94.

28. Lederman RJ. Anterior interosseous neuropathy in instrumental musicians. MPPA. 2006 Jan 9;21(3):137–41.

29. Ell N. Surgery on the hands of musicians with rheumatoid arthritis. MPPA. 2002 Jan 9;17(3):121–7.

Chapter 9

Musicians' illness perceptions of musculoskeletal complaints

Laura M. Kok

Theodora P.M. Vliet Vlieland

Marta Fiocco

Ad A. Kaptein

Rob G.H.H. Nelissen

Clin Rheumatol. 2013 Apr;32(4):487-92

ABSTRACT

Introduction The purpose of this study is to know the views of people about their illness, i.e., illness perceptions, determine coping strategies, and outcome. Previous research suggests a higher prevalence and a different perception of musculoskeletal complaints between musicians and non-musicians. The aim of this study is to compare illness perceptions related to musculoskeletal complaints between musicians and non-musicians.

Methods In this cross-sectional study, students from three music academies (n=345) and one university medical centre (n=2,870) in the Netherlands received an electronic questionnaire concerning questions on sociodemographic characteristics, use of musical instruments, occurrence and characteristics of musculoskeletal complaints in the past year, and the Brief Illness Perception Questionnaire (B-IPQ). Baseline and B-IPQ scores were compared between the samples by means of t tests, chi-square tests, and regression models to adjust for differences in sociodemographic characteristics.

Results Eighty-seven music academy students and 503 medical students completed the questionnaire, of which 83 and 494 were included in the current study (response rates 25% and 18%, respectively). Seventy-four (89%) persons in the musician group and 382 (78%) persons in the non-musician group reported occurrence of musculoskeletal complaints during the last 12 months. Adjusted for sociodemographic characteristics, the B-IPQ scores of the domains consequences (my illness is a serious condition), concern (I am extremely concerned about my illness), and emotions (my illness makes me scared) were significantly higher among musicians, whereas personal control (there is little I can do to improve my illness), identity (number of symptoms patient sees as part of illness) were not significantly different. Music academy students had a significantly more positive score on treatment control.

Conclusions Music academy students report more negative perceptions of their musculoskeletal complaints compared to medical students. Although some selection bias is present, this is supposed to have a minor effect on the outcomes of this study. Addressing illness perceptions in musicians with musculoskeletal complaints could have beneficial effects on physical and functional outcomes.

INTRODUCTION

Musculoskeletal complaints are the most common cause of severe, long-term pain and physical disability in the general population, representing almost 25% of the total health cost in European countries.(1) Certain occupational groups are associated with higher rates of musculoskeletal complaints. Musicians are more frequently affected compared to age- and sex-matched controls(2–5), with prevalence rates of musculoskeletal complaints ranging from 39% up to 90% in adult musicians, depending on the severity of the evaluated complaints.(5–9)

A wealth of factors influences the impact of musculoskeletal complaints on physical and psychological functioning.(10) Beliefs about a personal health condition, e.g., musculoskeletal complaints, are called illness perceptions. They are influenced by the personal experience of the illness and its management, cultural, and social factors such as experiences of illness in the social environment, and social comparison processes.(11,12) In Leventhals' self-regulation model, illness perceptions are considered determinants of quality of life.(13) It is stated that patients are active problem solvers, who seek to make sense of illness; they form mental representations that influence coping strategies.(13) People regulate both their behavioural and emotional reactions to illness based on (1) the symptoms attributed to the illness, e.g., pain or numbness (identity); (2)beliefs about causes of the illness, e.g., overuse (cause); (3) curability or controllability of the illness (cure/control); (4) perceived consequences of the illness in everyday life, e.g., not being able to work (consequences); (5) expected duration of the illness, e.g., chronic or intermittent (time line). Patients with a strong illness identity, severe perceived consequences of the illness, low perceived controllability, and a chronic perceived time line have been shown to report low well-being in various chronic somatic diseases.(11,14–16) These mental representations of illness (illness perceptions) partly determine how individuals respond to illness, and thereby their coping strategy; together, they determine the quality of life.(10) These findings have important clinical implications: Illness perceptions are not merely predictors for the outcomes of various diseases(14–19), changing illness perceptions has been shown to be associated with improvements in outcome after interventions.(12) A recent review also showed that illness perceptions play a role in the work participation of patients.(20) Interventions targeted at changing these perceptions of how to deal with the occurrence of disease or complaints are promising.(13,17,20)

Many musicians believe that pain is inherent to the level of performance they try to achieve.(21) Furthermore, injuries may be interpreted as presence of an inferior talent and thus as a failure as a performer.(22) Musculoskeletal complaints often result in not being able to perform at the necessary level. In the competitive environment where most musicians do not have a permanent job contract but rather do freelance work, minor complaints could immediately result in financial problems. As a result, almost half of the musicians in a study with playing-related injuries were not able to return to their career.(23) These factors stress the importance of research into the nature of illness perception of these musicians and to identify potential means of preventive and curative interventions in order to improve outcome of interventions for these professionals. Thus, the aim of this study is to compare perceptions of musculoskeletal complaints between musicians and non-musicians.

METHODS

This cross-sectional study compares the scores on the Brief Illness Perception Questionnaire (B-IPQ) between music academy and medical students with musculoskeletal complaints during the past 12 months. The study was performed at four Dutch institutions: The Royal Conservatoire, the CODARTS University for the Arts, the Amsterdam School of the Arts, and the medical faculty of the Leiden University—all between February and May 2011. Students from the aforementioned music academies, with a classical instrument as main subject, and medical students received an invitation. All students involved in the research spoke Dutch. Music academy students were selected from the student registries of the four institutions by employees of the musical academies. Medical students were selected from attendance lists from courses ranging from years 1 through 6. All eligible students received an e-mail with an invitation to complete the online questionnaire. After completing the questionnaire, students younger than 18 or older than 30 years were excluded in order to create a homogenous population. The Medical Ethical Committee of the Leiden University Medical Center approved the protocol.

The electronic questionnaire comprised of the following items: sociodemographic characteristics, general health, musculoskeletal complaints, and illness perceptions. In *Appendix A* the content of the questionnaire is described.

For the assessment of illness perceptions of students with musculoskeletal complaints in both samples, the Dutch version of the Brief IPQ was used.(24) This questionnaire consists of nine items, eight questions are rated using a 0– 10 response scale. Five of these items assess cognitive illness representations. The five domains are consequences (e.g., "My illness has major consequences on my life", "My illness is a serious condition"), timeline (e.g., "My illness is likely to be permanent rather than temporary", "My illness will last for a long time"), personal control (e.g., "There is little I can do to improve my illness"), treatment control (e.g., "My treatment will be effective in curing my illness"), and identity (Rating of a number of symptoms that the patient sees as part of the illness). Two of the items assess emotional representations: concern (e.g., "I am extremely concerned about my illness") and emotions (e.g., "My illness makes me angry, scared, upset or depressed"). One item assesses illness comprehensibility (e.g., I understand my illness).

All statistical analyses were performed in SPSS. For continuous normally distributed variables, mean and standard deviation were calculated or median and range when not normally distributed. Baseline and B-IPQ scores were compared by means of t-tests and chi-square tests. Regression models to adjust for differences in sociodemographic characteristics were employed.

RESULTS

The questionnaire was sent to 345 musical and 2,870 medical students. A total of 590 students completed the questionnaire, 87 music academy students (response rate, 25%) and 503 medical students (response rate, 18%), an overall response of 18%. Thirty-three of the 135 students studying at the Royal Conservatoire completed the questionnaire (response rate 24%), as well as 26 of the 124 students of the Amsterdam school of the Arts (response rate 21%) and 24 of the 86 students of CODARTS University of the Arts (response rate 28%). Three individuals were excluded, all from the music academy students group because they were younger than 18 years. Another eight subjects were excluded since they were older than 30 years. Two subjects were excluded because of being a singer. Among 83 music academy students and 494 medical students, 74 music academy students (89%) and 382 medical students (78%) reported musculoskeletal complaints during the past 12 months.

Table 1: Baseline characteristics of music academy students and medical students

	Music academy students (n=74)	**Medical students (n=384)**	**Difference (p)**
Age (years) (SD)	21.3 (2.2)	22.1 (2.6)	0.013
Gender (%)	Male: 18 (24.3%)	Male: 87 (22.7%)	0.746
	Female: 56 (75.7%)	Female: 297 (77.3%)	
Study grade (%)	Bachelor: 68 (91.9%)	Bachelor: 193 (50.5%)	<0.001
	Master: 6 (8.1%)	Master: 191 (49.5%)	
Smoking (%)	8 (10.8%)	21 (5.5%)	0.068
Sport (hours in 1 week) (SD)	2.2 (2.3)	2.9 (3.0)	0.021
Alcohol consumption (U/week) (SD)	3.9 (4.7)	5.3 (6.3)	0.129
Body mass index (kg/m2) (SD)	21.2 (3.1)	22.0 (2.5)	0.018
Hand preference (%)	Right: 62 (83.8%)	Right: 333 (86.7%)	0.538
	Left: 12 (16.2%)	Left: 51 (13.3%)	

The proportion of students reporting complaints of hands, wrists, elbows (54.1% and 28.3%, respectively) and shoulders, neck, and upper back (87.8% and 60.5%, respectively) was higher among music academy students compared to medical students.

The distribution of instruments of music academy students was: 24 (32.4%) played a string instrument (e.g., violin, cello), 25 (33.8%) played a woodwind instrument (e.g., flute, clarinet), 6 (8.1%) played a brass instrument (e.g., trumpet, tuba), 16 (21.6%) played percussion or keyboard (e.g., piano, timpani), and 3 (4.1%) played a plucked string instrument (e.g., harp).

Characteristics of the population are presented in *Table 1*. The two groups were comparable for gender, cigarette and alcohol consumption, and hand dominance. Differences in age, study grade, hours of sport in a week, and body mass index have been found.

In *Table 2*, the results of Brief IPQ scores are depicted. Scores range from 0 to 10. Music academy students perceived significantly more negative perception scores compared to the medical students with respect to the domains consequences (4.5 and 2.7, respectively; $p<0.001$), personal control (6.1 and 6.7, respectively; $p=0.014$), identity (4.7 and 4.0, respectively; $p=0.037$), concern (3.9 and 2.3, respectively; $p<0.001$), and emotions (4.3 and 2.3, respectively; $p<0.001$). These differences remained significant when adjusted for age,

gender, study grade, smoking, sport, alcohol consumption, body mass index, and hand preference, except for personal control and identity. There was no significant difference, but still a negative tendency after the adjustments in the domains timeline (5.2 and 3.9, respectively; p=0.108) and comprehensibility (7.0 and 7.2, respectively; p=0.176). Music academy students had a significantly more positive score on treatment control (5.7 and 4.2, respectively; p=0.003), also after controlling for the afore mentioned confounders.

Table 2: B-IPQ outcomes of music academy and medical students with musculoskeletal complaints

	Music academy students (n=74)	**Medical students (n=382)**	**Difference (p)**
Consequences (0–10)	4.5 (2.7)	2.2 (2.2)	<0.001
Timeline (0–10)	5.2 (3.4)	3.9 (3.5)	0.108
Personal control (0–10)	6.1 (2.2)	6.7 (2.4)	0.014
Treatment control (0–10)	5.7 (2.6)	4.2 (3.0)	0.003
Identity (0–10)	4.7 (2.6)	4.0 (2.7)	0.037
Concern (0–10)	3.9 (2.6)	2.3 (2.4)	<0.001
Understanding (0–10)	7.0 (2.1)	7.2 (2.4)	0.176
Emotions (0–10)	4.3 (2.8)	2.3 (2.4)	<0.001

DISCUSSION

Musicians report worse perceptions of their musculoskeletal complaints compared to medical students. This study shows considerable differences between the two groups with respect to the cognitive and emotional aspects of their complaints. Students at music academies perceive more severe consequences, are more concerned and emotionally more affected by their musculoskeletal complaints, compared to students at a medical school. These results support the hypothesis concerning a more severe impact of musculoskeletal complaints on musicians compared to non-musicians.(21,22)

This study has some limitations: by choosing medical students as a control, a selection bias was created. Medical students might be more focused on health in general, even more they have different perceptions of the health system and pathology (i.e., “complaints”), possibly leading to different perceptions of their complaints.(25) On the other hand, two very different groups (i.e., presence of medical knowledge or not) will also make a contrast between two groups more evident.

A second limitation concerns the relatively low response rate for both groups. This unfortunately happens quite often when questionnaires are involved in studies.(26) There are several reasons for not responding to a questionnaire and possible selection bias due to non-responders should be kept in mind. However, the prevalence of musculoskeletal complaints in both music academy students and medical students are in line with the literature (8,27), underlining the representativeness of our samples. As the subjects of this study did not know in advance that they would receive questions concerning their perception of their complaints (and therefore did not choose to respond or not respond for this reason), and the fact that the prevalence numbers are in line with the literature, it is supposed that the B-IPQ outcomes of the students in this study are representative for all students who received an invitation. Summarizing, the effect of the bias due to the low response rate is probably very small.

A third limitation concerns the difference in the localization of the complaints between the two groups, creating a possible selection bias with respect to musculoskeletal complaints of the upper extremity in musicians. A fourth important issue is the exclusion of confounding factors. As regression models were used to adjust for differences in age, gender, study grade, smoking, sport, alcohol consumption, body mass index, and hand preference, the effect of many important confounding factors was eliminated. At the same time, our study is important as it explores an issue which is clinically very relevant in this group of performing artists. In addition, our study may help to shed light on tailoring interventions—preventive coping strategies as well other medical interventions—to musicians' needs.

A surprising finding of the current study is the difference in the perception of "treatment control". Musicians think that treatment for their musculoskeletal complaint(s) is more effective than medical students (non-musicians). A hypothesis for the lower scores of the medical students on treatment control is the more extensive and probably more realistic knowledge of these students on the current treatment possibilities and outcomes of musculoskeletal complaints. Compared to patients in other studies, musicians' scores on treatment control are low.(10,24,28,29) This is in line with the fact that musicians tend to consult more with alternative practitioners than with traditionally trained providers, often because of a lack of trust of the medical establishment.(30) Musicians are frustrated by the absence of knowledge of medical care providers concerning the physical demands of playing their instrument and the lack of recognition of the importance of the occupation

of the musician.(31) Are physicians unable to satisfy the high demands of the musicians? An exploration of the expectations of a patient is essential, especially when the treatment expectations are as high as in musicians.

The subjects in this study have complaints which vary from myalgia to invalidating pain. This is reflected in the relatively positive B-IPQ scores compared to other studies on patients with by example systemic lupus erythematosus (SLE), chronic obstructive pulmonary disease, lung cancer, and myocardial infarction.(10,12,24,29)

This study shows important differences in illness perceptions between music academy and medical students concerning their conceptualization of musculoskeletal complaints. Because of the known impact of perception on outcomes of treatments, doctors treating musicians should be aware of the substantial influence of cognitive and emotional aspects of an illness and coping style of their patients. Addressing these concerns, for example with a cognitive– behavioral technique such as motivational interviewing, may be more beneficial, effective and efficient than a strictly biomedical approach. Intervention studies in patients with a myocardial infarction, pain, and SLE showed effectiveness of this approach in producing positive behavioral and psychological outcome.(12,16,32) Interaction between a patient and a healthcare provider stimulating interaction on expectations and beliefs about the complaint can reduce unhelpful perceptions, improve coping skills, and improve health and work outcomes (20) as well as surgical outcome.(33,34) In conclusion, a biopsychosocial approach of musicians with musculoskeletal complaints appears to hold promise.

REFERENCES

1. Woolf AD, Akesson K. - Can we reduce the burden of musculoskeletal conditions? The European action towards better musculoskeletal health. - Best Pr Res Clin Rheumatol2007 Feb;21(1)1-3. (1521-6942 (Print)).
2. Roach KE, Martinez MA, Anderson N. Musculoskeletal pain in student instrumentalists: a comparison with the general student population. MPPA. 1994 Dec;9(4):125–30.
3. Fry HJH, Ross P, Rutherford M. Music-related overuse. MPPA. 1988 Dec;3(4):133–4.
4. Kok LM, Vlieland TPV, Fiocco M, Nelissen RG. A comparative study on the prevalence of musculoskeletal complaints among musicians and non-musicians. BMC Musculoskelet Disord. 2013;14.
5. Caldron PH, Calabrese LH, Clough JD, Lederman RJ, Williams G, Leatherman J, et al. A survey of musculoskeletal problems encountered in high-level musicians. MPPA. 1986 Dec 12;1(4):136–9.
6. Middlestadt SE, Fishbein M. The prevalence of severe musculoskeletal problems among male and female symphony orchestra string players. MPPA. 1989 Mar;4(1):41–8.
7. Lederman RJ. Neuromuscular and musculoskeletal problems in instrumental musicians. Muscle Nerve. 2003 May;27(0148–639X (Print)):549–61.
8. Zaza C. Playing-related musculoskeletal disorders in musicians: a systematic review of incidence and prevalence. CMAJ. 1998 Apr 21;158(0820–3946 (Print)):1019–25.
9. Hoppmann RA, Reid RR. Musculoskeletal problems of performing artists. CurrOpinRheumatol. 1995 Mar;7(1040–8711 (Print)):147–50.
10. Daleboudt GM, Broadbent E, Berger SP, Kaptein AA. Illness perceptions in patients with systemic lupus erythematosus and proliferative lupus nephritis. Lupus. 2011 Mar;20(1477–0962 (Electronic)):290–8.
11. Aalto AM, Heijmans M, Weinman J, Aro AR. Illness Perceptions in coronary heart disease. Sociodemographic, illness-related, and psychosocial correlates. JPsychosomRes. 2005 May;58(0022–3999 (Print)):393–402.
12. Petrie KJ, Cameron LD, Ellis CJ, Buick D, Weinman J. Changing illness perceptions after myocardial infarction: an early intervention randomized controlled trial. PsychosomMed. 2002 Jul;64(0033–3174 (Print)):580–6.
13. Leventhal H, Nerenz DR, Steele DJ. Illness representations and coping with health threats. In: Baum A, Taylor SE, Singer JE, editors. Handbook of Psychology and Health, Volume IV: social psychological aspects of health. Hillsdale: Lawrence Erlbaum; 1984. p. 219–52.
14. Scharloo M, Kaptein AA, Weinman J, Bergman W, Vermeer BJ, Rooijmans HG. Patients' illness perceptions and coping as predictors of functional status in psoriasis: a 1-year follow-up. Br J Dermatol. 2000 May;142(5):899–907.
15. Frostholm L, Oernboel E, Christensen KS, Toft T, Olesen F, Weinman J, et al. Do illness perceptions predict health outcomes in primary care patients? A 2-year follow-up study. JPsychosomRes. 2007 Feb;62(0022–3999 (Print)):129–38.

16. Foster NE, Bishop A, Thomas E, Main C, Horne R, Weinman J, et al. Illness perceptions of low back pain patients in primary care: What are they, do they change and are they associated with outcome? Pain. 2008 May;136(1):177–87.

17. van Wilgen CP, Kaptein AA, Brink MS. Illness perceptions and mood states are associated with injury-related outcomes in athletes. DisabilRehabil. 2010;32(1464–5165 (Electronic)):1576–85.

18. Groarke A, Curtis R, Coughlan R, Gsel A. The role of perceived and actual disease status in adjustment to rheumatoid arthritis. Rheumatology(Oxford). 2004 Sep;43(1462–0324 (Print)):1142–9.

19. Moss-Morris R, Chalder T. Illness perceptions and levels of disability in patients with chronic fatigue syndrome and rheumatoid arthritis. JPsychosomRes. 2003 Oct;55(0022–3999 (Print)):305–8.

20. Hoving JL, van der Meer M, Volkova AY, Frings-Dresen MH. - Illness perceptions and work participation: a systematic review. - Int Arch Occup Env Heal Aug;83(6)595-605Epub 2010 Feb 4. (1432-1246 (Electronic)).

21. Amadio PC, Russotti GM. Evaluation and treatment of hand and wrist disorders in musicians. Hand Clin. 1990 Aug;6(0749–0712 (Print)):405–16.

22. Brandfonbrener AG. Special issues in the medical assessment of musicians. PhysMedRehabilClinNAm. 2006 Nov;17(1047–9651 (Print)):747–53, v.

23. Heinan M. A review of the unique injuries sustained by musicians. JAAPA. 2008 Apr;21(1547–1896 (Print)):45–46,48,50.

24. Broadbent E, Petrie KJ, Main J, Weinman J. The Brief Illness Perception Questionnaire. JPsychosomRes. 2006 Jun;60(0022–3999 (Print)):631–7.

25. Ross S, von FM, Cleland J. Medical students' illness-related cognitions. Med Educ. 2011 Dec;45(1365–2923 (Electronic)):1241–50.

26. Asch DA, Jedrziewski MK, Christakis NA. - Response rates to mail surveys published in medical journals. - J Clin Epidemiol1997 Oct;50(10)1129-36. (0895-4356 (Print)).

27. Picavet HS, Schouten JS. Musculoskeletal pain in the Netherlands: prevalences, consequences and risk groups, the DMC(3)-study. Pain. 2003 Mar;102(0304–3959 (Print)):167–78.

28. Sluiter JK, Frings-Dresen MH. - Quality of life and illness perception in working and sick-listed chronic RSI patients. - Int Arch Occup Env Heal Feb;81(4)495-501Epub 2007 Jul 19. (0340-0131 (Print)).

29. Kaptein AA, Scharloo M, Fischer MJ, Snoei L, Cameron LD, Sont JK, et al. Illness perceptions and COPD: an emerging field for COPD patient management. JAsthma. 2008 Oct;45(1532–4303 (Electronic)):625–9.

30. Dommerholt J. Performing arts medicine - instrumentalist musicians part I - general considerations. JBodywMov Ther. 2009 Oct;13(1532–9283 (Electronic)):311–9.

31. Guptill C. The lived experience of working as a musician with an injury. Work. 2011 Jan 1;40(1875–9270 (Electronic)):269–80.

32. Goodman D, Morrissey S, Graham D, Bossingham D. - Illness representations of systemic lupus

erythematosus. - Qual Heal Res2005 May;15(5)606-19. (1049-7323 (Print)).

33. Ronnberg K, Lind B, Zoega B, Halldin K, Gellerstedt M, Brisby H. - Patients' satisfaction with provided care/information and expectations on clinical outcome after lumbar disc herniation surgery. - Spine (Phila Pa 1976)2007 Jan 15;32(2)256-61. (1528-1159 (Electronic)).

34. Nilsdotter AK, Toksvig-Larsen S, Roos EM. - Knee arthroplasty: are patients' expectations fulfilled? A prospective study of pain and function in 102 patients with 5-year follow-up. - Acta Orthop2009 Feb;80(1)55-61. (1745-3682 (Electronic)).

35. www.uib.no/ipq. 2012.

Appendix: Questionnaire content

Age, gender, length, weight, right/left-handed, study year (bachelor 1 until 4, master 1 or 2), playing an instrument and study (music academy student/medical student), main instrument (violin, viola, cello, base, piano/keyboard, guitar/ mandolin, bassoon, oboe, clarinet, flute/piccolo, horn, trombone, tuba, harp, percussion, recorder, and other in which the participants had to fill in their instrument) were asked. The instruments were divided in five categories: (1) bowed strings, (2) plucked strings, (3) woodwinds, (4) brass, and (5) percussion and keyboards. In addition, the questionnaire included questions concerning smoking (none/up to a half pack a day/half to one pack a day/more than one pack a day), alcohol (number of glasses per week), and sports (number of hours per week).
Musculoskeletal complaints

Musculoskeletal complaints were comprehensively questioned, using a self-constructed questionnaire on musculoskeletal complaints consisting of 144 questions, in which the occurrence of complaints in six specific body regions, subdivided in 21 sub-body regions (yes/no) was asked. Each of these groups of questions started by asking whether the individual had complaints about a specific body region during the last 12 months. The first body region “elbows, wrists and hands” was subdivided in six localizations (elbow left and right, wrist left and right, hand left and right). The second one “neck shoulders and upper back” was subdivided in four localizations (shoulders left and right, neck, upper back). The third region “lower back” was not subdivided, while the fourth region “hips and knees” was subdivided in four localizations (hip left and right and knee left and right). The fifth region “ankles and feet” was subdivided in four sub-regions (ankle left and right, foot left and right). The last region “jaw and mouth” was subdivided in jaw and mouth. The total prevalence score was calculated by adding all subjects with at least one complaint. The prevalence concerning a specific body region was also computed by adding all subjects with at least one complaint in that body region. If the above mentioned question concerning complaints during the last 12 months was answered with yes, it was specified: it was asked whether the complaint was still present (yes/no). Then again the question on whether there were more complaints of the same body region was asked. In case the question was answered with yes, this was again specified; otherwise the next body part was questioned.

For this study, only the data from respondents that indicated having had one or more musculoskeletal complaints over the past 12 months were used. For the assessment of illness perceptions, the Dutch version of the Brief IPQ was used.(35)

PART 3

BIOMECHANICAL ANALYSIS OF VIOLIN PLAYING

Chapter 10

Differences in violin fixation force and muscle activity among violinists with and without complaints in the neck shoulder region

Laura M. Kok

Jim Schrijvers

Marta Fiocco

Barend J. van Royen

Jaap Harlaar

Submitted

ABSTRACT

Introduction Musculoskeletal complaints are a frequent, serious and potentially career threatening problem among professional musicians. Approximately half of the professional violinists report current complaints in the neck and shoulder region. In violinists playing with pain, muscle activity seems to be altered compared to their healthy colleagues. The aim of this study is to determine the relationship between complaints of the neck shoulder region, the jaw-shoulder violin fixation force, and the activity of the neck and shoulder muscles in professional violinists.

Methods In this observational case-control study professional violinists were evaluated. Complaints were evaluated with a questionnaire including the Disabilities of Arm, Shoulder and Hand and Neck Disability Index. Violin fixation force between and activity of the upper part of the trapezius (mTP) (bilateral), sternocleidomastoid (mSCM) (bilateral) and anterior part of the left deltoid (mDTA) muscles were evaluated while performing one static procedure and four musical excerpts ('playing conditions'). Also chin and shoulder rest height as well as neck length were measured. To investigate the effect of complaints of the neck shoulder region and playing condition, linear regression models with fixation force and muscle activity of the five muscles as outcome variable were estimated.

Results Twenty violinists were included, of which ten with current complaints of the neck shoulder region and ten without these complaints. Each group consisted of eight female and two male violists with a mean age of 29 years. Violinists with complaints had more muscle activity of all evaluated muscles compared to violinists without complaints; in our linear regression models complaints was significantly associated with the muscle activity of all evaluated muscles (left mSCM +48.5%; right mSCM +43.6%; left mTP +75.2%; right mTP +43.3%; left mDTA +24.2%). Complaints were not significantly associated with the violin fixation force. The playing condition significantly predicted the violin fixation force and the activity of all muscles except the left mTP. No significant differences in neck length or height of the shoulder and chin rest were present between subjects with and without complaints.

Conclusions Violinists with complaints of the shoulder region have more muscle activity of the superficial neck and shoulder muscles. Co-contraction is thought to play a relevant role in violinists with these complaints. With increasing difficulty of the music, increasing muscle activity and increasing jaw-shoulder violin fixation force is present.

INTRODUCTION

Musculoskeletal complaints are a frequent, serious and potentially career threatening problem among professional musicians.(1,2) The majority of professional musicians suffer from musculoskeletal complaints affecting their ability to play their instrument.(2,3) In a recent systematic review, the year-prevalence of musculoskeletal complaints in professional musicians ranged between 41% and 93%.(2) The neck and shoulders are among the body regions most affected, especially among the higher string instrument players, i.e. violinists (violin players) and violists (viola players).(2,4–6)

Violinists primarily strive for a beautiful sound, which is produced by a playing technique with efficient motion patterns and avoidance of unnecessary muscle activity.(7,8) However, some static muscle activity in the neck and shoulder region is necessary as the violin is stabilised and fixated (both for right and left-handed individuals) between the left shoulder and jaw during active playing the instrument.(9) Although the left hand also supports the violin, its contribution is minimal, as this hand needs to move freely while playing.(9)

In neck pain patients in the general population altered activation of the neck muscles is observed.(10–13) Therefore, in violinists playing with pain, muscle activity is likely to be altered compared to their healthy colleagues. However, contradicting results are reported in the literature on this subject.(8,14,15) Berque et al.(2002) observed more muscle activity in the trapezius muscles of pain-free violinists and violists, compared to violinists who reported pain while playing the instrument.(14) These results are contrary to the results of the study of Philipson et al.(1990), showing more muscular activity in violinists with pain in the neck and shoulder region.(8) Also Park et al.(2012) reported more activity of the neck muscles in violinists with complaints while playing the instrument.(15)

Most violinists use a shoulder rest, which is designed to aid in holding the violin while playing. There is a lack of ergonomic consensus on optimal adjustment of this shoulder rest, some violinists even prefer playing without.(16–20) As the shoulder rest adds height to the violin, it modulates the biomechanics of violin playing; both static loading and the repetitive movements of playing.

In other occupational groups, prolonged static loading of the neck musculature is associated with pain.(21) We hypothesize the same association is present in professional

violinists. The aim of this study is therefore to determine the relationship between complaints of the neck shoulder region in violinists and the violin fixation force and muscle activity. We hypothesize that the violin fixation force is higher among violinists with complaints of the neck shoulder region compared to violinists without these complaints. Furthermore, we hypothesize more muscle activity of the sternocleidomastoid muscles (mSCM), upper trapezius muscles (mTP) and left anterior part of the deltoid muscle (mDTA) among violinists with complaints of the neck shoulder region compared to violinists without these complaints. Finally, we hypothesize a difference in the adjustment of the violinists' own shoulder-rest between the two groups of violinists

MATERIALS & METHODS

SUBJECTS

We asked professional violinists to participate in this observational case-control study, aiming to balance violinists with and without current complaints of the neck shoulder region. Professional violinists were defined as either currently attending a music academy or a finished music academy degree, with the violin as main subject. Inclusion criteria included playing the violin on a professional level, age 18 years or older and fluent Dutch speaking and writing. Exclusion criteria included recent fractures or operations of the spine and upper extremities (<1 year) and systemic diseases influencing the musculoskeletal system. Aiming for a heterogenous study population, we choose to include violinists and exclude violists; the viola is a somewhat bigger and heavier instrument compared to the violin, therefore biomechanical properties of playing these instruments differ. Violinists were approached at music institutions, social media, and by word of mouth.

The study protocol was reviewed by the local ethical committee (Medical Ethics Review Committee of VU University Medical Centre, US Office for Human Research Protections (OHRP): IRB00002991), who decided the Medical Research Act did not apply. All participants provided written informed consent.

QUESTIONNAIRE

All subjects were asked to complete a Dutch questionnaire, consisting of baseline demographic questions (age, gender, length, weight, hand dominance, smoking, sports), questions on profession (professional mainly teaching / professional mainly performing / student / other) and playing habits (average playing hours in a week during last four weeks, age of start playing the violin) and the occurrence of complaints of the neck and shoulders (current complaints, complaints during the past week, past month and past year). The questionnaire also included the Dutch version of the Neck Disability Index (NDI) and Disabilities of the Arm, Shoulder and Hand (DASH).(22,23) The NDI assesses physical abilities of subjects with neck pain, the outcome is reported as a percentage score, 0 being the best and 100 being the worst clinical outcome. The DASH questionnaire is designed to measure physical function and symptoms in patients with any or several musculoskeletal disorders of the upper limb.(22) Although the questionnaire was initially developed for evaluating complaints of the upper extremity, it was has shown acceptable validity and responsiveness of the DASH for use in patients with nontraumatic neck complaints.(24) Both the regular DASH the optional 4-item music module were used in the current study. The results of both the DASH and the music module of the DASH are reported on a scale from 0-100, the latter being the worst clinical outcome.

MEASUREMENT PROCEDURES

This study was performed at the movement laboratory of the VU University Medical Center, measurements were performed between April and August 2017. All violinists played on the provided violin with instrumented chin-rest but used their own shoulder rest. The excerpts were made available to the subjects prior to data collection; subjects were asked to prepare the excerpts. Five different measurements ('playing conditions') were performed by each violinist, a static position and four playing conditions: 'open strings', 'first position', 'shifts', and 'virtuosic' *(Table 1).* Fatigue is supposed to play no role in our measurements(25,26), therefore no resting interval was established in between the different playing conditions. The static position was performed with the left hand in first position and the bow at the tip on the E-string. The subject was asked to hold this position for five seconds. The following excerpts were used and played once: *(Figure 1);* The first fragment consisted of open strings; four times each string, while using the whole bow. In this excerpt, the fingers of the left hand were not used other than supporting the violin. This excerpt is considered as technically low-demanding, it could be learnt at a first violin lesson. The second fragment consisted of Ševčík etude 29 from book one (27); in this

excerpt, the left hand is entirely in first position; there are no shifts of the left hand. This fragment is considered of medium technical difficulty. The third fragment was derived from Ševčík etude 3 from book 3(27); this fragment was chosen for its repeated shifts of the left hand between the first and fifth position. Compared to fragment two it is of increasing difficulty. The last fragment, the virtuosic musical excerpt, consisted of the first nine bars from Kreisler opus 6, Recitativo and Scherzo Caprice.(28) For this last excerpt violists were instructed to play expressive and free, like performing during a concert. During this virtuosic piece of music both the left and right-hand part are demanding, including shifts and double stops for the left hand, and various bowing techniques for the right hand. All excerpts except the last one were played while using a metronome with a tempo of 100 beats per minute. The last fragment was played without metronome.

Table 1: Playing conditions

Name	Playing condition	Fragment	Excerpt	Technical description
Static	1	-	Static	Left hand in first position and the bow at the tip on the E-string. The subject was asked to hold this position for five seconds.
Open strings	2	1	Open strings	Open strings technically low demanding; static position left hand
First position	3	2	Ševčík etude 29	Entirely in first position of the left hand; no shifts of the left hand
Shifts	4	3	Ševčík etude 3	Repeated shifts of the left hand
Virtuosic	5	4	Kreisler opus 6; Recitativo and Scherzo Caprice	Virtuosic; technically demanding

VIOLIN FIXATION FORCE

The violin fixation force was measured by using an instrumented chin-rest (height: 2.6 cm); an ATI-mini40 6D force-sensor (ATI Industrial Automation) was used and build within a 3D printed chinrest (*Figure 2).* The three components of the force were sampled at 1000 Hz using Vicon Nexus acquisition software. Prior to the measurements of each subject the offset of the unloaded force sensor was measured during a calibration measurement.

MUSCLE ACTIVITY

The activity of the following muscles was measured using a surface-EMG (electromyogram): The left and right sternocleidomastoid muscles (mSCM, the left and right upper trapezius muscles (mTP) and the anterior part of the left deltoid muscle (mDTA). Recordings were made using self-adhesive electrodes (Kendall H124SG), with an

interelectrode distance of 25 mm. The EMG signal was recorded and wirelessly transmitted (WAVE by Cometa Systems) The EMG was synchronously sampled with the forces at 1000 Hz. Normalisation of the EMG was based on maximum voluntary isometric contractions (MVIC); during three seconds, i.e. an isometric force was applied against a resistance applied by the researcher. A normalisation set consisted of three times three seconds maximal isometric force, alternated with maximal relaxation in between, also for three seconds. All tests were performed seated, with full back support. The following normalisation procedures were followed, all of them performed both left and right; 1. 'Shoulder flexion'; Shoulder flexion in 125 degrees as resistance applied above elbow and at inferior angle of scapula attempting to de-rotate scapula; (normalisation of the mTP and mDTA)(29) 2. 'Empty can'; Shoulder abducted 90 degrees in the plane of the scapula, internally rotated and the elbow extended. The arm was abducted as resistance was applied at wrist by the researcher (normalisation of the mTP and mDTA).(29) 3. 'Anterolateral neck flexion'; anterolateral neck flexion while resistance was applied to both shoulder and head. (normalisation of the mSCM).(30)

Shoulder rest, chin rest, neck length

The brand of the subjects' own shoulder rest was noted, as was the height of the left and right wing of the shoulder rest. The height of the wings was measured, ranging between the part of the wing resting on the shoulder and the part of the wing supporting the violin. A photograph with ruler was taken of each shoulder rest. Also, the height of the subjects' own chin rest was measured at the point halfway between the two clamps fixating the chin rest to the violin. The neck length of all subjects was measured twice; at the beginning and at the end of the study protocol.

Data Processing

The force signals along the three axes were low pass filtered using a 3Hz cut-off frequency after being corrected for offset in the unloaded calibration measurement. The violin fixation force was calculated as the average magnitude of the force vector applied during each excerpt. All EMG signals were high pass filtered (second order Butterworth filter with a cut-off frequency of 20 Hz) to remove motion artefacts. Then the signal was rectified, after which a low pass filter was applied (first order, Butterworth 3Hz cut-off frequency) to obtain the envelope. The MVIC was determined by calculating the mean activity of the middle second of all relevant normalisation procedures for the relevant muscle. (Shoulder flexion and empty can for both the mTP and mDTA; anterolateral neck flexion for the

mSCM). EMG normalisation was then achieved by dividing each envelope value by its MVIC. The mean of the EMG envelope and its standard deviation were calculated over total playing period for each muscle for each trial. A custom designed Matlab script was used for all signal processing.

DATA ANALYSIS

Subject variables are presented as mean and SD, except for the DASH and NDI which are presented as median with an interquartile range. Categorical variables are presented as a percentage. Comparisons between patient characteristics of the two groups were performed with chi-squared tests (for categorical variables), independent samples t-tests (for normally distributed continuous variables) or Mann Whitney U-tests (for continuous variables, not normally distributed). Multivariable linear regression analysis were performed, with the activity of the five muscles and jaw-shoulder violin fixation force as dependent variable and complaints of the neck shoulder region and playing condition as independent variables. Correlation between the activity of the left and right mSCM ('co-contraction') was calculated using Pearsons' correlation coefficient. The level of statistical significance was set at $p \leq 0.05$ for all analyses. Statistical analyses were performed in SPSS (IBM, version 23).

RESULTS

SUBJECT CHARACTERISTICS

Twenty violinists were included in this study, of which ten with current complaints of the neck shoulder region and ten without these complaints. Baseline variables for the two groups are presented in *Table 2*. The groups were comparable for all evaluated baseline variables except for BMI. Each group consisted of eight female and two male violinists; the mean age of the subjects in both groups was 29 years. All violinists were able to play the four musical excerpts, including the virtuous excerpt. The scores of the outcome measures NDI, DASH and the music module of the DASH were significantly different between the two groups *(Table 2)*, thereby validating our stratification. The median score of the NDI was 13.0 (IQR 10.0-21.0) and 4.0 (IQR 0.5-6.0) in the group with and without complaints respectively. The median score of the regular DASH was 7.5 (IQR 6.0-21.8) compared to 0.9 (IQR 0.0-2.3) in the control group. The median score of the music module

of the DASH was 3.2 (IQR 0.0-11.6) in the control group. None of the participants had to call in sick or missed earnings due to complaints of the neck shoulder region.

Table 2: Subject characteristics of the included violinists with and without neck complaints

		Violinists with complaints (n=10)	**Violinists without complaints (n=10)**	**Significance (p)**
Age (years)		29.4 (3.7)	29.3 (3.9)	0.954*
Gender	Male:	2 (20%)	2 (20%)	1.000~
	Female:	8 (80%)	8 (80%)	
BMI (kg/m^2)		23.2 (1.8)	20.6 (1.9)	0.006*
Hand dominance	Right:	10 (100%)	9 (90%)	0.305~
	Left:	0	1 (10%)	
Smoking	Yes:	2 (20%)	0	0.136~
	No:	8 (80%)	10 (100%)	
Sports (hours/week)		2.2 (2.1)	1.5 (1.0)	0.274*
Profession	Mainly performing:	8 (80%)	8 (80%)	0.513~
	Music academy student:	1 (10%)	2 (20%)	
	Other:	1 (10%)	0	
Playing load (hours/week)		23.0 (10.0)	33.2 (15.2)	0.094*
Starting age		5.9 (1.6)	6.3 (1.5)	0.529*
NDI*		13.0 (10.0-21.0)	4.0 (0.5-6.0)	0.009^
DASH*		7.5 (6.0-21.8)	0.9 (0.0-2.3)	<0.001^
music module DASH*		28.2 (14.1-42.2)	3.2 (0.0-11.6)	0.009^

*Nominal values: number (%), continue variables: mean (SD), *median and IQR*
** independent-samples t-test*
~ Chi-squared test
^ Mann-Whitney U test

VIOLIN FIXATION FORCE & MUSCLE ACTIVITY

The mean jaw-shoulder violin fixation force as measured by the force sensor in the chin rest during playing of the five playing conditions is shown in *Table 3.* The muscle activity of the mSCM (left and right), mTP (left and right) and mDTA in violinists with and without complaints are displayed in *Table 4.* Violinists with complaints have higher activity of all evaluated muscles compared to violinists without complaints. (left mSCM +48.5%; right mSCM +43.6%; left mTP +75.2%; right mTP +43.3%; left mDTA +24.2%).

Table 3: Mean violin fixation force in violinists with and without complaints of the neck shoulder region for the different playing conditions

	Violinists with complaints (N) (n=10)	**Violinists without complaints (N) (n=10)**
Static	1.44 (1.18)	1.03 (0.62)
Open strings	1.88 (1.32)	1.98 (1.51)
First position	2.59 (1.98)	2.00 (1.30)
Shifts	5.27 (2.93)	5.47 (2.47)
Virtuosic	5.29 (3.22)	4.72 (2.38)

Results displayed as mean violin fixation force in Newton (SD)

Table 4: Muscle activity in violinists with and without complaints of the neck shoulder region

		Violinists with complaints (% MVIC) (n=10)	**Violinists without complaints (% MVIC) (n=10)**	**Difference**
Static	mSCM left	7.5% (4.7%)	5.1% (3.8%)	47.0%
	mSCM right	7.0% (3.8%)	4.2% (2.1%)	66.7%
	mTP left	15.6% (18.4%)	8.0% (4.9%)	95.0%
	mTP right	5.3% (4.5%)	3.6% (3.4%)	47.2%
	mDTA	25.2% (14.4%)	20.1% (7.7%)	25.4%
Open strings	mSCM left	10.6% (6.4%)	6.2% (3.2%)	71.0%
	mSCM right	12.0% (6.5%)	7.5% (6.0%)	60.0%
	mTP left	18.2% (17.6%)	9.9% (5.9%)	83.8%
	mTP right	22.9% (13.6%)	14.3% (5.2%)	60.1%
	mDTA	21.7% (10.8%)	18.1% (6.6%)	19.9%
First position	mSCM left	14.6% (9.6%)	9.1% (4.9%)	60.4%
	mSCM right	13.3% (7.1%)	10.2% (10.3%)	30.4%
	mTP left	18.8% (17.6%)	10.8% (4.8%)	74.1%
	mTP right	19.7% (8.2%)	9.9% (4.1%)	99.0%
	mDTA	20.6% (13.6%)	16.3% (4.6%)	26.4%
Shifts	mSCM left	19.6% (11.1%)	15.3% (10.1%)	28.1%
	mSCM right	15.3% (8.8%)	10.3% (8.3%)	51.4%
	mTP left	16.8% (14.3%)	10.9% (6.3%)	54.1%
	mTP right	19.6% (9.7%)	15.2% (4.3%)	28.9%
	mDTA	16.5% (12.2%)	13.3% (4.6%)	24.1%
Virtuosic	mSCM left	22.6% (11.6%)	14.6% (8.6%)	54.8%
	mSCM right	20.0% (8.3%)	14.9% (14.1%)	34.2%
	mTP left	21.8% (13.5%)	12.9% (7.2%)	69.0%
	mTP right	32.4% (18.2%)	24.1% (6.1%)	34.4%
	mDTA	16.2% (14.8%)	12.8% (4.2%)	26.6%

Results displayed as mean (SD)

To investigate the effect of complaints of the neck shoulder region and the playing condition (fragment) linear regression models with fixation force and muscle activity of the five muscles as outcome variable were estimated; results are displayed in *Table 5.* Complaints had a significant effect on the activity of the five muscles, but did not significantly predict the violin fixation force. Playing condition (the musical fragment) was significant in all models except for the left mTP.

Co-contraction of both the mSCM is different between the two groups; in violinists with complaints there was a strong positive correlation between the activity of the left and right mSCM (0.771, p<.001), while in violinists without complaints there was a moderate positive correlation (0.425, p=0.002)

Table 5: Results of the linear regression modelling

	Complaints		**Playing condition (fragment)**	
	B (SE)	**p-value**	**B (SE)**	**p-value**
mSCM left	0.049 (0.016)	0.002	0.034 (0.006)	<0.001
mSCM right	0.041 (0.016)	0.011	0.027 (0.006)	<0.001
mTP left	0.079 (0.024)	0.001	0.011 (0.008)	0.201
mTP right	0.058 (0.019)	0.003	0.046 (0.007)	<0.001
mDTA left	0.039 (0.020)	0.050	-0.021 (0.007)	0.003
Violin fixation force	0.256 (0.185)	0.167	1.097 (0.065)	<0.001

Estimated effect (B) along with the standard error (SE) from a multivariable linear regression model

Table 6: Shoulder rest adjustment & neck length

	Violinists with complaints (n=10)	**Violinists without complaints (n=10)**	**p-value**
Neck length (cm)	13.34 (1.62)	12.35 (1.21)	0.148
Chin rest height (cm)	2.18 (0.38)	2.15 (0.41)	0.868
Left shoulder rest height (cm)	3.62 (1.73)	3.14 (1.92)	0.565
Right shoulder rest height (cm)	3.25 (1.61)	3.69 (2.22)	0.619
neck length - length left shoulder rest (cm)	9.72 (2.75)	9.21 (2.46)	0.671
neck length - length right shoulder rest (cm)	10.09 (2.82)	8.66 (3.00)	0.288

Results displayed as mean (SD); independent samples t-test

SHOULDER REST ADJUSTMENT & NECK LENGTH

No significant differences in neck length or height of the shoulder or chin rest were present between subjects with and without complaints. In *Table 6* the measurements of neck length, shoulder rest and chin rest are displayed, as well as for the shoulder rest

height corrected neck lengths. Also, after exclusion of the subjects playing without a shoulder rest (n=3), no significant differences were found in these variables between the two groups.

DISCUSSION

The aim of this study was to investigate the relationship between complaints of the neck shoulder region and the violin fixation force and muscle activity in professional violinists. To our knowledge this is the first study to compare both muscle activity and direct measurement of the violin fixation force in violinists with and without complaints.

In this study the presence of complaints is significantly associated to muscle activity of both the sternocleidomastoid muscles, trapezius muscles and left deltoid muscle. Despite this increased muscle activity, complaints did not significantly predict the jaw-shoulder violin fixation force.

Our results are partly in line with the literature in which differences in muscle activity are described between violinists with and without complaints. However, there seem to be conflicting results concerning the effect of the complaints on the activity of the several neck and shoulders muscles.(8,14,15) In a study by Philipson et al. more muscle activity of the left and right upper trapezius, right deltoid and right biceps was reported in violinists with complaints compared to their colleagues without these complaints.(8) Also Park et al. found more muscle activity in a group of violinists with neck pain compared to pain free subjects.(15) In contrast, Berque et al found lower trapezius activity in violinists with complaints compared to the violinists without.(14) However, they found more trapezius activity in the complaints group at rest (without playing the violin).

The above reported differences in studies examining muscle activity in violinists with and without complaints could be explained by differences in study protocols, for example the played excerpts, measuring techniques, heterogeneity of the study groups, different inclusion criteria and the small number of participants in the afore-mentioned studies. Also, the severity of and disability due to the complaints is a relevant factor, which was not fully addressed in the above-mentioned studies. In the current study we aimed to increase scientific quality; therefore we evaluated a homogenous group of violinists, thereby excluding violists as the viola is a bigger instrument and therefore has different

biomechanical playing properties. Within the current study baseline variables, except for BMI, were evenly distributed between the two groups of violinists. Above, the severity and disability due to the complaints were evaluated using validated outcome measures.

We hypothesize that co-contraction is likely to be a relevant factor in violinists with complaints; a high correlation between activity of the left and right mSCM is present in violinists with complaints compared to a low correlation in violinists without complaints. This finding is consistent with the literature evaluating the general population, in which patients with neck pain show increased antagonistic activity of their superficial neck muscles.(31–33) Altered behaviour of the superficial neck flexors in violinists with complaints was also observed by Steinmetz et al.(34) Also, comparable to our study, Steinmetz et al. reported more activity of the mSCM in violinists with complaints compared to violinists without.(34)

A remarkable finding in the current study is the difference between the regular DASH score and the score of the optional performing arts module in the group of violinists with complaints. The DASH and NDI scores in this group are near-normal, however the score on the performing arts module of the DASH indicates an incapacitating influence of the complaints on professional functioning as a musician. The same discrepancy between the regular DASH and performing arts module of the DASH is found in other studies evaluating musicians.(35,36) A recent study evaluated the psychometric properties of the music module of the DASH, which showed a good internal consistency and good discriminative validity, but moderate construct validity.(37) Future research should evaluate norm scores for the music module of the DASH in musicians, which will aid interpreting the outcome scores in this specific group.

A major strength of this study is the homogeneous distribution of the two groups of violinists in this study. Age and gender are evenly distributed among the two groups of violinists, reducing the risk of bias. Above, contrary to all comparable studies in the literature evaluating biomechanical aspects of violin playing, the complaints and the impact of functioning on the subjects were quantified by validated questionnaires. Another strength of this study is the sample size of twenty violinists, which is considerably larger than previous studies.

A possible limitation of this study concerns the use of the instrumented chin-rest, as it was generally somewhat higher compared to the subjects' own chin rest due to the

insertion of the force-sensor. Therefore, despite using their own shoulder rest, the study situation was not completely comparable to the usual adjustment of the violinist. However, as this mean difference in height of the shoulder rest was only 4 mm, we consider this difference, and therefore the risk of bias, minimal. Also, the influence of not playing on their own instrument is regarded negligible, as the size of a violin is standardized.

Another limitation concerns the inclusion of subjects with minor complaints. As we did not exclude participants due to minor complaints, the differences between the group with and without complaints are confined, reflected by relatively minor differences in DASH and NDI scores and the ability of all individuals to work. However, this sample of violinists is more representative compared to a sample of violinists with only severe complaints. Despite this lack of maximal contrast, and a moderate sample size, significant differences in the primary outcome measures were present between the two groups. might hide potential differences in outcomes between the groups.

Future research in this field should aim at increasing knowledge on muscle activity during violin playing. The use and adjustment of the shoulder rest could be evaluated in an experimental setting in order to evaluate its influence of playing kinematics. Also, biofeedback training based on EMG activity could be evaluated, especially co-contraction of mSCM, as this study showed this co-contraction is associated with complaints of the neck and shoulder region. Finally, in all studies evaluating subjects with complaints, the severity and impact of these complaints should be evaluated, preferably by using validated outcome measures.

Concluding, this study shows that the presence of complaints is significantly associated with the activity of the superficial neck and shoulder muscles. Co-contraction is thought to play a relevant role in violinists with complaints of the neck shoulder region. Therefore, in violinists complaints are hypothesized to be related to a coordination problem of the neck and shoulder muscles.

ACKNOWLEDGEMENTS

We thank Danny Koops (department of medical technology of the VU medical Center) for his contribution to the development of the instrumented chin-rest.

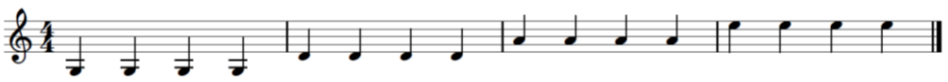

Figure 1: Fragment 1 / Playing condition 2: 'Open strings'

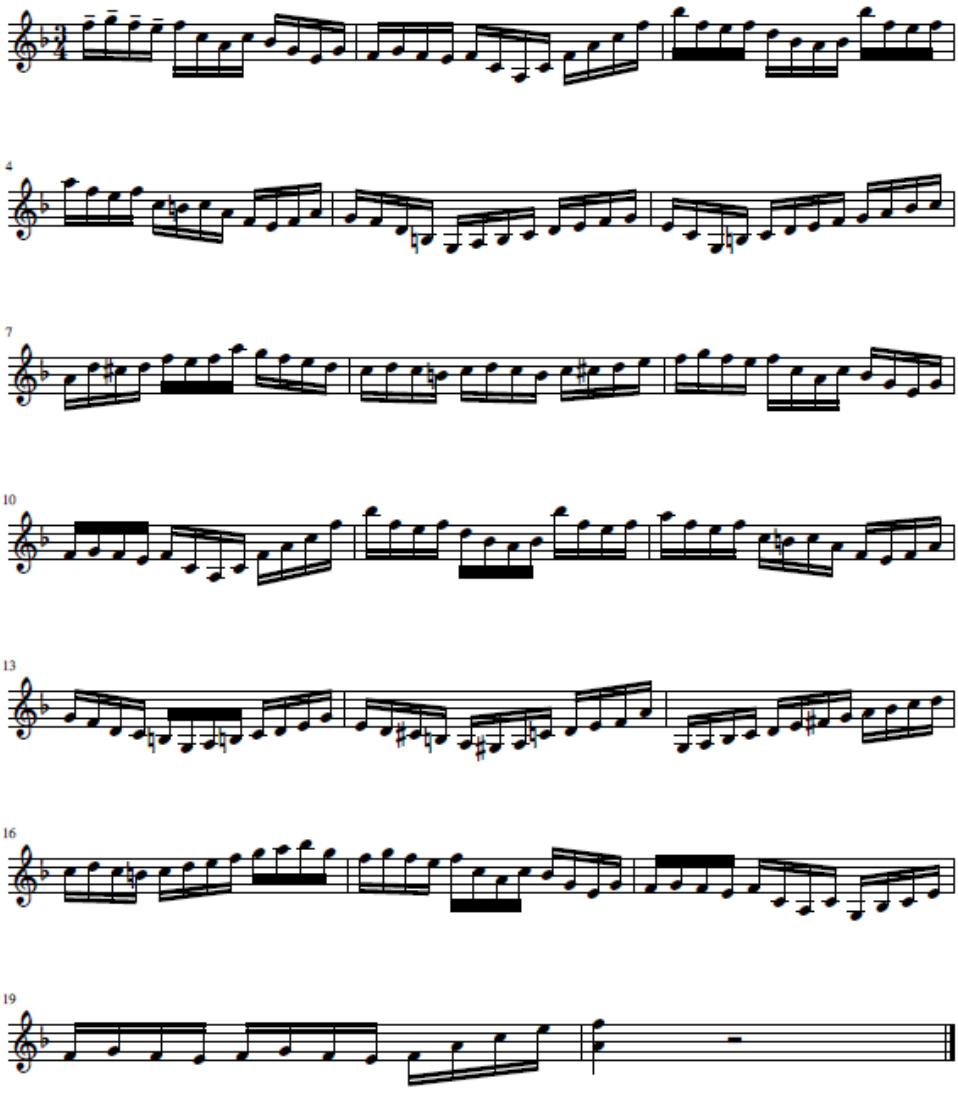

Figure 2: Fragment 2 / Playing condition 3: 'First position', Ševčík etude 29

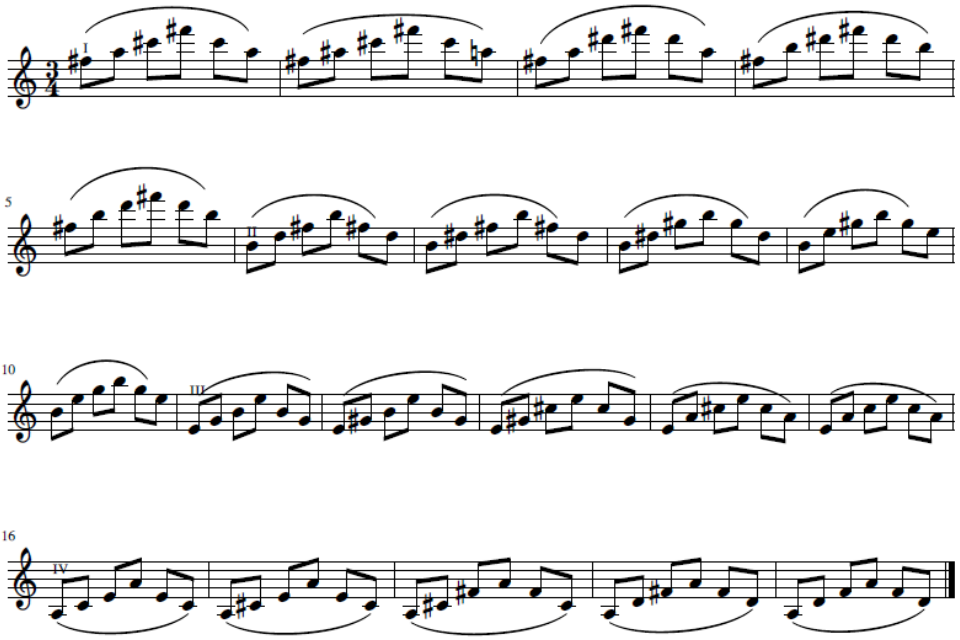

Figure 3: Fragment 3 / Playing condition 4: 'Shifts', Ševčík etude 3

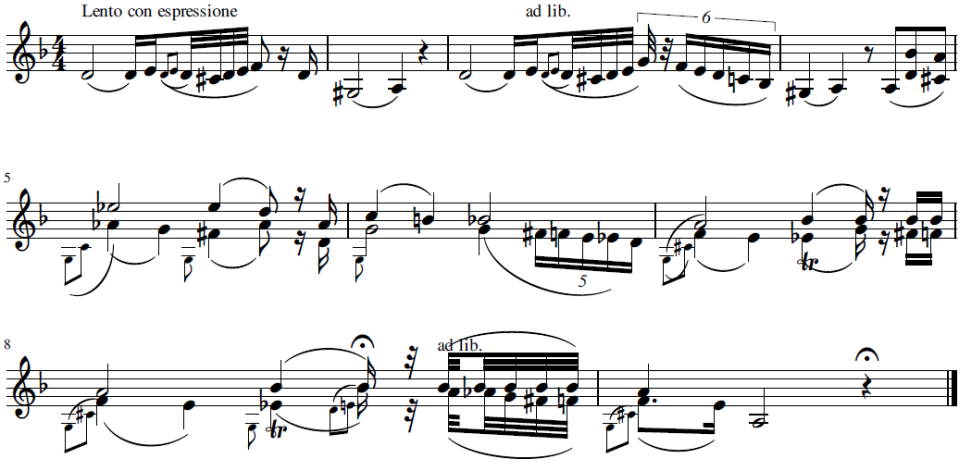

Figure 4: Fragment 4 / Playing condition 5: 'Virtuosic', Kreisler opus 6, Recitativo and Scherzo Caprice

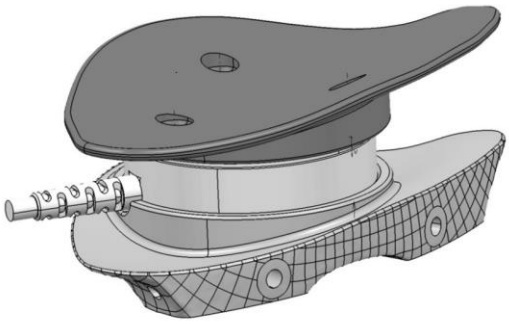

Figure 5: The custom-made 3D printed violin chin-rest with built-in force sensor

REFERENCES

1. Zaza C, Charles C, Muszynski A. The meaning of playing-related musculoskeletal disorders to classical musicians. SocSciMed. 1998 Dec;47(0277–9536 (Print)):2013–23.
2. Kok LM, Huisstede BMA, Voorn VMA, Schoones JW, Nelissen RGHH. The occurrence of musculoskeletal complaints among professional musicians: a systematic review. Vol. 89, International Archives of Occupational and Environmental Health. 2016. p. 373–96.
3. Kok LM, Nelissen RGHH, Huisstede BMA. Prevalence and Consequences of Arm, Neck, and/or Shoulder Complaints Among Music Academy Students. MPPA. 2015;30(3):163–8.
4. Roach KE, Martinez MA, Anderson N. Musculoskeletal pain in student instrumentalists: a comparison with the general student population. MPPA. 1994 Dec;9(4):125–30.
5. Engquist K, Orbaek P, Jakobsson K. Musculoskeletal pain and impact on performance in orchestra musicians and actors. MPPA. 2004;19(2):55–61.
6. Middlestadt SE, Fishbein M. The prevalence of severe musculoskeletal problems among male and female symphony orchestra string players. MPPA. 1989 Mar;4(1):41–8.
7. Fjellman-Wiklund A, Grip H, Karlsson J. EMG trapezius muscle activity pattern in string players:: Part I—is there variability in the playing technique? Int J. 2004;
8. Philipson L, Sorbye R, Larsson P, Kaladjev S. Muscular Load Levels in Performing Musicians As Monitored by Quantitative Electromyography. MPPA. 1990;5(2):79–82.
9. Tubiana R, Chamagne P, Brockman R. Fundamental positions for instrumental musicians. MPPA. 1989;4(2):73–6.
10. Lazzarini L, Novelli A, Marzano N, Timillero L, Fallani S, Viola R, et al. Regional and systemic prophylaxis with teicoplanin in total knee arthroplasty: a tissue penetration study. JArthroplasty. 2003 Apr;18(0883–5403 (Print)):342–6.
11. Lindstrøm R, Schomacher J, Farina D, Rechter L, Falla D. Association between neck muscle coactivation, pain, and strength in women with neck pain. Man Ther. 2011 Feb;16(1):80–6.
12. Boudreau SA, Falla D. Chronic neck pain alters muscle activation patterns to sudden movements. Exp brain Res. 2014 Jun 15;232(6):2011–20.
13. Bech KT, Larsen CM, Sjøgaard G, Holtermann A, Taylor JL, Søgaard K. Voluntary activation of the trapezius muscle in cases with neck/shoulder pain compared to healthy controls. J Electromyogr Kinesiol. 2017 Oct;36:56–64.
14. Berque P, Gray H. The influence of neck-shoulder pain on trapezius muscle activity among professional violin and viola players: An electromyographic study. MPPA. 2002;17(2):68–75.
15. Park KN, Kwon OY, Ha SM, Kim SJ, Choi HJ, Weon JH. Comparison of electromyographic activity and range of neck motion in violin students with and without neck pain during playing. MPPA. 2012 Dec;27(0885–1158 (Print)):188–92.
16. Levy CE, Lee WA, Brandfonbrener AG, Press J, Levy AE. Electromyographic Analysis of Muscular-Activity in the Upper Extremity Generated by Supporting A Violin with and Without A Shoulder Rest. MPPA. 1992;7(4):103–9.
17. Okner M, Kernozek T. Chinrest pressure in violin playing: type of music, chin rest, and shoulder pad as possible mediators. ClinBiomech(Bristol, Avon). 1997 Apr;12(1879–1271 (Electronic)):S12–

3.

18. Rabufetti M, Converti RM, Boccardi S, Ferrarin M. Tuning of the violin-performer interface. MPPA. 2007 Jan 6;22(2):58–66.

19. Watson AHD. The biology of musical performance and performance-related injury. Scarecrow Press; 2009. 369 p.

20. Menuhin Y. Violin : six lessons with Yehudi Menuhin. 2nd ed. Faber Music; 1974. 144 p.

21. Larsson B, Søgaard K, Rosendal L. Work related neck–shoulder pain: a review on magnitude, risk factors, biochemical characteristics, clinical picture and preventive interventions. Best Pract Res Clin. 2007;

22. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). AmJIndMed. 1996 Jun;29(0271–3586 (Print)):602–8.

23. Vernon H, Mior S. The Neck Disability Index: a study of reliability and validity. J Manipulative Physiol Ther. 1991 Sep;14(7):409–15.

24. Huisstede BMA, Feleus A, Bierma-Zeinstra SM, Verhaar JA, Koes BW. Is the disability of arm, shoulder, and hand questionnaire (DASH) also valid and responsive in patients with neck complaints. Spine (Phila Pa 1976). 2009 Feb 15;34(4):E130-8.

25. Chan RFM, Chow CY, Lee GPS, To LK, Tsang XYS, Yeung SS, et al. Self-perceived exertion level and objective evaluation of neuromuscular fatigue in a training session of orchestral violin players. Appl Ergon. 2000;

26. Yeung SS, Yeung EW, Chan RF, Chow C, Lee GP, To L, et al. Evaluation of Training Induced Neuromuscular Fatigue of Orchestral Violin Players. Proc Hum Factors Ergon Soc Annu Meet. 2000 Jul 5;44(30):5-614-5–614.

27. Ševčík O (Otakar), Mittell P. School of violin technics : op. 1 : in four parts. G. Schirmer; 1905.

28. Kreisler F. Recitativo-Scherzo Caprice Op.6. 1911.

29. Boettcher C, Ginn K, Cathers I. Standard maximum isometric voluntary contraction tests for normalizing shoulder muscle EMG. J Orthop. 2008;

30. Kendall FP, Kendall FP. Muscles : testing and function with posture and pain. Lippincott Williams & Wilkins; 2005.

31. Lindstrøm R, Schomacher J, Farina D, Rechter L. Association between neck muscle coactivation, pain, and strength in women with neck pain. Man Ther. 2011;

32. Falla D, Rainoldi A, Merletti R, Jull G. Spatio-temporal evaluation of neck muscle activation during postural perturbations in healthy subjects. J Electromyogr. 2004;

33. Graven-Nielsen T, Svensson P, Arendt-Nielsen L. Effects of experimental muscle pain on muscle activity and co-ordination during static and dynamic motor function. Electroencephalogr Clin Neurophysiol Mot Control. 1997 Apr;105(2):156–64.

34. Steinmetz A, Claus A, Hodges PW, Jull GA. Neck muscle function in violinists/violists with and without neck pain. ClinRheumatol. 2015 Jul 15;(1434–9949 (Electronic)).

35. Kochem FB, Silva JG. Prevalence and Associated Factors of Playing-Related Musculoskeletal Disorders in Brazilian Violin Players. MPPA. 2017 Mar 1;32(1):27–32.

36. Rodriguez-Romero B, Perez-Valino C, Ageitos-Alonso B, Pertega-Diaz S. Prevalence and

Associated Factors for Musculoskeletal Pain and Disability Among Spanish Music Conservatory Students. MPPA. 2016 Dec;31(0885–1158 (Print)):193–200.

37. Baadjou V, Bie R de, Guptill C. Psychometric properties of the performing arts module of the Disabilities of the Arm, Shoulder, and Hand questionnaire. Disabil. 2017;Epub ahead:1–7.

Chapter 11

The use of a shoulder rest for playing the violin revisited: An analysis of the effect of shoulder rest height on muscle activity, violin fixation force and player comfort

Laura M. Kok

Jim Schrijvers

Marta Fiocco

Barend van Royen

Jaap Harlaar

Accepted; MPPA

ABSTRACT

Objective For violinists the shoulder rest is an ergonomical adaptation to reduce musculoskeletal load. In this study we aim to evaluate how the height of the shoulder rest effects the violin fixation force and ElectroMyoGraphic (EMG) activity of the superficial neck and shoulder muscles.

Methods In an experimental study of professional violinists four different shoulder rest heights during five playing conditions were evaluated. Outcome variables included the jaw-shoulder violin fixation force and bilateral surface EMG of the upper trapezius muscles (mTP), sternocleidomastoid muscles (mSCM) and the left anterior part of the left deltoid muscle (mDTA). Playing comfort was subjectively rated using a visual analogic scale (VAS). Linear regression models were estimated to investigate the influence of the shoulder rest height on muscle activity and violin fixation force as well as the influence of the muscle activity of the five evaluated muscles on the violin fixation force.

Results Twenty professional violinists were included in this study; four males and sixteen females with a mean age of 29.4 years old. The shoulder rest condition had a significant effect on playing comfort ($p<0.001$); with higher shoulder rest conditions subjective playing comfort decreased. The mean violin fixation force for each shoulder rest condition ranged between 2.92N and 3.39N; higher shoulder rests were related to a higher violin fixation force ($p<0.001$). An increase in activity of the left mDTA was observed with increasing height of the shoulder rest, with a mean maximal difference of 3.5% of the maximal voluntary isometric contraction (MVIC)($p=0.025$). Activity of the left mSCM ($p<0.001$) and right mTP ($p<0.001$) were significantly positive associated and the right mSCM ($p<0.001$) and left mDTA ($p<0.001$) significantly negative associated with the violin fixation force.

Conclusion In this study there is an increase in violin fixation force and muscle activity of the left mDTA while playing with an increasing height of the shoulder rest. As the shoulder rest influences muscle activity patterns and violin fixation force, adjustment of this shoulder rest and positioning the violin need to be carefully optimised. Future studies should evaluate if minimalizing or omitting the shoulder rest clinically reduces musculoskeletal complaints in violinists.

INTRODUCTION

Controversy surrounds the use of a shoulder rest in violinists.(1–3) Most, but not all violinists use some form of a shoulder rest, which is an in height adaptable support placed under the violin.(2) For those favouring the shoulder rest, its use is hypothesized to reduce tension while playing, and increase control over the instrument, especially in virtuosic repertoire.(1) Violinists who favour playing without a shoulder rest argue this this allows a 'more natural' playing technique and also argue that the sound of the violin is better while playing without a shoulder rest. (1,4) In addition to the debate about whether or not to play with a shoulder rest, violinists who play with a shoulder rest have differing opinions concerning its optimal adjustment.(1,3,5) For many violinists, finding and fitting the shoulder rest is a time-consuming, sometimes lifelong search.

Professional violinists strive for an optimal positioning of the violin on the body. A shoulder rest is thereby carefully chosen and adapted by the individual player, or a well-considered decision is made to play without, as the use of a shoulder rest is thought to strongly influence playing technique.(1,3) However, violin students and their teachers may potentially adjust their shoulder rests to a suboptimal ergonomic arrangement.(3,6)

For classical violinists, the violin is positioned between the left shoulder and jaw. Playing the violin requires a nearly full external rotation of the left shoulder, as well as supination of the forearm.(7,8) Violinists strive for a non-tense playing technique, as this gives them the best sound quality and virtuosic playing capacities.(5,9) The violinist should only minimally support the violin with the left hand, as this hand needs to be able to move freely while playing. It seems obvious that if a lower fixation force is desirable between the eft shoulder and jaw, to minimize muscle tension, this would be associated with less fatigue and musculoskeletal complaints in violinists.(10,11)

Scientific literature on the adjustment of the shoulder-rest is limited. Three biomechanical studies evaluating shoulder rest use in violinists are published, and in these studies conflicting outcomes are presented. Levy et al. studied fifteen violinists while playing with and without a shoulder rest. EMG activity of the right sternocleidomastoid decreased and left anterior deltoid increased while using a shoulder rest.(1) However, non-normalised EMG was used in this study, thereby limiting the possibility to compare results between individuals and extrapolation of these results to other violinists. Okner et al. evaluated

the effect of two different types of shoulder rests and concluded that shoulder rests proved effective in changing the peak pressure and the total contact area utilized over the chin rest.(2) Rabufetti et al. also studied the effect of shoulder rest variations on playing kinematics.(3) They found a complex and distributed adaptation of the player posture and movement, and concluded that a skilled player is able to adapt to any shoulder rest setup. However, how the shoulder rest effected the musculoskeletal load was not evaluated, neither objectively nor subjectively.

The aim of this study is to investigate the effect of the shoulder rest on musculoskeletal load in professional violinists. We choose to evaluate all potential relevant shoulder and neck muscles which could be reliably evaluated by surface EMG. Therefore, we evaluated both sternocleidomastoid muscles (mSCM), trapezius muscles (mTP) and the left anterior part of the deltoid muscle (mDTA). We hypothesize that shoulder rest use and adjustment influences the violin fixation force and the muscle activity of the mSCM, mTP and mDTA. Moreover, we aim to explore the relation between the superficial neck and shoulder muscles (mSCM, mTP, mDTA) and the violin fixation force. Finally, we also hypothesize that a higher level of playing comfort is associated with a reduction of the violin fixation force and less muscle activity of the superficial neck and shoulder muscles.

Materials & Methods

Participants

Professional violinists were invited to participate in this experimental study. Professional violinists were defined as either currently attending a music academy or a finished music academy degree, with the violin as main subject. Inclusion criteria included being a professional violinist, aged 18 years or older and fluent in Dutch language both speaking and writing. Exclusion criteria included recent fractures or operations of the spine and upper extremities (<1 year) and systemic diseases influencing the musculoskeletal system. Violinists were approached at music institutions, social media, word of mouth. Also, participants were asked if they would know colleagues who would be interested. The presence of neck and shoulder complaints in the current convenience sample is comparable to the prevalence reported in the literature(12–15); ten violinists with current complaints and ten violinists without these complaints were included.

The study protocol was reviewed by the regional ethical committee; Medical Ethics Review Committee of VU University Medical Center, US Office for Human Research Protections (OHRP): IRB00002991) who decided the Medical Research Act did not apply. All participants provided written informed consent.

QUESTIONNAIRE

All participants were asked to complete a Dutch questionnaire (Appendix A), of demographic characteristics (age, sex, length, weight, hand dominance, smoking, sports), profession (professional mainly teaching / professional mainly performing / student / other), playing habits (average playing hours in a week during last 4 weeks, age of start playing the violin) and the occurrence of complaints of the neck and/or shoulder(s). In addition to this baseline questions, the questionnaire included the Dutch version of the Neck Disability Index (NDI) and Disabilities of the Arm, Shoulder and Hand outcome measure (DASH) and the performing arts module of the DASH.(16,17) The questionnaire scores of both the NDI and DASH range between 0 and 100, the latter representing the worst clinical outcome.

MEASUREMENT PROCEDURES

Subjects were asked to play four musical excerpts and perform one static procedure ('playing conditions'). All violinists played on the provided violin with instrumented chin-rest but used their own shoulder rest. The excerpts were made available to the participants prior to data collection and participants were asked to prepare the excerpts. The static position was performed with the left hand in first position and the bow at the tip on the E-string. Each subject was asked to hold this position for five seconds. The following excerpts were used: *(Figure 1-4);* The first fragment consisted of playing open strings; 4 times each string, while using the whole bow. In this excerpt the fingers of the left hand are not used other than supporting the violin. This excerpt is considered as technically low-demanding (it could be learnt at a first violin lesson). The second fragment consisted of the 29th etude from the first technique book by Ševčík(18); in this excerpt the left hand is entirely in first position; there are no shifts of the left hand. This fragment is considered of medium technical difficulty. The third fragment is the 3rd etude of the 3rd technique book by Ševčík(18); this fragment was chosen for its repeated shifts of the left hand between the first and fifth position. Compared to fragment two it is of increasing difficulty. The last fragment consisted of the first nine bars from Kreisler op 6; Recitativo and Scherzo Caprice.(19) For this last excerpt violists were instructed to play expressive

and free, like performing during a concert. During this virtuosic piece of music both the left and right-hand part are demanding, including shifts and double stops for the left hand, and various bowing techniques for the right hand. All excerpts except the last one were performed while using a metronome with a beat of 100 per minute. The last fragment was played without metronome. After completing all playing conditions with a certain shoulder rest condition, violinists were asked to rate the comfort of the shoulder rest setting on a visual analogic scale (VAS). The best score was 0 ('as comfortable as you can imagine'), the worst 10 ('unplayable').

The following shoulder conditions were assessed: 1. Absence of a shoulder rest; 2. The lowest position of the Wolf shoulder rest (height left wing 3.0 cm, height right wing 2.0 cm); 3. The middle position of the Wolf shoulder rest (height left wing 5.0 cm, height right wing 4.0 cm); 4. The highest position of the Wolf shoulder rest (height left wing 7.0 cm, height right wing 6.0 cm).

VIOLIN FIXATION FORCE

The violin fixation force was recorded by using an instrumented chin-rest (height: 2.9 cm); an ATI-mini40 6D force-sensor (ATI Industrial Automation) was used and build within a 3D printed chinrest (*figure 6).* The 3 orthogonal components of the force vector (i.e. Fx, Fy and Fz) were sampled at 1000 Hz using Vicon Nexus acquisition software. Prior to the measurements the offset of the unloaded force sensor was measured.

MUSCLE ACTIVITY

The activity of the following muscles was recorded using a surface-EMG: The left and right sternocleidomastoid muscles (mSCM), the left and right trapezius muscles (upper part) (mTP) and the left anterior part of the deltoid muscle (mDTA). Recordings were made using self-adhesive Ag/AgCl disposable electrodes (Kendall H124SG; foam discs with solid gel, diameter 24mm), with an interelectrode distance of 25 mm. For the mSCM the electrodes were placed along the sternal portion of the muscle, with the electrode centre 1/3 of the distance between the mastoid process and the sternal notch.(20) For the mTP the medial electrode was placed 2 cm lateral to the midpoint of the C4-C45 interspinous distance and oriented along the palpated anterior border of the trapezius in line with the muscle fibres.(21) For the mDTA the cranial electrode was placed three cm under the tip of the anterior part of the acromion, the second electrode was placed following the direction of the muscle fibres. The EMG signal was recorded and wirelessly transmitted

(WAVE by CometaSystems) The EMG was synchronously sampled with the forces at 1000 Hz. Normalisation of the EMG was based on maximum voluntary isometric contractions (MVIC); during 3 seconds. For each of the procedures the participant maintains a given position isometrically to the maximum of their muscular ability against the external force applied by the examiner. After training of the procedures, with verbal feedback of the researcher concerning maintaining the adequate positioning of the joints and adequate (maximum) force, a normalisation procedure was carried out: a set consisted of three times 3 seconds maximal isometric force, alternated with maximal relaxation in between. All tests were performed seated, with full back support. The following normalisation procedures were followed, all of them performed both left and right; 1. Shoulder flexion; Shoulder flexion in 125 degrees as resistance applied above elbow and at inferior angle of scapula attempting to de-rotate scapula; (normalisation of the mTP and mDTA)(22) 2. Empty can; Shoulder abducted 90 degrees in plane of scapula, internally rotated and elbow extended. Arm abducted as resistance applied at wrist by the researcher. (normalisation of the mTP and mDTA)(22) 3. Anterolateral neck flexion; anterolateral neck flexion while resistance applied to both shoulder and head. (normalisation of the mSCM)(23)

Data Processing

The force signals along the three axes were low pass filtered using a 3Hz cut-off frequency and corrected for offset in the unloaded situation. The violin fixation force was calculated as the average of the magnitude of the force vector applied during each excerpt.

The sampling rate for the EMG signals was 1000 Hz. A one-directional high pass filter was applied to reduce the influence of the motion artefact and / or environmental electrical noise (second order Butterworth filter with a cut-off frequency of 20 Hz).(24) Then the signal was rectified, after which a two-directional low pass filter was applied (second order, Butterworth 3Hz cut-off frequency) to obtain the envelope.(25,26) From each 3 seconds maximal isometric force contraction of the muscle, the mean of the middle second was used to obtain a reliable estimate of the maximal value.(27) The MVIC was then calculated by taking the average of this middle second of the maximal isometric force contraction values of the three repetitions. (Shoulder flexion and empty can for both the mTP and mDTA; anterolateral neck flexion for the mSCM). EMG normalisation was

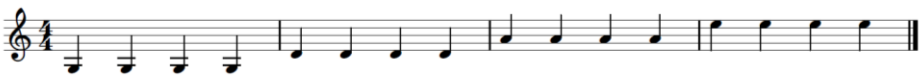

Figure 1: Fragment 1 / Playing condition 2: 'Open strings'

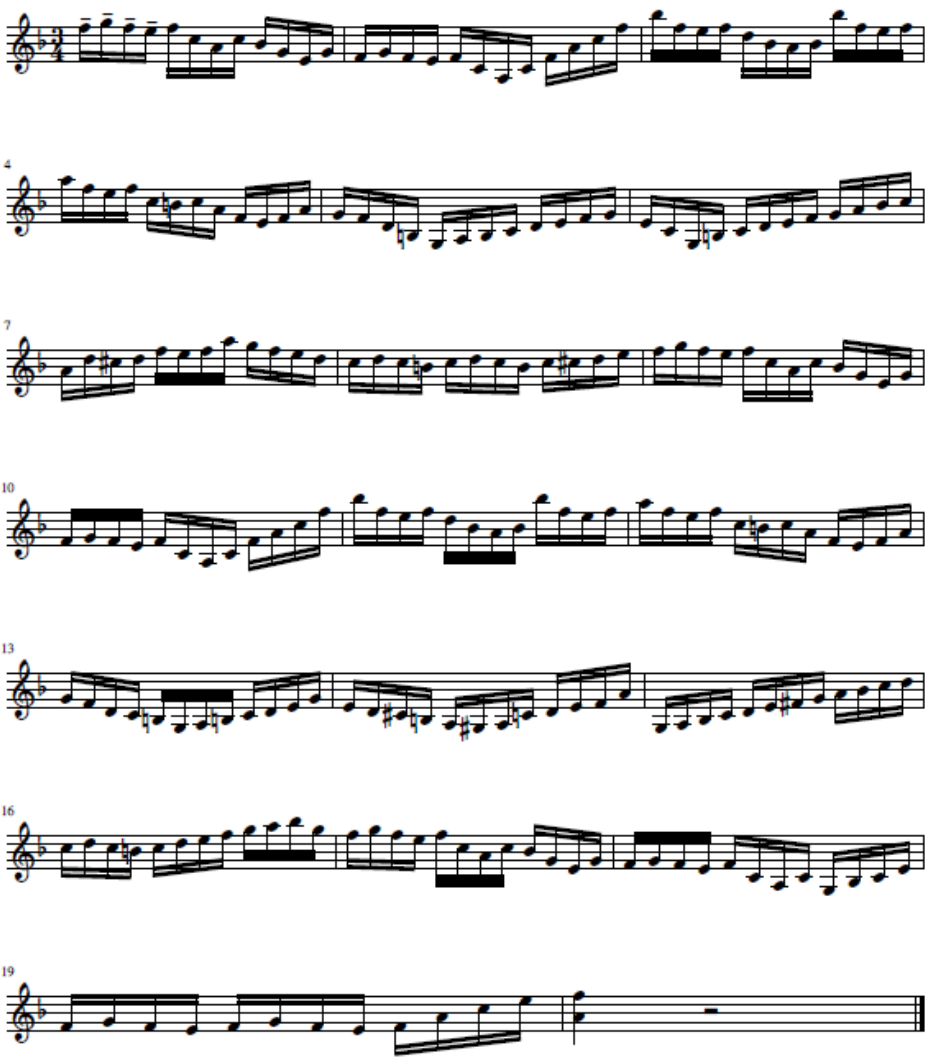

Figure 2: Fragment 2 / Playing condition 3: 'First position', Ševčík etude 29

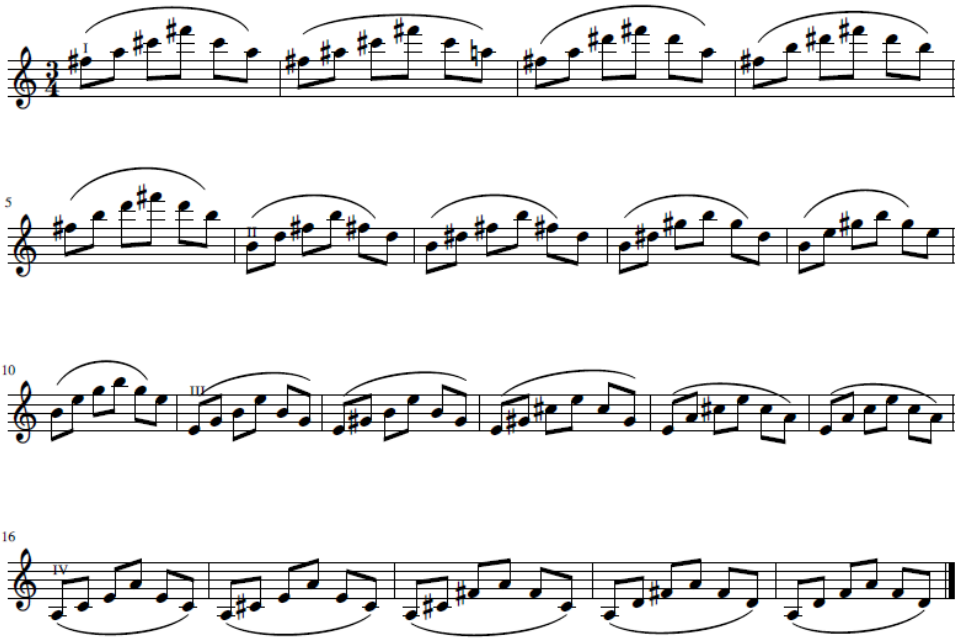

Figure 3: Fragment 3 / Playing condition 4: 'Shifts', Ševčík etude 3

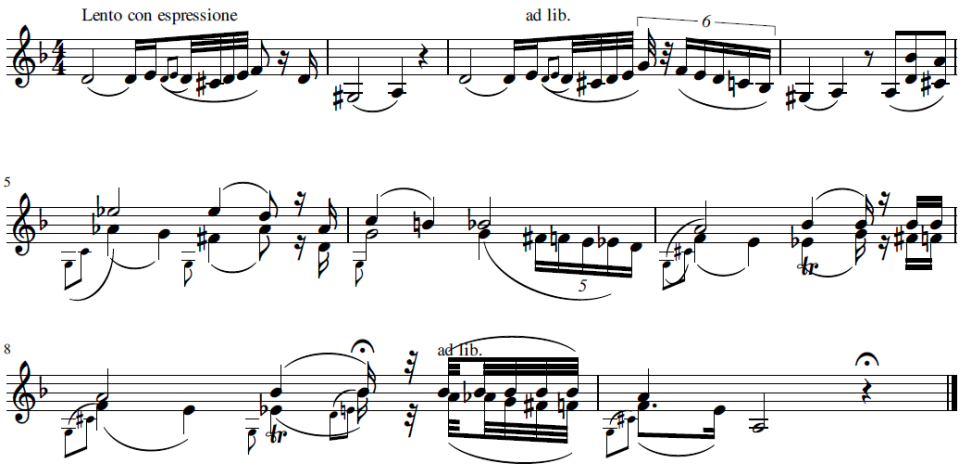

Figure 4: Fragment 4 / Playing condition 5: 'Virtuosic', Kreisler opus 6, Recitativo and Scherzo Caprice

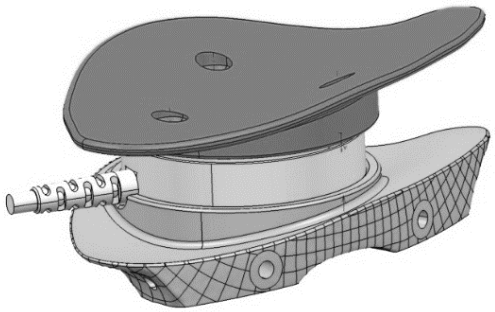

Figure 5: The custom-made 3D printed violin chin-rest with built-in force sensor

then achieved by dividing each envelope value by its MVIC. The mean of the EMG envelope and its standard deviation were calculated over total playing period for each muscle for each trial. A custom designed Matlab script was used for all signal processing.(28)

DATA ANALYSIS

Baseline variables are presented as mean and SD, except for the DASH and NDI which are presented as median with an interquartile range. Categorical variables are presented as percentage. Multivariable linear regression models were estimated to investigate the relationship between the outcome activity of the five muscles and jaw-shoulder violin fixation force and the dependent variables shoulder rest condition, complaints of the neck shoulder region, and playing condition. To investigate the effect of the activity of several muscles on the violin fixation force, an additional linear regression model was estimated. A linear regression model was also used to investigate the effect of the shoulder rest height, violin fixation force, muscle activity and complaints on subjective playing comfort. All analyses were performed in SPSS version 23.0.(29)

RESULTS

Twenty professional violinists were included in this study; four males and sixteen females with an average age of 29.4 years. Sixteen of them graduated at a music academy and worked predominantly as performing artists. One subject graduated from a music

academy but worked predominantly in another field. Three participants were music academy students. None of the violinists was sick or worked less during the preceding year due to complaints of the neck and / or shoulder(s). Sixteen violinists (80%) were content with their current shoulder rest, while four violinists (20%) were not content. Baseline variables of the violinists are presented in *Table 1.*

Table 1: Baseline variables

		Professional violinists (n=20)
Age (years)		29.4 (3.7) (range 21-38)
Sex	Male:	4 (20%)
	Female:	16 (80%)
BMI (kg/m2)		21.9 (2.2)
Hand dominance	Right:	19 (95%)
	Left:	1 (5%)
Smoking	Yes:	2 (10%)
	No:	18 (90%)
Sports (hours/week)		1.8 (1.7)
Profession	Mainly performing:	16 (80%)
	Music academy student:	3 (15%)
	Other	1 (5%)
Playing load (hours/week)		28.1 (13.6)
Starting age		6.1 (1.5)
NDI*		8.0 (3.5-12.5)
DASH*		2.9 (1.3-7.1)
music module DASH*		12.5 (0.0-32.9)

*Nominal values: number (%), continue variables: mean (SD), *median and IQR*

MUSCLE ACTIVITY

The MVIC variability within and between the subjects was small for all muscles was small. The results of the linear regression models with muscle activity of the five muscles as outcome variables and shoulder rest condition and playing condition and complaints as independent variable are displayed in *Table 3*. The shoulder rest had a significant effect on the activity of the left mDTA (p=0.025). However, it was not significantly associated to the activity of the mSCM and mTP muscles. An increase in activity of the mDTA was observed with increasing height of the shoulder rest, with a mean maximal difference of

3.5% of the MVIC (p=0.025). The activity of the muscles for each shoulder rest condition is displayed in *Figure 6*.

VIOLIN FIXATION FORCE

The mean violin fixation force for each playing condition and shoulder rest condition ranged between 2.92N and 3.39N (*Table 2).* For all non-shifting playing conditions (static, open strings; 1st position) there was an increase of the violin fixation force with higher shoulder rest conditions. Also, there was a higher violin fixation force in the playing conditions in which shifting of left hand was involved compared to the non-shifting left hand conditions (shifts and virtuosic versus static, open strings and first position position). To investigate the effect of the shoulder rest condition on violin fixation force, a linear regression model with fixation force as outcome variable, and shoulder rest condition, playing condition, and complaints of the neck and/or shoulder(s) was estimated. The shoulder rest condition had a significant effect on the violin fixation force (p<0.001). *(Table 3)* Complaints had a significant on the activity of both the mSCM and both the mTP (p<0.001).

Table 2: Violin fixation force

	Static	**Open strings**	**First position**	**Shifts**	**Virtuosic**	**Total (mean)**
No shoulder rest	1.06 (0.72)	1.80 (1.19)	1.81 (0.99)	5.48 (2.50)	4.38 (2.49)	2.92 (2.44)
Lowest condition shoulder rest	1.63 (1.10)	2.18 (1.56)	2.28 (1.50)	4.90 (2.31)	4.74 (2.56)	3.15 (2.32)
Middle condition shoulder rest	2.10 (1.16)	2.42 (1.48)	2.56 (1.57)	4.89 (2.28)	4.81 (2.58)	3.36 (2.22)
Highest condition shoulder rest	2.13 (1.46)	2.56 (1.60)	2.71 (1.72)	4.90 (2.13)	4.65 (2.59)	3.39 (2.23)
Total (mean)	1.73 (1.20)	2.24 (1.47)	2.35 (1.49)	5.04 (2.29)	4.65 (2.51)	3.20 (2.31)

Mean violin fixation force in N (SD) for each shoulder rest condition and playing condition

VIOLIN FIXATION FORCE & MUSCLE ACTIVITY

To investigate the effect of the activity of the several muscles on violin fixation force, a linear regression model with fixation force as outcome variable, and the activity of the five muscles as explanatory variables was estimated. The muscle activity of the left mSCM (6.407 (1.318), p<0.001), and right mTP (7.828 (1.079), p<0.001) and had a significant positive effect on the violin fixation force; the right mSCM (-3.782 (0.941), p<0.001) and left mDTA (-3.120 (0.786), p<0.001) had a significant negative effect on the violin force;

Table 3: Regression coefficients (B) along with their standard error (SE) from the linear model

	Shoulder rest condition		**Playing condition**		**Complaints**	
	B (SE)	**p-value**	**B (SE)**	**p-value**	**B (SE)**	**p-value**
mSCM left	-0.005 (0.003)	0.122	0.032 (0.003)	<0.001	0.047 (0.008)	<0.001
mSCM right	-0.007 (0.005)	0.197	0.020 (0.004)	<0.001	0.049 (0.011)	<0.001
mTP left	-0.005 (0.006)	0.332	0.011 (0.004)	0.010	0.089 (0.012)	<0.001
mTP right	-0.006 (0.005)	0.239	0.037 (0.004)	<0.001	0.042 (0.011)	<0.001
mDTA left	0.012 (0.005)	0.025	-0.018 (0.004)	<0.001	0.003 (0.012)	0.794
Violin fixation force	0.162 (0.039)	<0.001	0.864 (0.031)	<0.001	-0.076 (0.087)	0.385

Estimated effect (B) along with their standard error (SE) from a multivariable linear regression model

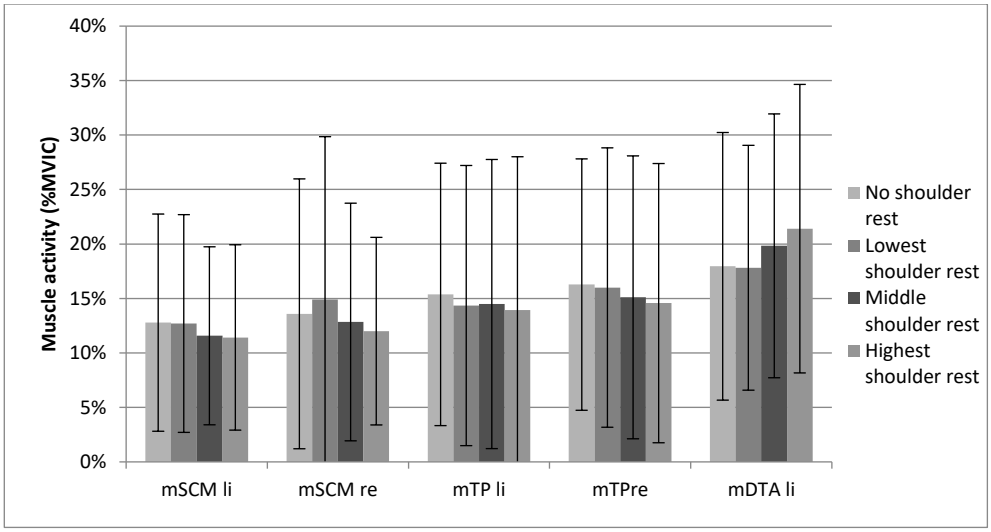

Figure 6: Muscle activity for the different shoulder rest conditions (in % MIVC (SD))

while the left mTP did not have significant effect on the violin fixation force (0.046 (0.967), p=0.962).

SUBJECTIVE EVALUATION OF THE SHOULDER REST

The lowest shoulder rest condition was subjectively indicated the most comfortable (VAS 4.9 (SD 2.1)), followed by the middle shoulder rest condition (VAS 6.8 (SD 2.1)), no shoulder rest (VAS 7.3 (SD 2.9)) and highest shoulder rest condition (VAS 8.8 (SD 1.5)). To

investigate the effect of the shoulder rest height, muscle activity, violin fixation force and complaints on subjective playing comfort, a linear regression model was estimated. The shoulder rest condition had a significant effect on playing comfort (0.584 (0.110), p<0.001). Also, the right mSCM (-4.044 (1.209), p=0.001), and left mTP (3.814 (1.306), p=0.004) and left mDTA (2.821 (1.021), p=0.006) were significantly associated. There was no significant association with the fixation force (0.046 (0.065), p=0.0476), left mSCM (-1.970 (1.778), p=0.269), right mTP (-0.857 (1.459), p=0.557) and complaints (0.010 (0.272), p=0.972).

DISCUSSION

The primary aim of this study was to evaluate the effect of the shoulder rest adjustment on muscular load of professional violinists, by examining the activity of the superficial neck and shoulder muscles and the violin fixation force. This study is the first in the literature to combine these biomechanical measurements in violinists. This is the first study in literature taking the subjective evaluation of violinists into account while evaluating the use of the shoulder rest.

In this study a higher violin fixation force was present in higher shoulder rest conditions and playing conditions requiring shifting of the left hand during playing. An increase in activity of the mDTA was observed with increasing height of the shoulder rest. The lowest shoulder rest condition was subjectively appreciated as most comfortable by the study participants.

An unexpected finding in this study were the correlations between the muscle activities and the violin fixation force. These could not be clearly explained from a biomechanical point of view. For example, the contraction level of the right mTP is positive associated with the violin fixation force. However, biomechanically one would expect a negative association, since the right mTP is an antagonist to left obliquity of the head. A possible explanation could be co-contraction of an antagonist pair of muscles, that stiffens up the position of the head. Another explanation could be that the function of neck muscles is not limited to a single plane; for example the sternocleidomastoid muscle has a function in latero-flexion of the neck and rotation of the neck (to the contralateral side). Bilateral activation of the neck induces flexion of the cervical spine, but also extension of the head. Also, when muscle is acting at a length that is suboptimal given the force-length

relationship of the evaluated muscles, it could show more EMG at a lower force. Finally, the bowing technique and therefore activity of the right mTP could be influenced by the bowing technique of the violinists. Therefore, interpretation of the relation between EMG results of the superficial neck muscles and the violin fixation force in violinists remains complex.

The increasing activity of the left mDTA with increasing height of the shoulder rest in this study could be explained by a higher position of the violin on the shoulder. With a higher positioning of the violin on the shoulder, the moment arm increases. This could potentially explain the increased muscle activity of the left mDTA as an opposing force. One could hypothesize that increasing the height of the chin rest instead of the shoulder rest could result in lower activity of the mDTA and therefore potentially improve playing comfort and reduce musculoskeletal complaints. Next to dynamic loading of the muscles, increasing the height of the chin rest could improve the static position of the violinists. For example, by decreasing left laterorotation, left lateroflexion and/or anteflexion of the neck and head. Future research should test this hypothesis.

Studies evaluating muscle activity of string instrumentalists using EMG are increasingly performed.(1,3,10,30–34) Among the studies evaluating violinists, our EMG results are partly in line with the study of Levy et al.(1); who also reported more muscle activity of the left anterior deltoid while playing with a shoulder rest. However, Levy et al. reported significantly less activity of the sternocleidomastoid and trapezius muscle following shoulder rest use, while we did not find a significant difference in activity of the mSCM and mTP in the current study. Rabufetti et al. reported an increase in left mSCM following shoulder rest use(3), a finding contrary to our results in which there is a small decrease in activity of the left mSCM following increasing height of the shoulder rest. In the study of Rabufetti et al. a non-normalised EMG was used. Also, the choice in music repertoire differs between our study and the study of Rabufetti, as in the latter the played repertoire included solely scales. As the repertoire influences muscle activity, as observed in the current study and the study of Levy et al.(1), this could potentially declare the differences in outcomes between the two studies.

The violin fixation force was also measured in a study by Okner et al.; in which a sensor mat on the chin rest was used to estimate this force.(2) Comparable to our results, Okner et al. found a relevant influence of the repertoire on the measured forces. However,

contrary to our results, they did not find the shoulder rest associated to the measured force. An explanation for this could lie in the different design of the studies; Okner evaluated two shoulder rest designs, while we choose to evaluate differences in height and use of the shoulder rest in this study. The latter is probably associated with bigger differences in the outcome variables.

A limitation of the current study concerns the adjustment of the shoulder rest and chin rest. At first, the instrumented chin rest used in this study is a little (4mm) higher compared to the average participants' own chin rest. Despite this small difference, this potentially influenced the outcomes, especially of the playing condition in which the own shoulder rest was used. Recently, the use of higher chin rests is trending among violinists, as some believe its use is thought to relieve musculoskeletal symptoms.(35) The three evaluated Wolf shoulder rest positions in the current study are a simplification of shoulder rest use in reality. In the current study we choose to increase the left and right wing of the shoulder rest symmetrically and use only one type of shoulder rest. There are however many possibilities to adjust shoulder rests, and also shoulder rest designs vary greatly.

Another limitation of this study concerns the learning effect which potentially influenced our results. A randomisation protocol could have reduced this risk of potential bias, however the current study was performed without. Although we did ask all violinists to prepare the excerpt, we sometimes noticed an increase in playing quality during the experiment. This could also be influenced by getting more used to the provided violin, despite the fact that violinists were given the opportunity to warm-up on the provided violin. Bias by learning effect will therefore in some extent be present. Also, fatigue might affect our results: During the experiment, which included a maximum of one hour of playing the instrument, fatigue could influence muscle activity. We think however that the bias as the result of fatigue is minimal as Levy et al. reported that fatigue did not play a role in violinists playing two hours.(1) Also, we choose not to normalise playing effort next to our regular normalisation procedures. Finally, the relatively small sample size in this study could mask an actual difference between the groups (type 2 error). However, it should be noted that compared with other literature in this field or research our study population is among the largest.

A major strength of this study is the incorporation of subjective playing comfort in our study design. Although biomechanical research is valuable in studying musicians; no

musician will adapt his or her playing technique to a biomechanical superior, but subjective inferior situation. For a translation of biomechanical studies to implementation in musical practice the subjective evaluation of the musician is needed; however, lacking in literature.(31) The current study aims engage in translation of biomechanical research to medical and musical practice.

In this study we choose to evaluate violinists with and without musculoskeletal complaints; half of the violinists in this study reported current complaints of the shoulder neck region This distribution is comparable to the prevalence of these complaints in professional violinists reported in the literature. (12–15) All of the violinists in this study reported not to have missed work due to their complaints. Therefore, despite the fact that musculoskeletal complaints are reported to influence muscle activity,(10,36), by including violinists with and without complaints, we think the violinists in this study are likely to be representative of the general working population of professional violinists. (12–15)

To our opinion, in all future studies evaluating biomechanical aspects of playing a musical instrument, a subjective evaluation of the situation by the violinists themselves should be part of the analysis. Scientific research in this field should be practically implementable. Researchers should realise that no violinist will play with a scientific 'good' but subjective uncomfortable fitting violin. Not taking the subjective evaluation into account will therefore be of no practical use. In the current study, playing without a shoulder rest or with a shoulder rest of minimal height has biomechanically the best properties. However, playing with a shoulder rest with minimal height was subjectively most comfortable for most violinists.

CONCLUSIONS

In this study among professional violinists, there is an increase in violin fixation force and muscle activity of the left mDTA while playing with an increasing height of the shoulder rest. Despite this higher violin fixation force, activity of the both mSCM and mTP did not differ significantly between the different shoulder rest conditions. As a shoulder rest influences muscle activity patterns and violin fixation force, adjustment of this shoulder rest and positioning the violin may need to be carefully optimised. Future studies should

evaluate if minimalizing or omitting the shoulder rest clinically reduces musculoskeletal complaints in violinists.

ACKNOWLEDGEMENTS

We thank Danny Koops for his contribution to the development of the instrumented chin-rest.

REFERENCES

1. Levy CE, Lee WA, Brandfonbrener AG, Press J, Levy AE. Electromyographic Analysis of Muscular-Activity in the Upper Extremity Generated by Supporting A Violin with and Without A Shoulder Rest. MPPA. 1992;7(4):103–9.
2. Okner M, Kernozek T. Chinrest pressure in violin playing: type of music, chin rest, and shoulder pad as possible mediators. ClinBiomech(Bristol, Avon). 1997 Apr;12(1879–1271 (Electronic)):S12–3.
3. Rabufetti M, Converti RM, Boccardi S, Ferrarin M. Tuning of the violin-performer interface. MPPA. 2007 Jan 6;22(2):58–66.
4. Rocha F. An analysis of violin sound spectra with different shoulder rests. 2016;
5. Watson AHD. The biology of musical performance and performance-related injury. Scarecrow Press; 2009. 369 p.
6. Ackermann BJ, Adams R. Interobserver reliability of general practice physiotherapists in rating aspects of the movement patterns of skilled violinists. MPPA. 2004;19(1):3–11.
7. Obata S, Kinoshita H. Chin force in violin playing. EurJ ApplPhysiol. 2012 Jun;112(1439–6327 (Electronic)):2085–95.
8. Tubiana R, Chamagne P, Brockman R. Fundamental positions for instrumental musicians. MPPA. 1989;4(2):73–6.
9. Menuhin Y. Violin : six lessons with Yehudi Menuhin. 2nd ed. Faber Music; 1974. 144 p.
10. Berque P, Gray H. The influence of neck-shoulder pain on trapezius muscle activity among professional violin and viola players: An electromyographic study. MPPA. 2002;17(2):68–75.
11. Sataloff RT, Brandfonbrener AG, Lederman RJ. Performing arts medicine. Vol. 3rd. Science & Medicine; 2013.
12. Abreu-Ramos AM, Micheo WF. Lifetime prevalence of upper-body musculoskeletal problems in a professional-level symphony orchestra: Age, Gender, and Instr-ument-specific results. MPPA. 2007;22(3):97–104.
13. Kochem FB, Silva JG. Prevalence and Associated Factors of Playing-Related Musculoskeletal Disorders in Brazilian Violin Players. MPPA. 2017 Mar 1;32(1):27–32.
14. Kok LM, Huisstede BMA, Voorn VMA, Schoones JW, Nelissen RGHH. The occurrence of musculoskeletal complaints among professional musicians: a systematic review. Vol. 89, International Archives of Occupational and Environmental Health. 2016. p. 373–96.
15. Ackermann B, Adams R. Physical characteristics and pain patterns of skilled violinists. MPPA. 2003;18(2):65–71.
16. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). AmJIndMed. 1996 Jun;29(0271–3586 (Print)):602–8.
17. Vernon H, Mior S. The Neck Disability Index: a study of reliability and validity. J Manipulative Physiol Ther. 1991 Sep;14(7):409–15.
18. Ševčík O (Otakar), Mittell P. School of violin technics : op. 1 : in four parts. G. Schirmer; 1905.

19. Kreisler F. Recitativo-Scherzo Caprice Op.6. 1911.

20. Falla D, Dall'Alba P, Rainoldi A, … RM-EJ of, 2002 undefined. Repeatability of surface EMG variables in the sternocleidomastoid and anterior scalene muscles. Springer.

21. Burnett A, Green J, Netto K, and JR-J of electromyography, 2007 undefined. Examination of EMG normalisation methods for the study of the posterior and posterolateral neck muscles in healthy controls. Elsevier.

22. Boettcher C, Ginn K, Cathers I. Standard maximum isometric voluntary contraction tests for normalizing shoulder muscle EMG. J Orthop. 2008;

23. Kendall FP, Kendall FP. Muscles : testing and function with posture and pain. Lippincott Williams & Wilkins; 2005.

24. Clancy E, Morin E, and RM-J of electromyography, 2002 undefined. Sampling, noise-reduction and amplitude estimation issues in surface electromyography. Elsevier.

25. Sakaki Y, Kaneko F, Watanabe K, … TK-J of, 2013 undefined. Effects of different movement directions on electromyography recorded from the shoulder muscles while passing the target positions. Elsevier.

26. Wattanaprakornkul D, Halaki M, Boettcher C, Cathers I, Ginn KA. A comprehensive analysis of muscle recruitment patterns during shoulder flexion: An electromyographic study. Clin Anat. 2011 Jul;24(5):619–26.

27. Netto KJ, Burnett AF. Reliability of normalisation methods for EMG analysis of neck muscles. Work. 2006;26(2):123–30.

28. Matlab. Natick, Massachusetts, United States: The MathWorks, Inc.;

29. SPSS. Armonk, NY: IBM Corp.;

30. Rickert DL, Halaki M, Ginn KA, Barrett MS, Ackermann BJ. The use of fine-wire EMG to investigate shoulder muscle recruitment patterns during cello bowing: the results of a pilot study. J Electromyogr Kinesiol. 2013 Dec;23(6):1261–8.

31. Kelleher LK, Campbell KR, Dickey JP. Biomechanical research on bowed string musicians: a scoping study. MPPA. 2013 Dec;28(0885–1158 (Print)):212–8.

32. Woldendorp K, Werk P van de, … AB-A of physical, 2013 undefined. Relation between muscle activation pattern and pain: an explorative study in a bassists population. Elsevier.

33. Fjellman-Wiklund A, Grip H, Karlsson J. EMG trapezius muscle activity pattern in string players:: Part I—is there variability in the playing technique? Int J. 2004;

34. Fjellman-Wiklund A, Grip H, Andersson H. EMG trapezius muscle activity pattern in string players: Part II—Influences of basic body awareness therapy on the violin playing technique. Int J. 2004;

35. Finding the right chin rest and shoulder rest | Focus | The Strad [Internet]. The Strad. 2015 [cited 2018 May 23]. Available from: https://www.thestrad.com/playing/finding-the-right-chin-rest-and-shoulder-rest/2206.article

36. Philipson L, Sorbye R, Larsson P, Kaladjev S. Muscular Load Levels in Performing Musicians As Monitored by Quantitative Electromyography. MPPA. 1990;5(2):79–82.

APPENDIX A: QUESTIONNAIRE CONTENT

1. Wat is uw leeftijd? *What is your age?*

2. Wat is uw geslacht? *What is your gender?*
0 Man *Male*
0 Vrouw *Female*

3. Wat is uw lengte? (in cm) *What is your length? (in cm)*

4. Wat is uw gewicht? (in kg) *What is your weight? (in kg)*

5. Wat is uw handvoorkeur? *What is your hand preference?*
0 Rechts *Right*
0 Links *Left*
0 Geen voorkeur *No preference*

6. Rookt u? *Do you smoke?*
0 Nee *No*
0 Ja *Yes*

7. Sport u? *Do you perform sports?*
0 Nee *No*
0 ja, … uur per week. Welke sport(en)? *Yes, … hours a week. Which Sport(s)?*

8. U bent violist, op welke manier oefent u uw vak uit? *You are a violinists, what are your main job activities?*
0 Professioneel musicus, voornamelijk lesgeven *Professional musician, mainly teaching*
0 Professioneel musicus, voornamelijk werk als uitvoerend musicus *Professional musician, mainly performing*
0 Conservatoriumstudent *Music academy student*
0 Een andere baan, namelijk: *Other, ….*

9. Hoeveel uur speelt u gemiddeld per week viool? (De laatste 4 weken) *How many hours a week do you play the violin? (During the last 4 weeks)*

10. Op welke leeftijd bent u begonnen met viool spelen? *At which age did you start playing the violin?*

11. Heeft u op dit moment nekklachten? *Do you currently have complaints of your neck?*
0 Nee *No*
0 Ja *Yes*

12. Heeft u de afgelopen week nekklachten gehad? *Did you have complaints of your neck during the past week?*
0 Nee *No*
0 Ja *Yes*

13. Heeft u de afgelopen maand nekklachten gehad? *Did you have complaints of your neck during the past month?*

0 Nee *No*
0 Ja *Yes*

14. Heeft u het afgelopen jaar nekklachten gehad? *Did you have complaints of your neck during the past year?*

0 Nee *No*
0 Ja *Yes*

15. Heeft u op dit moment schouderklachten? *Do you currently have complaints of your shoulder(s)?*

0 Nee *No*
0 Ja, links *Yes, left*
0 Ja, rechts *Yes, right*
0 Ja, beiderzijds *Yes, bilateral*

16. Heeft u de afgelopen week schouderklachten gehad? *Did you have complaints of your shoulder(s) during the past week?*

0 Nee *No*
0 Ja, links *Yes, left*
0 Ja, rechts *Yes, right*
0 Ja, beiderzijds *Yes, bilateral*

16. Heeft u de afgelopen maand schouderklachten gehad? *Did you have complaints of your shoulder(s) during the past month?*

0 Nee *No*
0 Ja, links *Yes, left*
0 Ja, rechts *Yes, right*
0 Ja, beiderzijds *Yes, bilateral*

17. Heeft u het afgelopen jaar schouderklachten gehad? *Did you have complaints of your shoulder(s) during the past year?*

0 Nee *No*
0 Ja, links *Yes, left*
0 Ja, rechts *Yes, right*
0 Ja, beiderzijds *Yes, bilateral*

18. Heeft u zich het afgelopen jaar ziek gemeld van uw werk, of werk niet aangenomen als gevolg van klachten van uw nek of schouder(s)? *Did you call sick of work, or dismiss work because of complaints of your neck and/or shoulder(s) during the past year?*

0 Nee *No*
0 Ja *Yes*

19. Heeft u het afgelopen jaar inkomsten gemist als gevolg van klachten van uw nek of schouder(s)? *Did you miss income due to complaints of your neck and/or shoulder(s) during the past year?*

0 Nee *No*
0 Ja *Yes*

20. Ben je tevreden over je schoudersteun? *Are you satisfied with your shoulder rest?*
0 Nee *No*
0 Ja *Yes*

21. Hoeveel verschillende soorten schoudersteunen heb je geprobeerd? *How many different shoulder rests did you test?*
0 1
0 2-4
0 5-9
0 10 of meer *10 or more*

22. Hoe ben je tot je keuze voor je schoudersteun gekomen? *How did you decide for your shoulder rest?*

23. Wie heeft je geholpen de keus voor je schoudersteun te maken? (Meerdere opties mogelijk) *Who helped you making your choice for a shoulder rest? (More options possible)*
0 Niemand *Nobody*
0 Vioolleraar *Violin teacher*
0 Verkoper/vioolbouwer *Violin seller / Violin maker*
0 Mensendieck therapeut *Mensendieck therapist*
0 Alexander techniek docent *Alexander technique therapist*
0 Collega violist *Collegiate violinist*
0 Arts *Physician*
0 Fysiotherapeut *Physiotherapist*
0 anders, namelijk: *Other, ….*

Neck Disability Index (NDI)(17)
DASH questionnaire, including the performing arts module(16)

Chapter 12

General Summary

PART 1: EPIDEMIOLOGY

The primary aim of this thesis is to evaluate the prevalence and severity of musculoskeletal health complaints in professional and amateur musicians. In the first part of this thesis the epidemiology of musculoskeletal complaints in musicians is studied. Prevalence of complaints as well as prognostic factors for these complaints are evaluated in several groups of musicians.

In **Chapter 2** of this thesis we evaluated the presence of musculoskeletal complaints in music academy students. In this study we compared the prevalence of musculoskeletal complaints in musicians with a control group. The twelve-month prevalence of musculoskeletal complaints in musicians was 89% compared to a prevalence of 78% in the control group (OR 2.3). Current musculoskeletal complaints were reported by 63% of the musicians compared to 43% of the subjects in the control group (OR 2.3). We therefore consider the occupation of the professional musician a relevant and substantial risk factor for musculoskeletal complaints.

We appreciated the prevalence of musculoskeletal complaints in chapter two of this thesis as remarkably high. Aiming to acquire an overview of the literature on musculoskeletal complaints in professional musicians, we performed a systematic review (**Chapter 3**). Reported point prevalences of the included studies ranged between 9% and 68%; year prevalences ranged between 41% and 93%. In most studies musculoskeletal complaints were more frequent among female compared to male instrumentalists. Heterogeneity of the included studies could explain the wide range of these prevalence rates. Nevertheless, this review underscores the extent of a serious musculoskeletal health problem among professional musicians.

While in the first two chapters of this thesis professional musicians were evaluated, amateur musicians were studied in **Chapter 4** . This study is the first large study in the literature examining the prevalence of musculoskeletal complaints in amateur musicians. The year prevalence of playing-related complaints in this study was 68%. Female gender and playing a string instrument were the main prognostic factors, next to age and BMI being associated with musculoskeletal complaints. The high prevalence of musculoskeletal complaints in amateur musicians stresses the importance of recognising the potential harmful effect of music making on musculoskeletal health, even on an amateur level.

In **Chapter 5** the results of a pilot study among amateur musicians are presented, evaluating the association between CANS and two potential risk factors for musculoskeletal complaints: arm position and playing time. We found that complaints of the left shoulder were significantly associated with playing an instrument requiring elevation of the left arm. In this group of amateur musicians, playing time did not significantly contribute to CANS.

Chapter 6 describes a longitudinal cohort study among high-level amateur musicians. In this study members of the two national Dutch student orchestras were studied during an intensive rehearsal period. This study aimed to prospectively evaluate an increase in playing time as a risk factor for musculoskeletal complaints among high-level amateur musicians. The point prevalence of playing-related musculoskeletal complaints at the start of the study was 28%, and increased dramatically to 80% after one week of intensive practising the instrument. Therefore, a sudden increase in playing time was considered a very strong risk factor for the development of musculoskeletal complaints in amateur musicians.

Female gender is an important risk factor for musculoskeletal complaints among musicians. **Chapter 7**, originally published as a book chapter, comprises a narrative review of musculoskeletal complaints in musicians, with a focus on sex differences.

PART 2: IMPACT & ILLNESS PERCEPTIONS

The aim of the second part of this thesis was to evaluate the impact of musculoskeletal complaints on musicians. Illness perceptions of professional musicians with musculoskeletal complaints, as well as the behavioural consequences of these musculoskeletal complaints are studied.

Chapter 8 describes the consequences of CANS in a group of professional musicians. In this study musculoskeletal complaints did have a more serious impact on daily functioning in professional musicians compared to their controls. Also, healthcare usage among musicians with musculoskeletal complaints was higher compared to the control group; in this study more healthcare providers were involved in treatment of musculoskeletal complaints in musicians. This may indicate a trend of 'medical shopping' in musicians.

In **Chapter 9** illness perceptions of professional musicians with musculoskeletal complaints were evaluated, using a patient perceived outcome score. In this study musicians with musculoskeletal complaints reported worse perceptions on most domains of the questionnaire compared to their control group: Musicians perceived a significantly more severe impact of musculoskeletal complaints on their personal life and were more concerned and emotionally affected by their complaints.

PART 3: BIOMECHANICAL ANALYSIS OF VIOLIN PLAYING

Neck and shoulder complaints are prevalent in violinists. The last part of this thesis aims to clarify biomechanical aspects of violin playing, which could potentially contribute to these complaints. Professional violinists were studied in a variety of playing conditions, while measuring the activity of the superficial neck and shoulder muscles and the violin fixation force using a force sensor in the chin rest of the violin.

In **Chapter 10** professional violinists with complaints of the neck shoulder region were compared with violinists without these complaints. Violinists with complaints showed more activity of the superficial neck and shoulder muscles while playing the instrument. Despite this increased muscle activity in violinists with complaints, no differences in jaw-shoulder violin fixation force were present between the two groups. Co-contraction is therefore thought to play a relevant role in violinists with complaints of the neck and shoulder region.

In **Chapter 11** biomechanical consequences of shoulder rest adjustment were evaluated in a group of twenty professional violinists. With an increasing height of the shoulder rest, an increase in violin fixation force and muscle activity of the left deltoid muscle was observed. From a biomechanical point of view, playing without a shoulder rest, or with a shoulder rest with minimal height seems favourable, the latter being subjectively most comfortable by the violinists.

CHAPTER 13

General Discussion

DEFINITIONS OF MUSCULOSKELETAL COMPLAINTS & STUDY DESIGNS

The main aim of this thesis was to evaluate the prevalence and severity of musculoskeletal health problems in both professional and amateur musicians. Secondly, factors associated with these were studied, as well as the impact of the complaints on functioning as a musician. By studying several groups of musicians with varying skill levels, thereby using a variety of study designs and outcome measures, I aimed to gain an comprehensive understanding of the musculoskeletal health of musicians.

Health can be evaluated on several domains according to the ICF model.(1,2) This model is therefore a useful tool to evaluate all aspects of a specific health condition. Aiming to clarify the knowledge acquired in this thesis I propose an applied ICF model for musculoskeletal complaints in musicians *(Figure 1)*. In this model we assume that musculoskeletal overload induce musculoskeletal disorders, which are expressed by symptoms. Individual appreciation by the musician determines if these symptoms are considered complaints.

In the first part of this thesis we evaluated the prevalence of musculoskeletal complaints in several groups of musicians. Three study strategies were used to evaluate these complaints, as displayed by the Venn-diagram in *Figure 1*. The first strategy consisted of evaluating all musculoskeletal complaints, without excluding based on localization or severity. The second strategy consisted of evaluating PRMDs, thereby excluding all complaints which did not interfere with playing the instrument. The third study strategy is using the CANS model; thereby evaluating upper extremity complaints (not caused by trauma or systemic disease).

In the second chapter of this thesis we evaluated the prevalence of all complaints in the musculoskeletal system, without rating their severity or the interference with the playing the instrument, thereby irrespective of their impact.(3) By using this study strategy, the prevalence rates were logically higher compared to the prevalence rates found in studies using a more limited definition of musculoskeletal complaints.(3)

A disadvantage of evaluating all musculoskeletal complaints, irrespective of their severity or interference with playing of the musical instrument, is that even minor, clinical

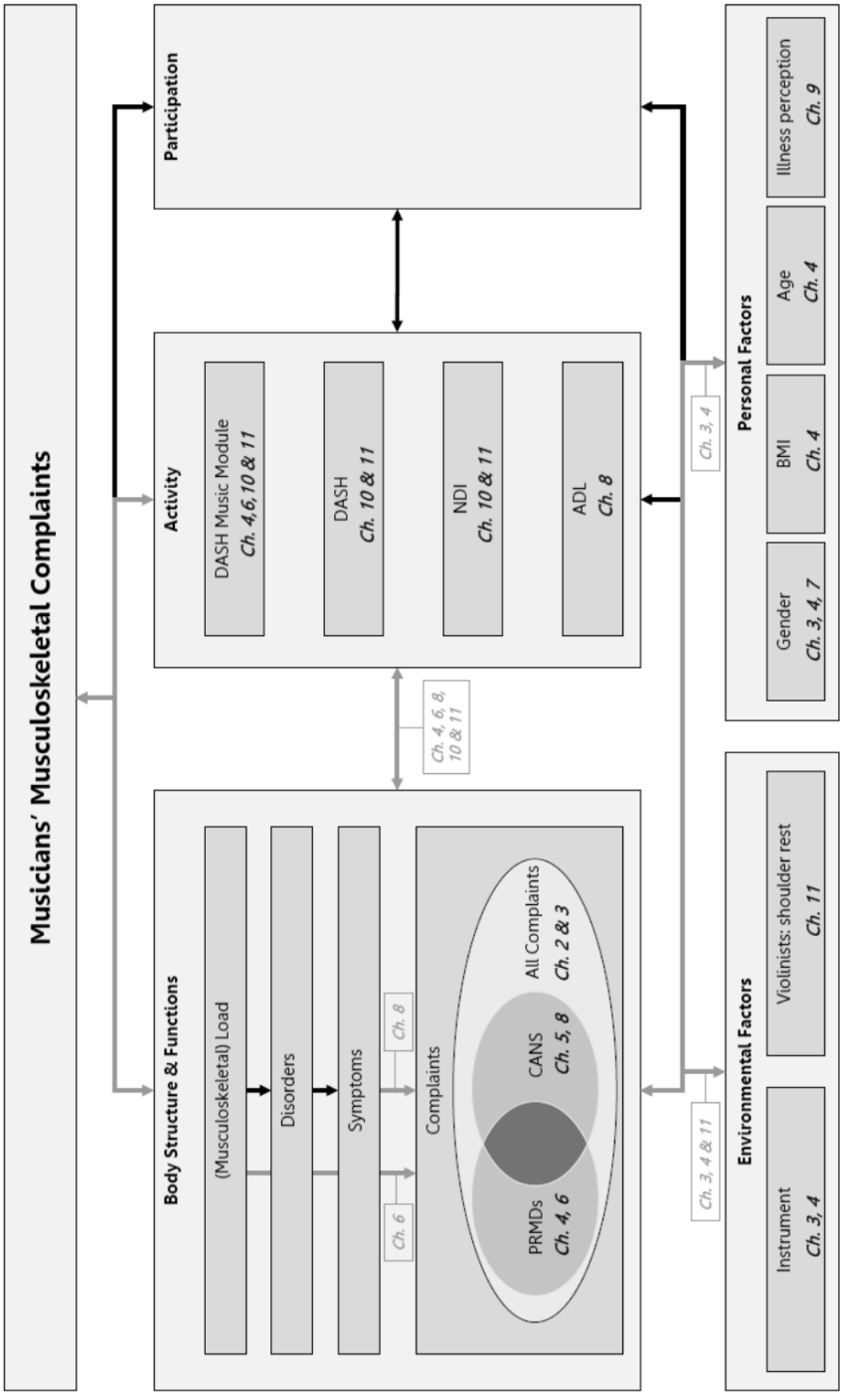

Figure 1: Applied ICF model for musicians' musculoskeletal complaints

irrelevant complaints were also reported. Therefore we used a more limited definition of complaints in the following chapters of this thesis.(4–7) Several researchers studying musculoskeletal complaints have proposed a definition of these complaints, mainly aiming to exclude minor, seemingly clinical irrelevant complaints.(8–12) In the field of performing arts medicine, Zaza developed a more precise definition in collaboration with musicians themselves.(13) She introduced the term PRMDs, 'playing-related musculoskeletal disorders'. PRMD's according to Zaza are complaints, which are 'Pain, weakness, numbness, tingling, or other symptoms that interfere with (their) ability to play (their) instrument at the level (they) are accustomed to.' She discussed this subject with musicians, who rated PRMDs as 'Personal, chronic and disabling health problems that affect the whole person physically, emotionally, occupationally and socially'.

Zaza did commendable efforts to define PRMDs. However, I would like to discuss two critical notes concerning these PRMDs. At first, the definition of PRMDs actually describes playing-related musculoskeletal *complaints* instead of playing-related musculoskeletal *disorders*. Zaza defined the term PRMDs as 'pain, weakness, numbness, tingling, or other *symptoms*, that interfere with (their) ability to play (their) instrument at the level (they) are accustomed to'. The musicians' definition however included 'personal, chronic, and disabling health *problems* that affect the whole person physically, emotionally, occupationally and socially'. Thereby *disorders, problems, complaints* and *symptoms* are alternately used. Especially when taking the ICF model into account, this could easily cause misunderstanding. In this thesis as well as in literature, the term PRMD should actually be interpreted as playing-related musculoskeletal *complaints*. Secondly, despite Zazas' commendable efforts to clearly define these PRMDs, the term PRMD is frequently used without strictly adhering to this definition.(8,14) In this thesis, we choose to evaluate musculoskeletal complaints in musicians using the PRMD definition, thereby strictly adhering to the exact operational definition of Zaza.(6,7,13)

Our third study strategy consisted of the use of the CANS model. In the CANS model complaints due to systemic disease or acute trauma are excluded.(15) This model was initially developed to support and compare scientific research and to increase multidisciplinary cooperation. It was developed by using a Delphi consensus strategy. The CANS model is suited for evaluating musculoskeletal complaints among musicians as most of them are non-specific complaints.(16) An important advantage of using this model is the possibility of comparing different studies. In this thesis musculoskeletal

complaints were evaluated using the CANS model, thereby comparing musicians to non-musicians. The latter in contrast to the vast majority of the literature on this subject lacking a non-musicians reference population.(8)

However, independently of the study method and definition of complaints used, the overwhelming majority of the studied musicians in this thesis did report musculoskeletal complaints during the year preceding the questionnaire.(3,5–8) There was a higher prevalence of musculoskeletal complaints among professional musicians compared to the control group.(3,5) Also, the prevalence of CANS among musicians was higher compared to both the control group as well as other occupational groups with repeated physical activity.(5,17,18)

PROFESSIONAL AND AMATEUR MUSICIANS

A minority of musicians is playing their instrument professionally, estimations are 20.000-25.000 professional musicians in The Netherlands. Contrary, there are about 3 million Dutch amateur musician, approximately 18% of the Dutch adult general population.(19,20) Nevertheless, the vast majority of research in the field of performing arts medicine focuses on professional musicians, whilst only a few studies in literature examined the musculoskeletal health of amateur musicians.(21–24) Knowledge on the occurrence of musculoskeletal disorders within this latter group is important. As there are so many amateur musicians, health problems in this group could be considered public health problems.

In this thesis, an attempt was made to adequately describe the occurrence of musculoskeletal complaints in musicians. Although musicians can be subdivided in different groups based on experience, playing style or instrument, the main distinction made in this thesis is based on professionality. Although the dichotomy between amateur and professional musicians is somewhat arbitrary, some relevant differences between amateur and professional musicians, can be distinguished.(14) The first and most obvious difference between professional and amateur musicians is playing load. The number of hours played by amateur musicians is generally less compared to professional musicians.(16) This difference is relevant as the amount of physical exposure is related to the occurrence of musculoskeletal complaints in the general and working population.(25–27) A second difference between amateur and professional musicians is the financial

dependency of the latter, necessitating the professional musician to be able to play the instrument also in presence of physical complaints. Many professional musicians are self-employed and financially dependent on the ability to play at their accustomed level.

During the training period of the professional musician, which generally starts at a very young age, continuous selection is performed. Therefore creating 'inclusion bias', since musculoskeletal unfit musicians will probably drop out and change their career path. Also, psychologically there are some very relevant differences between professional and amateur musicians. Professional musicians frequently report mental problems.(28–31) The job requirements for professional musicians contain a number of psychological risk factors for musculoskeletal complaints: Performance anxiety is among the most reported psychological problems among this group, influencing daily life of the professional musician.(29,32–34) For that matter, low-control and high-demanding work are known risk factors for development of health complaints in the overall working population. Professional musicians score low compared to other occupational groups on autonomy and control, which makes them susceptible for developing musculoskeletal complaints.(31)

Taking the above-mentioned differences into account, professional and amateur musicians share a passion for making music, they are inspired by similar composers and performers. For most of them making music is a form of emotional expression and for all of them it is a part of their life. Both amateur and professional musicians have invested a significant amount of time practicing their instrument. They invested money in music lessons and their instrument. Even more important, musical activities have a social, and for the professional musician financial, function as well. Therefore, musculoskeletal complaints influencing playing capabilities a threat and therefore are stressful for both the amateur and professional musician, with subsequent impact on the joy, expressional and social function of making music.

RISK AND ASSOCIATED FACTORS

Risk factors for musculoskeletal complaints are comprehensively studied in the general and working population.(35–37) Most of the work-related risk factors studied among other occupational groups can be applied to the group of professional musicians. As discussed above, playing an instrument on an amateur level can also be seen as an

additional risk factor for the development of musculoskeletal complaints.(7,21,22) One of the aims of this thesis was to identify specific subgroups of musicians with an increased risk of developing musculoskeletal complaints.

Female gender is the most important risk factor for musculoskeletal complaints in musicians.(8,14) This finding is consistent with the literature on the general as well as the working population.(14,25,36,38–41) In this thesis this gender difference is observed in both amateur and professional musicians.(6,8,14) These gender differences are also in line with the performing arts medicine literature; the majority of studies in the literature report a higher prevalence of musculoskeletal complaints among female compared to male musicians.(9,10,31,42–44)

Many clinicians specialised in treating musicians consider the type of instrument played a risk factor for musculoskeletal complaints among musicians.(20,45,46) It is an often-studied factor, as it seems logical that the playing posture influences the occurrence of musculoskeletal complaints. However, in the literature no unanimity is present concerning the instrument group or groups with the highest risk.(8) In our systematic review we could however identify brass players as having the lowest risk for developing musculoskeletal complaints.(8) In the studies among amateur musicians in this thesis, string instrumentalists and instrumentalists playing with an elevated left arm reported higher prevalence rates for musculoskeletal complaints.(4,6) Due to heterogeneity of the included studies in our systematic review, it was not possible to draw firm conclusions concerning which instrument group has the highest risk of developing musculoskeletal complaints. Therefore, future studies should report on instrumental groups of musicians and specify anatomic localisations and type of musculoskeletal complaints instead of reporting an overall prevalence of musculoskeletal complaints. As a result, preventive strategies can be specified for these instrumental groups of musicians according to their profile of complaints.

An example of this directed strategy is the last part of this thesis: Upper string instrumentalists report most of their complaints in the neck and shoulder region.(6,8,10,31,47). We performed a more in-depth analysis of playing biomechanics in this group of musicians, thereby evaluating muscle activity in the neck shoulder region in violinists. Also, we aimed to contribute to optimal adjustment of the shoulder rest in violinists.

Playing load is associated with musculoskeletal complaints in professional musicians.(4,7) The higher prevalence of musculoskeletal complaints among professional musicians compared to amateurs, and among musicians compared to non-musicians suggests an association between the playing time (exposure) and musculoskeletal complaints.(3–5,8,14) However, this suggested load-dependent relationship is potentially confounded by other factors as discussed in the section on professional and amateur musicians. In a study among professional musicians Kaufmann et al. found a correlation between musculoskeletal complaints and playing time.(48) In three chapters of this thesis we evaluated if this association between playing time and complaints in professional musicians was reproducible in amateur musicians.(4,6,7) In the first (pilot) study we evaluated this relation in a sample of amateur musicians by using a cross-sectional design; no significant association was found.(4) In the second study, also with a cross-sectional design, we found an association between playing time and complaints, but this did not reach significance.(6) Finally a prospective cohort study was performed, evaluating the effect of a sudden increase in playing time in a group of high-level amateur musicians.(7). The latter showed, that after intensifying playing load the point prevalence of musculoskeletal complaints raised from 28% to 80%.

IMPACT OF MUSCULOSKELETAL COMPLAINTS ON MUSICIANS

An important subject of discussion in the literature of performing arts medicine is the severity of the musculoskeletal complaints experienced by musicians. One could question, what makes the difference between a minor ache or benign myalgia, and a 'serious' complaint influencing the health and well-being of the musician? As discussed before, some researchers aim to exclude these minor complaints, evaluating playing-related musculoskeletal complaints, with some authors adhering to the original definition of Zaza and some not.(13) However, even when following this definition, defining succinctly the severity of musculoskeletal complaints remains difficult.

Although healthcare utilisation behaviour is potentially influenced by many factors, including coping, it is an objective measure evaluating the impact of complaints on the individual. In this thesis nearly half of the evaluated musicians with musculoskeletal complaints visited a healthcare provider for their musculoskeletal complaints, clearly exceeding healthcare usage of the control group.(49) This was a surprising outcome, as in previous literature healthcare avoiding behaviour was described among

musicians.(13,50) The differences between our studies and the studies describing healthcare avoiding behaviour could be related to socio-economic differences, i.e. health care insurance, between The Netherlands and the United States. In contrast to citizens of the United States, all Dutch have a private healthcare insurance, with subsequent easy access to healthcare.

In general, musicians reported worse perceptions of their musculoskeletal complaints compared to the Dutch control population in this thesis.(51) Especially cognitive and emotional aspects of their complaints were addressed more negatively. In addition, they experienced more severe consequences of these musculoskeletal complaints in daily life. Healthcare providers should be aware of these negative coping mechanisms, as they should be targets for therapy by the healthcare provider. By modifying these illness perceptions, treatment outcomes are likely to improve, as established in other somatic diseases.(52–56)

BIOMECHANICAL ANALYSIS OF VIOLIN PLAYING

In the first two parts of this thesis high prevalence rates of musculoskeletal health problems in musicians were found. Ideally, these complaints should be prevented. Van Mechelen described the 'sequence of prevention', a model often used in sports medicine.(57) In the first step of this model, the extent of the health problem should be identified and described. This is followed by a second step in which the factors and mechanisms which play a part are identified. Finally, this acquired knowledge is used for implementing preventive measures.(57)

The first step of the Van Mechelen model is reflected in the first part of this thesis. The second step of the Van Mechelen model is reflected in the last part of this thesis, in which we evaluate biomechanical aspects of playing an instrument in a high-risk group of musicians: professional violinists. Thereby we choose to focus on complaints of the neck and shoulders, which are the body regions most affected by complaints.(8)

A combination of measurement techniques was used to evaluate these professional violinists in the last part of this thesis. The presence of complaints and their impact on functioning was evaluated using a questionnaire, which included among other questions the validated outcome measures DASH (Disabilities of Arm, Shoulder and Hand) and NDI

(Neck Disability Index). Secondly, activity of the superficial neck and shoulder muscles was evaluated using a surface electromyogram (EMG). And finally, the jaw-shoulder violin fixation force was studied using an instrumented chin rest, which included a sensitive force sensor. The studies in the last part of this thesis are unique in the literature as they combine these three outcome measures.(58) Above, in contrary to all studies evaluating these biomechanical aspects of violin playing (58–64), the studies included in the last part of this thesis also take the subjective evaluation of the violinist in account.(65,66) Thereby an increased understanding of violin playing technique is obtained in this last part of the thesis.

While playing the instrument, violinists with musculoskeletal complaints of the neck and shoulder region showed more muscle activity of the neck and shoulder muscles. However, no significant difference in violin fixation force was observed between the two groups.(66) We assume the latter is probably due to co-contraction of agonists and antagonists, a hypothesis supported by the finding that among violinists with complaints there is more co-contraction of the both sternocleidomastoid muscles compared to the group of violinists without complaints. Although we did not study the causality of the above mentioned relationship between complaints and muscle activity, the finding of increased and altered muscle activity is consistent with the literature on non-musicians, in which patients with neck pain show increased antagonistic activity of their superficial neck muscles.(67–69)

The altered pattern of muscle activation and increased co-contraction is a possible target point for preventive measures. For instance, biofeedback training using an EMG could be evaluated for the relevant (right-sided) superficial neck muscles as no activity of these muscle is needed for playing the violin (this instrument is always clamped between the left shoulder and jaw while playing). There is limited, but promising, literature on biofeedback training in musicians.(70,71) Also in the general and working population biofeedback training has proven to be able to reduce complaints of the neck and shoulders.(72–75)

The size of a violin is standardised within millimetres; the chin rest and shoulder rest are used to adjust the violin to the individual player.(60,65,76) Especially the height of the shoulder rest varies greatly between violinists, thereby influencing playing kinematics and static loading of the muscles and joints of the upper extremity, neck and trunk.(59–61)

Professional violinists strive for an optimal positioning of the violin on the body; the shoulder rest is thereby carefully chosen and adapted by the individual player.(59,61) However, the subjective rating of the adjustment shoulder rest by the violinist and/or his or her teacher is a fair, but suboptimal approach.(61,77)

In the last chapter of this thesis we aimed to increase knowledge on optimal shoulder rest adjustment. Therefore, we evaluated the effect of shoulder rest height on muscle activity and violin fixation force. A higher violin fixation force was present in higher shoulder rest conditions, and an increase in activity of the mDTA was observed with increasing height of the shoulder rest. Therefore, from a biomechanical point of view, playing without a shoulder rest, or a shoulder rest with minimal height seems favourable.(65)

This biomechanical superiority of lower shoulder rest condition is guided by the highest rating of subjective playing comfort. Biomechanical research is valuable in studying musicians. However, as no musician will adapt his or her playing technique to a biomechanical superior, but subjective inferior situation. However, to our knowledge, there is no biomechanical literature who took this subjective rating into account when evaluating shoulder rests, despite the fact that is obviously highly relevant. Therefore, future biomechanical studies in instrumentalists should take a subjective evaluation of the musician into account.

FUTURE PERSPECTIVES & SUGGESTIONS FOR PRACTICAL IMPLEMENTATION OF THIS THESIS

Prevention is the best strategy for reducing musculoskeletal complaints in musicians. This thesis provides the necessary epidemiological and theoretical background, which can be used to develop and evaluate those preventive measures.(57) Ideally, preventive strategies should be pragmatically implemented by a close collaboration of the different stakeholders in the field of performing arts.

THE MUSICIAN

To reduce the individual burden of musculoskeletal complaints, musicians should take their responsibility to improve their own health. A basic theoretical knowledge of musculoskeletal anatomy and physiology is likely to improve healthy playing

behaviour.(78,79) Also, they should have knowledge on effective preventive measures. Thereby the musician should be able to adopt healthy playing habits. Especially music teachers play a crucial role in creating a healthy (future) working climate for their pupils. Professional musicians, especially teachers and those with a flourishing career should be aware of their function as a role model for the younger generation. They could for example contribute to diminish the taboo on playing-related complaints by discussing their experiences.

THE MUSIC ACADEMY

At each music academy efforts should be made to reduce health complaints among its students. Primary focus should be on prevention; therefore, health classes should be incorporated in the curriculum. Options could include health education, primarily focusing on prevention and increasing awareness and knowledge of effective preventive measures. Such a health educational program should start in the first semester of the first year, in order to have a maximum effect on preventive effect. The latter is important since especially first year students are prone to develop these musculoskeletal complaints, due to a sudden increase in musical playing load at the start of their professional career.

Health screening of students could have beneficial effects, as regular screening could reveal physical weaknesses, as well as students prone for developing complaints. Preventive measures can be taken aiming to reduce the chance of injury. Furthermore, regular health screening is likely to reduce the taboo on playing-related complaints among musicians, which also will contribute to a healthier working climate.

Next to this health-related course within the curriculum, individual music teachers, who are often an example for their students, should be educated and encouraged to promote healthy playing behaviour. For that matter, physical activity classes to improve specific muscle groups, thereby improving stamina are likely to prevent musculoskeletal complaints.(78–83). Also, general physical activities which improve overall physical fitness might be effective. Importance of the latter is stressed even more since in a survey among professional musicians, it was found that these players had a positive attitude towards reducing injury rates by physical exercise.(84) As not all preventive programs have proven to be effective (79–81,85,86), these new prevention programs should be evaluated before introduction.(87,88)

Each music academy would benefit by collaborating with dedicated healthcare professionals with knowledge of both the musculoskeletal system as well as instrument-specific playing kinematics. The main focus of these healthcare professionals at a music academy is to coordinate prevention programs. Optimally, also first-line treatment of a physiotherapist should be easily available within the institute. For more complex problems, referral to specialized healthcare professionals and multidisciplinary teams should be available for all students.

THE HEALTHCARE PROFESSIONAL

A great part of the added value of the dedicated healthcare professional for musicians is a mutual understanding both the working climate of the musician, as well as understanding the essence and necessity for a musician of being able to play the instrument.

Up till recently healthcare professionals with a special interest in performing artists had a pioneer role. Most knowledge on how to prevent and treat musculoskeletal complaints of individual musicians was based on expert opinion. Nowadays, aiming to improve the quality of care for musicians, we should improve the scientific substantiation. Dedicated health care providers should aim to objectively evaluate the effectiveness of their treatment, and this knowledge should be published and used to improve the treatment of musicians. In other words, I think in performing arts medicine we should not accept level three evidence but reach higher in the scientific pyramid.

Another responsibility of the dedicated healthcare professional should be to share knowledge. As only a small part of all musicians is nowadays treated by a healthcare professional with a special interest to this specific performing arts group, knowledge on this subject should become common knowledge for general practitioners, physiotherapists, orthopaedic surgeons and other healthcare professionals involved in the treatment of musicians. Teaching these groups about musicians' health is a very effective way of improving health for a large part of the population. The Dutch society for performing arts medicine (NVDMG) is for that matter a good platform to exchange such knowledge.

Finally, dedicated healthcare professional should be involved in educating the musicians and to motivate them to engage in prevention programs. As mentioned before, a health course at music academies should be mandatory to my opinion. In order to have

maximum effect of the course, a close collaboration between music teachers and healthcare professionals is essential.

THE HEALTHCARE INSTITUTE & AUTHORITIES

In the young field of performing arts medicine, important lessons can be learned from sports medicine. Dedicated sports physicians provide healthcare tailored to the sport-specific needs of the athlete. Also, they play an essential role in prevention programs.(89) In contrary to patients with sport-related injuries, most musicians are treated by regular physicians, without specific knowledge of the requirements of this high-demanding profession and specific needs. The latter might be a reason for medical shopping and unsatisfied medical needs of musicians.(49) A well-collaborating multidisciplinary team, which can cover the complete recovery process of the musculoskeletal system would be the most optimal care.

FINALLY

During the preparation of this thesis I noticed a rapid increase in scientific publications as well as a growing number of dedicated health care providers. Also, I noticed a growing awareness for musculoskeletal complaints at music academies. Some music academies in The Netherlands recently introduced a promising healthcare program.(90) However, despite these positive changes a big step forward still needs to be made by all stakeholders, including musicians and their teachers, to make a substantial difference for the better of the musicians.

This thesis contributes to such a change in the health landscape of the performing arts. Personally, both as a health professional but also as a musician I keep on focussing on improving the musicians' health, both in science as well as in clinical practice. In the end music will be able to enrich life.

REFERENCES

1. Towards a Common Language for Functioning, Disability and Health. 2002.
2. ICF website WHO [Internet]. [cited 2018 Feb 17]. Available from: http://www.who.int/icidh
3. Kok LM, Vlieland TPV, Fiocco M, Nelissen RG. A comparative study on the prevalence of musculoskeletal complaints among musicians and non-musicians. BMC Musculoskelet Disord. 2013;14.
4. Kok LM, Huisstede BM, Douglas TJ, Nelissen RG. Association of Arm Position and Playing Time with Prevalence of Complaints of the Arm, Neck, and/or Shoulder (CANS) in Amateur Musicians: A Cross-Sectional Pilot Study Among University Students. MPPA. 2017 Mar 1;32(1):8–12.
5. Kok LM, Nelissen RGHH, Huisstede BMA. Prevalence and Consequences of Arm, Neck, and/or Shoulder Complaints Among Music Academy Students. MPPA. 2015;30(3):163–8.
6. Kok L., Groenewegen KA, Huisstede BMA, Nelissen RGHH, Rietveld ABM, Haitjema S. The high prevalence of playing-related musculoskeletal complaonts and its associated factors in amateur musicians playing in student orchestras: a cross-sectional study.
7. Kok LM, Haitjema S, Groenewegen KA, Rietveld ABM. The influence of a sudden increase in playing time on playing-related musculoskeletal complaints in high-level amateur musicians in a longitudinalcohort study. PLoS One. 2016;11(9).
8. Kok LM, Huisstede BMA, Voorn VMA, Schoones JW, Nelissen RGHH. The occurrence of musculoskeletal complaints among professional musicians: a systematic review. Vol. 89, International Archives of Occupational and Environmental Health. 2016. p. 373–96.
9. Leaver R, Harris EC, Palmer KT. Musculoskeletal pain in elite professional musicians from British symphony orchestras. Occup Med. 2011 Dec;61(1471–8405 (Electronic)):549–55.
10. Roach KE, Martinez MA, Anderson N. Musculoskeletal pain in student instrumentalists: a comparison with the general student population. MPPA. 1994 Dec;9(4):125–30.
11. O'Neill L, Taunton J, MacIntyre DL. Making music: challenging the physical limits of the human body: a survey of musicians in western Canada. Physiother Canada. 2001 Apr;53(2):101.
12. Arnason K, Arnason A, Briem K. Playing-related musculoskeletal disorders among icelandic music students: differences between students playing classical vs rhythmic music. MPPA. 2014 Jun;29(2):74–9.
13. Zaza C, Charles C, Muszynski A. The meaning of playing-related musculoskeletal disorders to classical musicians. SocSciMed. 1998 Dec;47(0277–9536 (Print)):2013–23.
14. Kok LM, Huisstede BMA, Nelissen RGHH. Musculoskeletal complaints in male and female instrumental musicians. In: Legato M, editor. Principles of gender-specific medicine. 3rd ed. Academic Press; 2017.
15. Huisstede BM, Miedema HS, Verhagen AP, Koes BW, Verhaar JA. Multidisciplinary consensus on the terminology and classification of complaints of the arm, neck and/or shoulder. OccupEnvironMed. 2007 May;64(1470–7926 (Electronic)):313–9.
16. Sataloff RT, Brandfonbrener AG, Lederman RJ. Performing arts medicine. Vol. 3rd. Science & Medicine; 2013.
17. Eltayeb S, Staal JB, Kennes J, Lamberts PH, de Bie RA. Prevalence of complaints of arm, neck and

shoulder among computer office workers and psychometric evaluation of a risk factor questionnaire. BMCMusculoskeletDisord. 2007;8(1471–2474 (Electronic)):68.

18. Ranasinghe P, Perera YS, Lamabadusuriya DA, Kulatunga S, Jayawardana N, Rajapakse S, et al. Work-related complaints of arm, neck and shoulder among computer office workers in an Asian country: prevalence and validation of a risk-factor questionnaire. BMCMusculoskeletDisord. 2011;12(1471–2474 (Electronic)):68.

19. Volz L, Deekman A, Heimans H. Factsheet Amateurkunst. Utrecht; 2014.

20. Wiel, A. van de RABM. Medische problemen bij musici. Ned Tijdschr Geneeskd. 2010;154(A1143):1–5.

21. Newmark J, RJ L. Practice doesn't necessarily make perfect: incidence of overuse syndromes in amateur instrumentalists. MPPA. 1987;2(4):142–4.

22. Dawson WJ. Upper extremity difficulties in the dedicated amateur instrumentalist. MPPA. 2001;16(4):152–6.

23. Buckley T, Manchester R. Overuse injuries in non-classical recreational instrumentalists. MPPA. 2006;21(2):80–7.

24. Sadeghi S, Kazemi B, Shooshtari SM, Bidari A, Jafari P. A high prevalence of cumulative trauma disorders in Iranian instrumentalists. BMCMusculoskeletDisord. 2004 Oct 14;5(1471–2474 (Electronic)):35.

25. de Zwart BC, Frings-Dresen MH, Kilbom A. Gender differences in upper extremity musculoskeletal complaints in the working population. Int ArchOccupEnvironHealth. 2001 Jan;74(0340–0131 (Print)):21–30.

26. Nordander C, Ohlsson K, Åkesson I, Arvidsson I, Balogh I, Hansson G-Å, et al. Exposure–response relationships in work-related musculoskeletal disorders in elbows and hands – A synthesis of group-level data on exposure and response obtained using uniform methods of data collection. Appl Ergon. 2013 Mar;44(2):241–53.

27. Kuijer PPFM, Van der Molen HF, Frings-Dresen MHW. Evidence-based exposure criteria for workrelated musculoskeletal disorders as a tool to assess physical job demands. Work. 2012;41(Supplement 1):3795–7.

28. Voltmer E, Zander M, Fischer JE, Kudielka BM, Richter B, C. S. Physical and mental health of different types of orchestra musicians compared to other professions. MPPA. 2012;27(1):9–14.

29. Voltmer E, Schauer I, Schroder H, C. S. Musicians and Physicians - A comparison of psychosocial strain patterns and resources. MPPA. 2008;23(4):164–8.

30. Kivimaki M, Jokinen M. Job perceptions and well-being among symphony orchestra musicians: a comparison with other occupational groups. MPPA. 1994;9(3):73–6.

31. Paarup HM, Baelum J, Holm JW, Manniche C, Wedderkopp N. Prevalence and consequences of musculoskeletal symptoms in symphony orchestra musicians vary by gender: a cross-sectional study. BMCMusculoskeletDisord. 2011 Oct 7;12(1471–2474 (Electronic)):223.

32. Brugues AO. Music performance anxiety - part 1. a review of its epidemiology. MPPA. 2011;26(2):102–5.

33. Kenny D, Ackermann B. Performance-related musculoskeletal pain, depression and music performance anxiety in professional orchestral musicians: A population study. Psychol Music. 2015;43(1):43–60.

34. Hagglund KL, Jacobs K. Physical and mental practices of music students as they relate to the occurrence of music-related injuries. Work. 1996;6(Ireland LG-English PT-Journal: Short Survey EM-199600 DD-19960214):11–24.

35. Roquelaure Y, Ha C, Rouillon C, Fouquet N, Leclerc A, Descatha A, et al. Risk factors for upper-extremity musculoskeletal disorders in the working population. Arthritis Rheum. 2009 Oct 15;61(0004–3591 (Print)):1425–34.

36. Hooftman WE, van Poppel MN, van der Beek AJ, Bongers PM, van MW. Gender differences in the relations between work-related physical and psychosocial risk factors and musculoskeletal complaints. ScandJ Work EnvironHealth. 2004 Aug;30(0355–3140 (Print)):261–78.

37. Bongers PM, Ijmker S, van den Heuvel S, Blatter BM. Epidemiology of work related neck and upper limb problems: psychosocial and personal risk factors (part I) and effective interventions from a bio behavioural perspective (part II). JOccupRehabil. 2006 Sep;16(1053–0487 (Print)):279–302.

38. Feleus A, Bierma-Zeinstra SM, Miedema HS, Bernsen RM, Verhaar JA, Koes BW. Incidence of non-traumatic complaints of arm, neck and shoulder in general practice. ManTher. 2008 Oct;13(1532–2769 (Electronic)):426–33.

39. Rollman GB, Lautenbacher S. Sex differences in musculoskeletal pain. ClinJPain. 2001 Mar;17(0749–8047 (Print)):20–4.

40. Unruh AM. Gender variations in clinical pain experience. Pain. 1996 May;65(0304–3959 (Print)):123–67.

41. Wijnhoven HA, de Vet HC, Picavet HS. Explaining sex differences in chronic musculoskeletal pain in a general population. Pain. 2006 Sep;124(1872–6623 (Electronic)):158–66.

42. Engquist K, Orbaek P, Jakobsson K. Musculoskeletal pain and impact on performance in orchestra musicians and actors. MPPA. 2004;19(2):55–61.

43. Middlestadt SE, Fishbein M. Health and occupational correlates of perceived occupational stress in symphony orchestra musicians. J Occup Med. 1988 Sep;30(0096–1736 (Print)):687–92.

44. Steinmetz A, Scheffer I, Esmer E, Delank KS, Peroz I. Frequency, severity and predictors of playing-related musculoskeletal pain in professional orchestral musicians in Germany. Clin Rheumatol. 2015 May;34(5):965–73.

45. Lockwood AH. Medical problems of musicians. NEnglJMed. 1989 Jan 26;320(0028–4793 (Print)):221–7.

46. Baadjou V, Roussel N, Verbunt J. Systematic review: risk factors for musculoskeletal disorders in musicians. Occupational. 2016;

47. Kaneko Y, Lianza S, Dawson WJ. Pain as an incapacitating factor in symphony orchestra musicians in Sao Paulo, Brazil. MPPA. 2005;20(4):168–74.

48. Kaufman-Cohen Y, Ratzon NZ. Correlation between risk factors and musculoskeletal disorders among classical musicians. OccupMed(Lond). 2011 Mar;61(1471–8405 (Electronic)):90–5.

49. Kok LM, Nelissen RG, Huisstede BM. The striking prevalence and alarming consequences of Complaints of Arm, Neck and/or Shoulder among music academy students - a comparative study. MPPA. 2015 Jan 9;30(3):163–8.

50. Bragge P, Bialocerkowski A, McMeeken J. Understanding playing-related musculoskeletal disorders in elite pianists: A grounded theory study. MPPA. 2006;21(2):71–9.

51. Kok LM, Vlieland TPMV, Fiocco M, Kaptein AA, Nelissen RGHH. Musicians' illness perceptions of musculoskeletal complaints. Clin Rheumatol. 2013;32(4).

52. Petrie KJ, Cameron LD, Ellis CJ, Buick D, Weinman J. Changing illness perceptions after myocardial infarction: an early intervention randomized controlled trial. PsychosomMed. 2002 Jul;64(0033–3174 (Print)):580–6.

53. Hoving JL, van der Meer M, Volkova AY, Frings-Dresen MH. - Illness perceptions and work participation: a systematic review. - Int Arch Occup Env Heal Aug;83(6)595-605Epub 2010 Feb 4. (1432-1246 (Electronic)).

54. Goodman D, Morrissey S, Graham D, Bossingham D. - Illness representations of systemic lupus erythematosus. - Qual Heal Res2005 May;15(5)606-19. (1049-7323 (Print)).

55. Ronnberg K, Lind B, Zoega B, Halldin K, Gellerstedt M, Brisby H. - Patients' satisfaction with provided care/information and expectations on clinical outcome after lumbar disc herniation surgery. - Spine (Phila Pa 1976)2007 Jan 15;32(2)256-61. (1528-1159 (Electronic)).

56. Nilsdotter AK, Toksvig-Larsen S, Roos EM. - Knee arthroplasty: are patients' expectations fulfilled? A prospective study of pain and function in 102 patients with 5-year follow-up. - Acta Orthop2009 Feb;80(1)55-61. (1745-3682 (Electronic)).

57. van Mechelen W, Hlobil H, Kemper HCG. Incidence, Severity, Aetiology and Prevention of Sports Injuries. Sport Med. 1992 Aug;14(2):82–99.

58. Kelleher LK, Campbell KR, Dickey JP. Biomechanical research on bowed string musicians: a scoping study. MPPA. 2013 Dec;28(0885–1158 (Print)):212–8.

59. Levy CE, Lee WA, Brandfonbrener AG, Press J, Levy AE. Electromyographic Analysis of Muscular-Activity in the Upper Extremity Generated by Supporting A Violin with and Without A Shoulder Rest. MPPA. 1992;7(4):103–9.

60. Okner M, Kernozek T. Chinrest pressure in violin playing: type of music, chin rest, and shoulder pad as possible mediators. ClinBiomech(Bristol, Avon). 1997 Apr;12(1879–1271 (Electronic)):S12–3.

61. Rabufetti M, Converti RM, Boccardi S, Ferrarin M. Tuning of the violin-performer interface. MPPA. 2007 Jan 6;22(2):58–66.

62. Obata S, Kinoshita H. Chin force in violin playing. EurJ ApplPhysiol. 2012 Jun;112(1439–6327 (Electronic)):2085–95.

63. Berque P, Gray H. The influence of neck-shoulder pain on trapezius muscle activity among professional violin and viola players: An electromyographic study. MPPA. 2002;17(2):68–75.

64. Philipson L, Sorbye R, Larsson P, Kaladjev S. Muscular Load Levels in Performing Musicians As Monitored by Quantitative Electromyography. MPPA. 1990;5(2):79–82.

65. Kok LM, Schrijvers J, Harlaar J. A biomechanical study evaluating shoulder rest use in professional violinists. 2017.

66. Kok LM, Schrijvers J, Fiocco M, Royen B van, Harlaar J. Differences in violin fixation force and muscle activity among violinists with and without complaints in the neck shoulder region. 2017.

67. Lindstrøm R, Schomacher J, Farina D, Rechter L, Falla D. Association between neck muscle coactivation, pain, and strength in women with neck pain. Man Ther. 2011 Feb;16(1):80–6.

68. Boudreau SA, Falla D. Chronic neck pain alters muscle activation patterns to sudden movements. Exp brain Res. 2014 Jun 15;232(6):2011–20.

69. Falla D, Rainoldi A, Merletti R, Jull G. Spatio-temporal evaluation of neck muscle activation during postural perturbations in healthy subjects. J Electromyogr. 2004;

70. Reynolds C, Morasky R. Intensity Without Tension + Pilot Program for Resolving Unnecessary Muscular Tension of Music Performers - Biofeedback. Music Educ J. 1981;67(9):52–5.

71. LeVine W, Irvine J. In vivo EMG biofeedback in violin and viola pedagogy. Appl Psychophysiol Biofeedback. 1984;

72. Ma C, Szeto GP, Yan T, Wu S, Lin C, Li L. Comparing Biofeedback With Active Exercise and Passive Treatment for the Management of Work-Related Neck and Shoulder Pain: A Randomized Controlled Trial. Arch Phys Med Rehabil. 2011 Jun;92(6):849–58.

73. Huang H-Y, Lin J-J, Guo YL, Wang WT-J, Chen Y-J. EMG biofeedback effectiveness to alter muscle activity pattern and scapular kinematics in subjects with and without shoulder impingement. J Electromyogr Kinesiol. 2013 Feb 1;23(1):267–74.

74. Madeleine P, Vedsted P, Blangsted AK, Sj∅gaard G, S∅gaard K. Effects of electromyographic and mechanomyographic biofeedback on upper trapezius muscle activity during standardized computer work. Ergonomics. 2006 Aug;49(10):921–33.

75. Holtermann A, Søgaard K, Christensen H, Dahl B, Blangsted AK. The influence of biofeedback training on trapezius activity and rest during occupational computer work: a randomized controlled trial. Eur J Appl Physiol. 2008 Dec 14;104(6):983–9.

76. Menuhin Y. Violin : six lessons with Yehudi Menuhin. 2nd ed. Faber Music; 1974. 144 p.

77. Ackermann B, Adams R. Physical characteristics and pain patterns of skilled violinists. MPPA. 2003;18(2):65–71.

78. Zander MF, Voltmer E, Spahn C. Health promotion and prevention in higher music education: results of a longitudinal study. MPPA. 2010 Jun;25(0885–1158 (Print)):54–65.

79. Spahn C, Hildebrandt H, Seidenglanz K. Effectiveness of a prophylactic course to prevent playing-related health problems of music students. MPPA. 2001;16:24–31.

80. T.M. L, Farias MJ. Strategies to promote health and prevent musculoskeletal injuries in students from the high conservatory of music of Salamanca, Spain. MPPA. 2013 Jun;28(2):100–6.

81. Ackermann B, Adams R, E. M. Strength or endurance training for undergraduate music majors at a university? MPPA. 2002;17(1):33–41.

82. Brown J, Sherrill C, Gench B. Effects of An Integrated Physical Education-Music Program in Changing Early-Childhood Perceptual-Motor Performance. Percept Mot Skills. 1981;53(1):151–4.

83. Chan C, Driscoll T, Ackermann BJ. Effect of a musicians' exercise intervention on performance-related musculoskeletal disorders. MPPA. 2014 Dec;29(0885–1158 (Print)):181–8.

84. Yeung E, Chang W, Pan F, Sau P, Tsui M, Yu B, et al. A survey of playing-related musculoskeletal problems among professional orchestral musicians in Hong Kong. MPPA. 1999;14(1):43–7.

85. Chan C, Driscoll T, Ackermann B. Development of a specific exercise programme for professional orchestral musicians. InjPrev. 2012 Dec 4;19(1475–5785 (Electronic)):257–63.

86. Baadjou V, Verbunt J. The musician as (in) active athlete?: Exploring the association between physical activity and musculoskeletal complaints in music students. MPPA. 2015;

87. Baadjou V, Verbunt J. PREvention STudy On preventing or reducing disability from musculoskeletal complaints in music school students (PRESTO): protocol of a randomised

controlled trial. J. 2014;

88. Hiller C. Commentary to: PREvention STudy On preventing or reducing disability from musculoskeletal complaints in music school students (PRESTO): protocol of a. J Physiother. 2014;

89. Baarveld F, Backx FJG, Voorn TB. Sportgeneeskunde. 1st ed. Bohn Stafleu van Loghum; 2009.

90. Codarts Performing Arts Medicine - Codarts [Internet]. [cited 2017 Jul 10]. Available from: http://www.codarts.nl/codarts-performing-arts-medicine/

Addenda

NEDERLANDSE SAMENVATTING

DEEL 1: EPIDEMIOLOGIE

De verzameling van gewrichten, spieren, pezen en banden in het menselijk lichaam wordt het steun- en bewegingsapparaat genoemd. In de algemene bevolking komen klachten van het steun- en bewegingsapparaat, ook wel spier- en gewrichtsklachten genoemd, veel voor. Deze klachten zijn een belangrijke oorzaak voor langdurige pijn en beperkingen. Of klachten als problematisch worden ervaren hangt onder andere af van de eisen die het individu aan zijn functioneren stelt. De functionele eisen van een musicus zijn bijzonder hoog; het bespelen van een instrument vraagt optimaal functioneren van het steun- en bewegingsapparaat. Bovendien vraagt het bespelen van een instrument, zeker op professioneel niveau, veel van een musicus en betekent dit dat de kans op het ontwikkelen van spier- en gewrichtsklachten groot is. Kortom, bij musici is er sprake van een uitdagende combinatie van hoge functionele eisen en tegelijkertijd een hoog risico op spier- en gewrichtsklachten.

Het primaire doel van dit proefschrift is om spier- en gewrichtsklachten bij musici te beschrijven: Welke klachten zijn dit, hoe zien deze klachten eruit en hoe vaak komen ze voor? We hebben dit onderzocht in diverse groepen musici, zowel professionele als amateurmusici.

In **Hoofdstuk 2** van dit proefschrift worden spier- en gewrichtsklachten bij conservatoriumstudenten onderzocht, en vergeleken met de aanwezigheid van deze klachten bij studenten in een controle groep. In het jaar voorafgaand aan het onderzoek had 89% van de conservatoriumstudenten spier- en gewrichtsklachten, vergeleken met 78% van de studenten in de controlegroep. Op het moment dat de vragenlijst werd ingevuld had 63% van de conservatorium studenten klachten, bij de controlegroep was dit 43%. We concludeerden hieruit dat het bespelen van een instrument op professioneel niveau een substantiële risicofactor is voor het ontwikkelen van spier- en gewrichtsklachten.

In **Hoofdstuk 3** worden de resultaten beschreven van een systematisch literatuuronderzoek dat we hebben uitgevoerd naar de aanwezigheid van spier- en gewrichtsklachten bij professionele musici. We hebben ons hierbij beperkt tot wetenschappelijke studies waarin de aanwezigheid van klachten van het steun- en

bewegingsapparaat in volwassen, professionele, instrumentele musici wordt beschreven. Uit deze studies kwam naar voren dat 9% tot 68% van de musici klachten hadden ten tijde van dat het betreffende onderzoek; in het jaar voorafgaand aan het betreffende onderzoek gaf 41% tot 93% van de musici aan dergelijke klachten te hebben ervaren. De relatief grote spreiding die wij in de verschillende studies vonden is toe te schrijven aan heterogeniteit in studie opzet en definities van de klachten.

In de hierop volgende hoofdstukken beschrijven we de resultaten van studies naar klachten van het steun- en bewegingsapparaat bij amateurmusici. Hoewel er in Nederland ongeveer 3 miljoen amateurmusici zijn, tegenover circa twintig duizend professionele musici, was er slechts beperkte over de invloed van musiceren op de gezondheid van het steun- en bewegingsapparaat. De in **Hoofdstuk 4** beschreven studie is dan ook het eerste grote wetenschappelijke onderzoek dat is uitgevoerd om de aanwezigheid van klachten van het steun- en bewegingsapparaat bij amateurmusici te bestuderen. In het jaar voorafgaand aan het onderzoek rapporteerden 68% van de amateurmusici klachten van het steun- en bewegingsapparaat. Vrouw zijn en het bespelen van een strijkinstrument bleken de belangrijkste factoren die geassocieerd zijn met het krijgen van klachten. Het grote aantal klachten van het steun- en bewegingsapparaat in deze groep benadrukt het potentieel nadelige effect van musiceren op de musculoskeletale gezondheid, zelfs wanneer dit op amateurniveau plaatsvindt.

In **Hoofdstuk 5** worden de resultaten gepresenteerd van een pilotstudie onder amateurmusici waarin we twee potentiele risicofactoren voor het ontwikkelen van spier- en gewrichtsklachten onderzoeken: het spelen met de arm in een (≥40 graden voorwaarts en / of zijwaarts) geheven positie en de speelduur. Musici die met een linker geheven arm speelden hadden meer klachten van de linkerschouder dan musici die in een neutrale linkerarm positie speelden. In dit onderzoek vonden we geen verbanden tussen spier- en gewrichtsklachten en speelduur.

Hoofdstuk 6 beschrijft de resultaten van een cohortstudie, waarbij we leden van de twee nationale studentorkesten vervolgden tijdens een intensieve repetitieperiode van een week. Het doel van deze studie was om het effect van een plotselinge toename van speelduur op spier- en gewrichtsklachten te analyseren bij deze, op hoog-niveau spelende, amateurmusici. Bij de start van het onderzoek rapporteerde 28% van de musici

klachten, na een week was dit percentage gestegen tot 80%. Een plotselinge toename van speelduur kan derhalve bij amateurmusici als een sterke risicofactor gezien worden voor het ontwikkelen van spier- en gewrichtsklachten.

In de bovenstaande onderzoeken rapporteerden vrouwelijke musici meer klachten van het steun- en bewegingsapparaat dan hun mannelijke collegae. In **Hoofdstuk 7** wordt dit sekse verschil verder uitgewerkt. Dit hoofdstuk is gepubliceerd in de derde druk van het handboek '*Principles of gender specific medicine*'.

DEEL 2: IMPACT & ZIEKTEPERCEPTIE

Uit deel een van dit proefschrift blijkt dat veel musici spier- en gewrichtsklachten ervaren. Wat is nou de impact van deze spier- en gewrichtsklachten op musici? En hoe ervaren musici deze klachten? In het tweede deel van dit proefschrift worden deze vragen beantwoord.

In **Hoofdstuk 8** worden de gevolgen van spier- en gewrichtsklachten op professionele musici onderzocht. Wanneer we deze klachten bij musici vergelijken met een controlegroep, blijkt dat ze meer impact hadden op het dagelijks functioneren bij musici. Daarnaast kwam in dit onderzoek naar voren dat musici met spier- en gewrichtsklachten meer gebruik maken van medische zorg. Tevens werd er een groter aantal verschillende zorgverleners bezocht.

In **Hoofdstuk 9** onderzoeken we de ziekteperceptie van professionele musici met spier- en gewrichtsklachten. Musici met spier- en gewrichtsklachten rapporteren negatievere percepties op de meeste domeinen van de gebruikte ziekteperceptie vragenlijst dan hun controlegroep met spier- en gewrichtsklachten. Ze ervaren een significant grotere impact op hun persoonlijke leven, en zijn bezorgder en meer geëmotioneerd door hun klachten. Op basis van eerder uitgevoerd onderzoek lijkt het waarschijnlijk dat het bespreken van deze negatieve percepties gezondheidswinst geeft. Anderzijds, wanneer er tijdens de behandeling van een musicus geen aandacht is voor de perceptie van zijn of haar klachten, is het waarschijnlijk dat de resultaten hiervan suboptimaal zijn vergeleken met een bio-psychosociale benadering.

DEEL 3: BIOMECHANISCHE ANALYSE VAN VIOLISTEN

Uit het eerste deel van dit proefschrift bleek dat de meerderheid van de violisten kampt met nek- en schouderklachten. In het laatste deel van dit proefschrift hebben we ons

derhalve, in een experimentele setting, gericht op professionele violisten, met als doel inzicht te krijgen in biomechanische factoren die van invloed zijn op deze nek- en schouderklachten.

In **Hoofdstuk 10** van dit proefschrift werden violisten met nek- en schouderklachten vergeleken met violisten zonder deze klachten. De violisten met klachten toonden meer spieractiviteit van de oppervlakkige nek- en schouderspieren dan violisten zonder klachten. Ondanks deze toegenomen spieractiviteit was de kracht waarmee de viool tussen de schouder en kaak werd geklemd vrijwel gelijk bij beide groepen. Daarom concludeerden we op basis van deze studie dat er bij violisten met nek- en schouderklachten sprake is van onnodige spierspanning in de nek- en schouderregio. Gelijktijdig aanspannen van de onderzochte spieren, zogenaamde co-contractie, speelt een belangrijke rol bij violisten met klachten, daarom zouden deze klachten mogelijk kunnen worden toegeschreven aan een coördinatieprobleem.

In **Hoofdstuk 11** onderzoeken we de biomechanische aspecten van het gebruik van een schoudersteun door professionele violisten. Bij spelen zonder, of met een zo laag mogelijke schoudersteun blijken violisten de minste spieractiviteit te hebben. Ook is dan de kracht waarmee de viool wordt vastgeklemd hierbij het laagst. De conclusie op basis van dit onderzoek was dan ook dat spelen zonder, of met een lage afstelling van de schoudersteun, vanuit biomechanisch oogpunt de voorkeur heeft.

CONCLUSIE

Musici hebben meer spier- en gewrichtsklachten vergeleken met niet-musici; dit geldt zowel voor professionele als amateur musici. Vrouwelijke musici hebben vaker spier- en gewrichtsklachten vergeleken met mannelijke musici. De impact van deze klachten op musici is groot, en beïnvloedt het dagelijks functioneren in grote mate. De hoge belasting van het bewegingsapparaat enerzijds en hoge functionele eisen van de musicus anderzijds spelen een belangrijke rol bij het ontwikkelen, onderhouden en ervaren van de klachten. Biomechanisch onderzoek kan een rol spelen bij het reduceren van de musculoskeletale belasting, en daarmee bij de preventie van klachten

LIST OF PUBLICATIONS

PUBLICATIONS CONTRIBUTING TO THIS THESIS

Kok, L.M.; Groenewegen, K.A.; Huisstede, B.M.A.; Nelissen, R.G.H.H.; Rietveld, A.B.M.; Haitjema, S.; The high prevalence of playing-related musculoskeletal disorders (PRMDs) and its associated factors in amateur musicians playing in student orchestras: A cross-sectional study. PLoS One. 2018 Feb 14;13(2)

Kok, L.M.; Huisstede, B.M.A.; Nelissen R.G.H.H.; Musculoskeletal complaints in male and female instrumental musicians. In: Legato M, editor. Principles of gender-specific medicine. 3rd ed. Academic Press; 2017

Kok, L.M.; Huisstede, B.M.A.; Douglas, T.J.; Nelissen, R.G.H.H. ;Association of Arm Position and Playing Time with Prevalence of Complaints of the Arm, Neck, and/or Shoulder (CANS) in Amateur Musicians: A Cross-Sectional Pilot Study Among University Students. MPPA. 2017 Mar 1;32(1):8–12

Kok, L.M.; Haitjema, S.; Groenewegen, K.A.; Rietveld, A.B.M.; The influence of a sudden increase in playing time on playing-related musculoskeletal complaints in high-level amateur musicians in a longitudinalcohort study. PLoS One. 2016;11(9)

Kok, L.M.; Huisstede, B.M.A.; Voorn, V.M.; Schoones, J.W.; Nelissen R.G.H.H.; The occurrence of musculoskeletal complaints among professional musicians: a systematic review. Int Arch Occup Environ Health. 2016 Apr;89(3):373-96

Kok, L.M.; Nelissen, R.G.H.H.; Huisstede, B.M.A.; Prevalence and Consequences of Arm, Neck, and/or Shoulder Complaints Among Music Academy Students: A Comparative Study. MPPA. 2015 Sep;30(3):163-8

Kok, L.M.; Vliet Vlieland, T.P.M.; Fiocco, M.; Kaptein, A.A.; Nelissen, R.G.H.H.; Musicians' illness perceptions of musculoskeletal complaints, Clin Rheumatology, 2013 Apr;32(4):487-92

Kok, L.M.; Vliet Vlieland, T.P.M.; Fiocco, M.; Nelissen, R.G.H.H.; A comparative study on the prevalence of musculoskeletal complaints among musicians and non-musicians. BMC Musculoskelet Disord. 2013 Jan 4;14:9

OTHER PUBLICATIONS

Kok L.M.; Hove, van R.; Noort, van A.; Luxatio erecta. Nederlands Tijdschrift voor Traumachirurgie, 2016 Apr,24(2), 11-12

Kok, L.M.; Bénard, M.R.; Arkel, van E.R.; Bilaterale achillespeesruptuur bij gebruik van levofloxacine en gluclocorticoiden. Ned Tijdschr Geneeskd. 2012;156(13)

Kok, L.M.; Steenhoven, van der T.J.; Nelissen R.G.H.H.; A retrospective analysis of bilateral fractures over sixteen years: localisation and variation in treatment of second hip fractures. Int Orthop 2011 Oct;35(10):1545-51

DANKWOORD

Een proefschrift schrijf je niet alleen. Mijn dank gaat dan ook uit naar iedereen die heeft bijgedragen aan de totstandkoming hiervan. Een paar mensen wil ik graag in het bijzonder bedanken.

Prof. dr. R.G.H.H. Nelissen, beste Rob, vanaf het moment dat ik bij je aanklopte met de vraag of je mijn afstudeerscriptie op het conservatorium wilde begeleiden, ben je betrokken geweest bij de diverse onderzoeken. Wat fijn dat ik de mogelijkheid kreeg mijn eigen onderzoekslijn uit te zetten. Je aanstekelijke enthousiasme en nieuwsgierigheid maakten dat ik na een overleg met meer vragen naar huis ging dan dat ik kwam.

Prof. dr. ir. J. Harlaar, beste Jaap, de vioolstudie heeft onder jouw supervisie plaatsgevonden. Je analytische, verfrissende en enthousiaste kijk op dit project waren stimulerend. Het was het mogelijk ons experimentele idee hebben uit te werken tot een mooi onderzoeksproject, waar ik met veel plezier aan heb gewerkt en veel van heb geleerd.

Dr. B.M.A. Huisstede, beste Bionka, bedankt voor je begeleiding bij het schrijven van dit proefschrift. Je hebt me uitgedaagd en gestimuleerd mijn wetenschappelijke vaardigheden naar een hoger niveau te tillen.

Leden van de leescommissie, prof. dr. B.J. van Royen, prof. dr. S.K. Bulstra, prof. dr. A.A. Kaptein, prof. dr. G. Kloppenburg, dr. J. Stubbe, dank voor de tijd en energie die jullie hebben gestoken in het lezen en beoordelen van mijn proefschrift. Ik ben benieuwd naar jullie vragen bij de verdediging.

Veel dank gaat uit naar de co-auteurs van de verschillende artikelen. Prof. dr. B.J. van Royen, beste Barend, dank voor je bijdrage aan de vioolstudie en de geopende deuren. Dr. Rietveld, dr. B., ik bewonder de gedrevenheid waarmee je als gepassioneerd pionier de dans- en muziekgeneeskunde op de kaart hebt gezet. Prof. dr. A.A. Kaptein, kunst en wetenschap gaan bij u hand in hand. Saskia en Karlijn, als indertijd drie enthousiaste PhD studenten hebben we een lacune in de wetenschappelijke literatuur gevonden en opgevuld, wat een mooi en geslaagd project, dank. Jim, wat een fijne samenwerking bij de vioolstudie, dank voor jouw nuchtere en kritische visie op het onderzoek. Tenslotte ook Thea, Marta, Veronique, Jan, en Taco bedankt voor de samenwerking.

Mijn opleiders in de ROGO-NW, Arthur en Bart, wil ik hier ook heel graag bedanken. Jullie hebben me gestimuleerd en ruimte geboden om me binnen de opleiding optimaal te ontwikkelen, zowel op orthopedisch als op persoonlijk vlak.

Zonder proefpersonen geen onderzoek, dank aan zowel de deelnemende proefpersonen alsmede de betrokken orkesten en conservatoria. In het bijzonder wil ik de violisten die mee hebben gedaan aan de vioolstudie bedanken.

Lieve Wen, met het afronden van onze proefschriften hebben zijn we weer een nieuwe gedeelde ervaring rijker. Mooi dat we dit afsluiten als wederzijdse paranimfen. Ellende bleek niet afkoopbaar, en gratis niet altijd beter, het wordt tijd voor een nieuwe lijfspreuk.

Ier, zusje, celliste in hart en nieren, wat bewonder ik je muzikaliteit. Bedankt voor je bijdrage aan de plechtigheid, zowel als paranimf als op muzikaal gebied. Ro, broertje, wat ben ik trots op jou. Wat fijn om te weten dat we altijd voor elkaar klaar staan.

Lieve ouders, jullie hebben me alle kansen gegeven om me te ontwikkelen en gestimuleerd om van deze kansen gebruik te maken. Wat een rijkdom, jullie onvoorwaardelijke steun.

Hannah, klein meisje, grote liefde. Als je dit boekje later ergens vindt hoop ik dat je stiekem een beetje trots zal zijn.

Tot slot, lieve Thomas, je onvoorwaardelijke steun was bij het schrijven van dit proefschrift onmisbaar. Zonder jouw vertrouwen in mij, liefde, geduld en relativeringsvermogen, was ik niet gekomen waar ik nu ben en waren we niet gekomen waar we nu zijn.

CURRICULUM VITAE

Laura Madelinde Kok (1987) was born in Zwolle, The Netherlands. She graduated from the Gymnasium Celeanum in 2005, after which she studied medicine at the University of Leiden. Simultaneously with her medicine she studied viola at the Royal Conservatory in The Hague with Ron Ephrat. In 2011 she graduated Cum Laude from her medicine studies and obtained her Master degree at the Conservatory.

As a keen chamber music musician she played multiple concerts throughout Europe and Asia and took part in a variety of international music festivals. Besides, she played in various national and international professional orchestras, but enjoyed most playing in the European Union Youth Orchestra (EUYO), working with inspiring conductors as Sir Colin Davis, Herbert Blomstedt, Vladimir Ashkenazy, and Vasily Petrenko. Laura also enjoys experimenting with cross-over and non-classical music, ranging from music theatre to electronic dance music shows. Also she contributed to several live and studio recordings, as well as radio and television broadcasts.

It turned out that music was not her only passion; orthopaedic surgery stole her hart too. In 2013 she started with her general surgical training. She continued with her orthopaedic training in the Spaarne Gasthuis (Dr. A. van Noort), followed by the NoordWest Ziekenhuisgroep (Dr. B. Burger) and Leiden University Medical Center (prof. dr. P.D.S. Dijkstra), where she is currently working. Next to the regular orthopaedic training program, she increased her clinical expertise in the treatment of performing artists during a fellowship at the Medical Center of Dance and Music Medicine (Dr. A.B.M. Rietveld). Laura expects to complete her studies at the Spaarne Gasthuis in 2020.

Laura lives with her fiancé Thomas and daughter Hannah. In her free time she is a keen (trail)runner and combines her musical and technical skills by making new and repairing old violins. In the future, Laura aspires to work as an orthopaedic surgeon with special interest in shoulder surgery and performing arts medicine.