Playing-related Musculoskeletal Problems in Children Learning Instrumental Music:

The Association Between Problem Location and Gender, Age, and Music Exposure Factors

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Purpose: Playing-related musculoskeletal problems (PRMP) are common in adult musicians, and risk factors include gender, music exposure, and particularly instrument type. Emerging evidence suggests PRMP are common in children and adolescents and that risk factors may be similar. The aim of this study was to determine the prevalence of PRMP, both symptoms and disorders, and PRMP location in children and adolescents as well as the associations with gender, age, and music exposure factors such as type and number of instruments and playing time. **Methods:** This study surveyed 731 children (460 females), aged 7 to 17 years, studying instrumental music in government schools in Perth, Australia. Lifetime and monthly symptoms, monthly disorders (inability to play an instrument as usual), and PRMP location were examined. Chi-squared analyses were used to evaluate associations between gender, age, music exposure, and PRMP outcomes. Logistic regression evaluated the independent association of these potential risk factors with PRMP prevalence and location. **Results:** Sixty-seven percent of students reported PRMP symptoms at some point, 56% reported them within the last month, and 30% reported an inability to play as usual within the last month. After adjustment for gender and age, the type of instrument played (upper and lower strings, woodwind, and brass) was significantly associated with all PRMP ($p<0.005$) and playing three instruments was protective against monthly symptoms (OR 0.43, $p=0.05$). The right (24%) and left (23%) hand/elbow and neck (16%) were the most commonly reported PRMP locations, with females affected significantly more than males Prevalence of PRMP increased with age for neck ($p<0.001$), mid-back ($p=0.007$), low back ($p<0.001$), right hand/elbow ($p=0.008$), and mouth ($p=0.011$). PRMP prevalence for the left hand/elbow and right and left shoulders demonstrated high rates across all childhood ages. Odds ratios for the risk of PRMP in different locations varied by instrument played. **Conclusions:** The high prevalence and location of PRMP are important issues for child and adolescent instrumentalists. Gender, age, and music exposure are associated with PRMP risk and need to be addressed to ensure musicians' personal well-being and musical longevity. *Med Probl Perform Art* 2011; 26(3): 123–139.

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It is well established that playing-related problems, both physical and psychological, exist among adult instrumentalists. Playing-related musculoskeletal problems (PRMP), which include muscle, nerve, bone, and joint problems such as tendinitis, tenosynovitis, peripheral neuropathy, and focal dystonia have been the focus of epidemiological research in performing arts medicine. Given that the pathologies of PRMP parallel those of work-related musculoskeletal disorders, it is thought that the multifactorial risk factors reported in occupational medicine literature may likewise be important for the development of PRMP in musicians. Intrinsic factors (such as gender, age, hypermobility, performance anxiety), extrinsic exposure factors (such as type of instrument, practice habits, playing environment), and interactive factors (such as playing posture) have been investigated among adult musicians. The association of risk factors with PRMP in the adult literature varies, due to different outcome and case definitions, study design, and statistical power. However, factors such as female gender and type of instrument have been associated with PRMP.

Musicians, unlike other occupations, commence their careers at early ages, yet only a few studies have investigated the prevalence of PRMP and risk factors for PRMP in children or adolescent instrumentalists. These studies have reported prevalence rates in children similar to those in adults. However, the available prevalence evidence is limited, and the relevance of known risk factors for adults remains unclear for the child instrumentalist.

In pain literature, the experience of spinal pain in adolescence has been associated with an increased risk of spinal pain in adulthood.[1,2] It is therefore imperative to understand PRMP in childhood and establish specific risk factors for the development of PRMP in this group of musicians, in order to prevent problems in later years.

PRMP in adult musicians have been classified into 1) mild aches and pains, experienced during and following playing, that may or may not affect performance (playing-related musculoskeletal symptoms, PRMS), and 2) pain, weakness, lack of control, numbness, tingling, or other symptoms that interfere with the ability to play the instrument as usual (playing-related musculoskeletal disorders, PRMD).[3] Examining PRMS in children may enable earlier detection and prevent the deterioration of symptoms and function, and subsequent development of more disabling disorders.

LITERATURE REVIEW OF PRMP

Prevalence

Lifetime and monthly prevalence rates of 40 to 70% have been reported among professional musicians[3,4] and 9 to 90% among tertiary music students.[5,6] A detailed review of prevalence rates among different groups of musicians by Ranelli et al.[7] found similar rates, 20 to 70%, have been reported among children instrumentalists.[8–16] The varied rates may be attributed to differing case definitions, methods of data collection (e.g., questionnaire vs physical examination), and small sample sizes. There is a clear need for a large-sample study with clear case definitions to provide more definitive symptom and disorder prevalence rates for children.

Risk Factors

Gender

The majority of existing studies in children have reported a higher prevalence of PRMP for females than males.[8,10,12,13,15,17] These studies were limited by lack of statistical comparisons and/or poor PRMP definitions; thus, better-quality evidence regarding the importance of gender as a risk factor for child instrumentalists is required.

In adults, females are more likely to report PRMP compared to males[4,6,16,18-26] and two times more at risk of developing PRMD.[27] This trend is also documented in broader pain literature (in adults and children) and occupational health literature, reinforcing the importance of understanding this factor for child instrumentalists.

Age

There is no clear evidence for age as a risk factor for PRMP within childhood. Studies that have considered child age merely reported descriptives[8,14,16,19,28] or overall prevalence rates.[13,16] A cross-sectional survey of 97 students aged between 4 to 18 yrs and a retrospective review of 314 students aged 18 yrs and younger found no association between age and playing-related injuries.[10,29]

In adults, there is no consensus with respect to age as a risk factor for PRMP.[18,26,30] However, there is evidence that the prevalence of other musculoskeletal problems, such as spinal pain, increases rapidly over adolescence,[31–33] and adolescent symptoms have been linked to symptoms in adulthood.[1,34,35] Therefore it is important to identify any association between age and PRMP over childhood and adolescence.

Music Exposure

Music exposure can be categorized into amount (such as time spent playing) or nature of the task (such as type of instrument). These factors may be confounded by age and gender. For example, the child instrumentalist may practice for longer as they progress with their instrumental instruction (tuition) over the years.

Time Spent Playing: The time children spend playing musical instruments has varied greatly in prior reports, as some reported practice times only and others reported total playing time. Mean practice times ranged from 0.8 hrs/day in 49 students aged 13 to18 years[12] to 3.3 hrs/day in 169 students aged 7 to 19 yrs.[13] However, practice times may not capture total exposure, and thus others have reported total playing time. Mean total playing time reported ranged from 7.6 hrs/wk in 425 junior and senior high students (aged 12 to 18 yrs)[17] to 19 hrs/wk in 131 secondary school students (aged 12 to 18 yrs).[15] Only Fry et al.[12] reported a positive association between practice time and PRMP.

Adult studies also reported varied time spent playing. Zaza[3] surveyed daily playing times which included individual practice, rehearsing, and performing and further sought information on how many hours were played on a "busy" and "light" day and practice habits before differing situations (e.g., exams, audition). Professionals spent an average of 27.4 hrs/wk playing, while tertiary students spent 17.9 hrs/wk. A busy day for professionals meant up to 7.4 hrs of playing and for students, 4.8 hrs. A "light" day involved 3.1 hrs for professionals and 2.1 hrs for students. Students increased practice time before exams or auditions. There was a positive association for increased playing time and problems, though it was not significant.

Other studies reported time playing as an average per day, such as 2.8 hrs/day among 227 tertiary music students,[5] or average per week, such as 11.4 hrs/wk among 1,639 Spanish tertiary music students and professional musicians as a collective group.[16] The association between practice time and PRMPs was positive in some studies[36,37] but not others.[5,22,23,27] Musicians have identified the sudden increase in time spent practicing, usually prior to performances and exams for tertiary students, as a risk factor for the experience of increased symptoms.[6,25,28,37-39] Further evidence is therefore needed to clarify the association of time spent playing and PRMP in children.

Number of Instruments: No study has reported the relationship between the number of instruments played by a child and PRMP. Playing more than one instrument may mean an increase in the amount of time spent practicing, which may increase the risk of PRMPs. Conversely, playing a second or third instrument may add task variety (change in exposure pattern), which in the occupational health literature has been

associated with a decreased risk for the development of musculoskeletal disorders.[40–43] Understanding the association between the number of instruments played and PRMP in child instrumentalists is therefore likely to be important to help minimize PRMP in children.

Number of Years Playing Main Instrument: While Shoup[17] reported an average of 4.1 yrs was spent playing the primary instrument (5.1 yrs for high school and 3.4 yrs for junior school students), no studies in children were found that reported an association between the years spent playing the main instrument and PRMP. However, among adult musicians, the number of years a musician has played his or her main instrument has been positively associated with PRMP.[3,16,44] Years of instrument playing therefore may be an important risk factor for child instrumentalists, but this is currently unknown.

Instrument Type: It has been well documented that individual instruments or classes of instruments are associated with specific problems. Postures adopted, weight of the instrument, force required, and physiological demands associated with particular instruments are thought to be contributing factors for the risk for PRMP peculiar to an instrument. Brandfonbrener[45] highlighted strings and keyboard players were at increased risk for PRMP due to the greatest number of repetitive actions. In occupational medicine literature, force, repetition, and posture have been identified as the main ergonomic factors to increase the risk of work-related musculoskeletal disorders,[46–48] further supporting the likely importance of instrument type as a risk factor.

However, only one childhood study has reported an association between instrument type and PRMP. Lockwood[15] reported PRMPs in all evaluated instrument categories, with large strings (cello and bass) more associated with PRMPs than small strings (violin and viola). However, this study did not evaluate keyboard risk. Other small childhood studies[8,13,28] have reported prevalence rates by instrument group but have not provided evidence of an association between instrument type and PRMP. Fry and Rowley,[13] in a survey of 168 music students (aged 7 to 19 yrs), reported the most problems in string (76%), woodwind (75%), keyboard (71%), and brass (57%) players. Betuel and Clairet[8] reported a high prevalence of spinal pain among woodwind and plucked string (harp and guitar) players. Dawson[28] reported problems in 1 of 7 woodwind players.

In adults, a higher prevalence of PRMPs has been reported in string[20,21,27,49] and keyboard players.[16,39,50-54] Woodwind and brass players often have lower risk, with percussion players at the least risk of problems.[20,50,55,56] Among tertiary music students, string, keyboard, woodwind, and brass instrumentalists have been reported to have a high prevalence of problems.[5,6,57]

Thus, the evidence from the occupational literature and adult and tertiary student instrumentalist literature suggests the type of instrument may be an important risk factor for child instrumentalists, but this is currently unknown.

PRMP Locations

Number of PRMP Locations

No studies in children were found which documented the number of areas in which PRMP were experienced. One adult study reported 55% of musicians (80 of 145) with pain reported problems at three or more locations and found a significant correlation between pain intensity and number of reported pain sites.[26] Other studies merely reported prevalence for one or more musculoskeletal complaints.[19,44,58,59] No study was found which investigated the association between the number of pain areas and risk factors.

Locations Affected

Studies in child instrumentalists have reported some information on the location of PRMP. Betuel and Clairet[8] reported higher prevalence rates of spinal pain among adolescents (76%) than adults (70%) and children (51%). Neck pain was prevalent in wind, guitar, and harp players; thoracic pain among piano players; and lumbar pain in guitar and harp players. Shoup[17] found most problems occurred in the left wrist, hand and fingers, the right fingers, forearm and elbow, followed by the neck in 149 junior and senior high school students.

Fry and Rowley[13] investigated pain in the hands and arms related to playing (71%) in 168 music students compared to pain in the hands and arms related to hand use such as writing (50%) in 348 non-music students. Left (30.5%) upper limb pain, specifically wrist and fingers, was more prevalent than right upper arm pain (13.8%) in a small group (n=36) of 10–22 year old music students.[11] However, all of these studies were limited by their data analysis, which at best reported prevalence of PRMP location but no statistical comparisons or evidence of an association between potential risk factors (such as gender or instrument type) and PRMP location.

Numerous studies in adults, professionals, and tertiary students have investigated the location of PRMP, and there is overwhelming consensus that the upper extremities and neck are the most common problem areas.[3,4,6,16,19,20,24,27,60–65] Only a few studies investigated the association between PRMP in specific locations and risk factors. Nyman et al.,[65] in a cross-sectional survey of 235 professional musicians, found a higher prevalence of neck-shoulder pain in musicians playing in an elevated arm position (>40°) compared to those playing in a neutral arm position. Wahlstrom and Fjellman-Wiklund[66] found music teachers playing instruments that required asymmetric postures (bowed strings, flute, trombone, and guitar) reported a significantly greater number of neck, shoulder, and back problems compared to teachers playing instruments that required symmetric postures (clarinet, oboe, bassoon, trumpet, piano, percussion). Fjellman-Wiklund et al.[67] reported that the strongest risk factors associated with neck-shoulder discomfort in music teachers (after adjusting for age) were high psychological demand and teaching at more than four schools per week for females and playing the guitar,

manual handling (lifting instruments), and low social support for male teachers.

Locations Associations with Specific Instruments

Some adult studies have described areas of PRMP with respect to specific instruments or instrument class. The majority of studies corroborate findings with regard to the most commonly reported areas of pain for instrument type.

Piano players most commonly reported problems affecting both hands, the right more than the left, with the specific requirements of repertoire, posture of the wrist and hands, and technique among some of the factors thought to contribute to this pattern of involvement.[45,51,53,63,68–70]

For *upper string* players, the left hand/arm and shoulder were more commonly involved than the right hand/arm; in addition, the neck and mid-back may be affected.[45,55,63,71] Problems in the left upper extremity may be explained by the asymmetric and extreme postures adopted and the specific techniques necessary to produce particular sounds.[60,66] In *lower string* players, more right hand and right shoulder problems have been reported than the left hand and shoulder, potentially due to the handgrip of the bow and bowing technique.[5,27,45] Middlestadt and Fishbein[55] found the prevalence of right shoulder problems to be high across all upper and lower string instrumentalists and surmised the bowing action common to all instruments placed them equally at risk for right shoulder problems. In the occupational literature EMG studies found high static handgrip force with the arm in elevated positions increased the load on stabilizing rotator cuff muscles.[72] This supports the pattern of involvement in the bowing arm of stringed instruments.

The problems experienced by *plucked string instruments* center around the playing posture, repetitive finger movements, and forces required with various techniques. Fjellman-Wiklund and Chesky[59] reported a trend for left upper extremity involvement among various categories of *guitar*, the left fingers and left hand among acoustic guitarists, electric guitarists, and electric bass players, and left shoulder problems among banjo players. The very flexed wrists and fingers and the requisite force to pluck, pull, or depress strings—or if a pick is used, the grasp required between the thumb and index finger—have been associated with distal upper extremity problems. The weight of the guitar and whether the musician is seated or standing may contribute to neck and back pain.[59,60,63,73–75] For *harpists*, the degree of shoulder abduction, wrist hyperextension, and the force of pull of the fingers against the strings are thought to contribute to upper extremity and back problems.[60]

In *woodwind* players, problems are thought to be due to the position of support of the instrument. For example, the right hand, specifically the thumb, is the most common problem area for clarinet and oboe players and the left hand for flautists. Other problems in the hand/elbow are thought to be from repetitively closing open holes or due to the force required to depress keys for sound production.[45,60]

Brass instrumentalists have reported high prevalence rates for low back (20%), left and right wrist and fingers, left and right neck, and right shoulder problems. Low brass musicians most commonly reported problems in the low back and right wrist, and trombonists reported highest rates for the left shoulder, left hand and wrist.[58] Embouchure problems are most common in both brass and woodwind instrumentalists.[45] For the musician with hypermobile joints, more effort may be required to prevent the collapse of joints under pressure, and this subsequent increase in muscle tension may compound problems.[45]

The location of PRMPs related to specific instruments or instrument classes in child instrumentalists is important to inform prevention initiatives, yet is currently unknown.

AIMS OF CURRENT STUDY

The majority of studies of PRMP prevalence and risk factors have been conducted on adult musicians, with very limited evidence on children. To best inform prevention and management strategies, clear evidence is needed to identify if gender, age, and music exposure factors are associated with PRMP in children. Therefore, the aims of this study were to:

1. Establish the prevalence of PRMP (lifetime and monthly playing-related musculoskeletal symptoms [PRMS] and monthly playing-related musculoskeletal disorders [PRMD]) and determine its relationship with music exposure factors: type of instrument, number of instruments played, and playing time, adjusting for gender and age;
2. Establish the prevalence of PRMP in different locations and determine differences with gender, age, and instrument type; and
3. Examine the independent associations of gender, age, and music exposure (instrument type, number of instruments played, playing time, and years of playing) with PRMP in each body location.

METHODS

Sample

Seven hundred thirty-one students (460 females) aged between 7 and 17 years (mean 12.7 yrs, SD 2.0 yrs) participating in the School of Instrumental Music program across government schools in Perth, Western Australia, were surveyed from August to December 2003. The process of school selection ensured a representative sample from a range of socioeconomic areas, ages, and instruments. Secondary (senior high) schools were selected and invited to participate, and then their feeder primary (elementary and junior) schools with high instrumental numbers were selected. In total, five secondary schools and six primary schools participated. The process has been reported previously[7] (see Appendix). All instrumental classes at the selected schools were sampled.

The School of Instrumental Music is a program that provides free instrumental instruction (tuition) to students and has guidelines with respect to the age of commencement for instruments. For example, upper strings are begun from 7 years of age (violin at 7 and viola at 8 years of age), woodwind instruments from the age of 10 years, and plucked strings from the age of 11 years. Students, however, may have com-

menced playing such instruments at an earlier age through private study. This study was approved by the Curtin University Human Research Ethics Committee (HR234/2002).

Variables

Students completed a music-specific version of the Young Peoples Activity Questionnaire (YAQ).[76] The survey focused on the experience of PRMS ("any soreness anywhere") during their playing career and within the past month (once a month, once a week, two to three times a week or daily) and the experience of a PRMD ("instrument playing-related soreness, tingling or weakness which stopped you playing your instrument as well as you usually play?") within the past month.

Children reported the location of their symptoms on a body diagram (neck, mid-back, low back, left and right upper and lower limbs, face) and rated the severity of symptoms for each location (on a visual analog scale, 0 = no soreness to 10 = extreme soreness). The number of pain locations was tallied.

Other music-specific questions covered music experience, such as the type of instrument played as main, second, and third; number of instruments played (one, two, or three), years spent playing any and main instruments, and practice habits, such as time spent playing (student playing diaries recorded type of playing, practice, rehearsals, recitals, and for how long [hours per week]) and taking breaks (never, almost never, sometimes, most times, always). The remaining general questions covered children's age, gender, year at school, hand dominance and general musculoskeletal complaints, general activity habits such as watching television, participation in physical activities, use of computers, and hand-intensive activities such as art and hand writing.

For the purpose of this paper, the covariates of age, gender, instrument type, number of instruments played, time spent playing, time spent playing main instrument, and number of PRMP locations were modeled to assess their independent prediction of PRMP location (Table 1).

Procedures

Children completed the questionnaire in class under the supervision of their instrumental teacher. For very young students, parents were able to assist in class with the completion of the questionnaire. Questionnaires took approximately 20 minutes to complete. The first author was present to answer queries and performed height and weight measurements (using a wall-based tape measure and digital scale, respectively).

Data Analysis

Descriptive statistics are presented for prevalence rates of PRMPs, with prevalence rates calculated as a percentage of the whole sample. Median values and interquartile range (IQR) are presented for non-normally distributed outcomes.

TABLE 1. Covariates Examined for PRMP Risk

Covariate	
Age (yrs) (mean, SD)	12.7 (2.0)
Gender, female	460 (63%)
Instrument type	
Main, second or third	(See Table 2)
No. of instruments	
1	403 (55%)
2	280 (38%)
3	48 (7%)
No. of pain locations	
1	184 (25%)
2	110 (15%)
3 or more	114 (16%)
Time spent playing (hrs/wk) (median, IQR)	5.3 (4.8)
Time spent playing instrument (yrs)	
Any (mean, SD)	4.7 (2.8)
Main (mean, SD)	3.6 (2.5)

IQR, interquartile range.

Chi-squared analysis was used to examine relationships between categorical covariates and PRMP.

Univariate logistic regression analyses were performed to estimate the unadjusted association of each independent variable for PRMP outcome. Age was parameterized as categorical rather than continuous when exploratory plots indicated a nonlinear relationship with outcome. Instruments were grouped into categories when evaluating the association between instrument class (upper, lower, and plucked strings, woodwind, brass, percussion, and piano) and PRMP location A series of multivariate, backward stepwise logistic regression analyses (entry level significance set to 0.05 and removal 0.06) (one for each PRMP location) were performed to estimate the association of each variable independent of other covariates. Analyses were performed using SPSS software, version 17 (SPSS Inc., Chicago, IL).

RESULTS

Prevalence

Sixty-seven percent of children (n = 489) reported a lifetime prevalence of PRMS, 56% (412) reported the experience of symptoms within the past month, and 30% (219) reported a PRMD (i.e., they were unable to play their instruments as usual).

Gender and Age

After adjusting for age, females remained more likely to report problems than males (odds ratio [OR] = 1.6–1.7, p = 0.004–0.014). When adjusting for gender, increased age remained significantly associated with PRMP (OR = 1.2, p = 0.003) (see Table 5). There was no significant interaction effect between gender and age for PRMP (p = 0.138, p = 0.189).

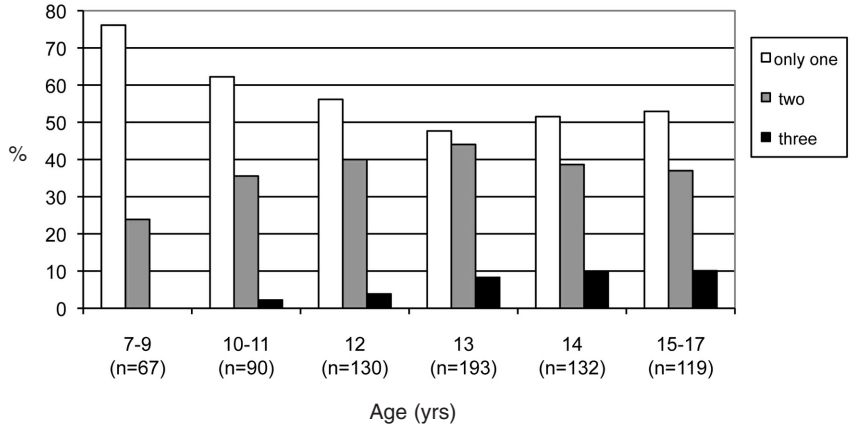

FIGURE 1. Percentage of children playing only one (*n* = 403), two (*n* = 280), or three (*n* = 48) instruments across age groups.

Music Exposure

Time Spent Playing

Children spent a mean of 5.3 hrs (IQR 4.8 hrs, range 17 min to 41 hrs) playing per week, with no difference between females and males. Playing time per week increased with age (Kruskal-Wallis χ^2 = 137.77, *df* (10), p <0.001). An increase in playing time of an hour was associated with a 5 to 7% increase in the odds for lifetime PRMS (p = 0.014) and monthly PRMS (p = 0.001) (see Table 4). The association between playing time remained significant for monthly PRMS only after adjusting for other covariates (such as gender and age) (see Table 4).

Number of Instruments Played

Fifty-five percent of children (403) played one instrument only, 38% (280) played two instruments, and 7% (48) played three instruments. There was no significant difference between genders in the number of instruments played (Fisher's exact test = 0.78, p = 0.97). The number of instruments played increased with age (F = 9.51, *df* (2), p <0.001) (Fig. 1). Playing three instruments in comparison to only one instrument *decreased* the odds for lifetime PRMS (p = 0.023) and monthly PRMS (p = 0.019) after adjusting for other covariates (see Table 5).

Instrument Type

The most commonly played instruments were piano (42%), violin (19%), clarinet (16%), guitar (15%), and flute (12%) (Table 2). The piano, violin and clarinet were most frequently played as the main instrument, with piano most commonly played as a second (and third) instrument.

There was a significant association between gender and type of instrument played for main instrument group (χ^2 = 63.01, *df* (6), p <0.001), with more females playing upper strings (21.3% vs 11.1%) and woodwinds (33.9% vs 19.2%) than males, and more males playing brass (24.7% vs 8.3%) than females (Fig. 2). The School of Instrumental Music has guidelines with respect to age of commencement of certain instruments, and thus there was an association between age and instrument type (*F* = 19.30, *df* (6), p <0.001). For example, younger children played upper strings and older children tended to play woodwind, brass, and plucked string instruments. The piano was played equally across age groups (Fig. 3).

Instrument Type and Prevalence of PRMP

Prevalences of PRMPs for instrument type and category are presented in Table 3. The piano demonstrated the lowest prevalence for all PRMP outcomes and was selected as the referent for subsequent analysis. A number of instruments showed significantly greater unadjusted odds for PRMP as compared to piano (see Table 4). The lower string category with the double bass and cello, and woodwind category with saxophone and flute, demonstrated very high odds for all PRMP compared to piano. After adjusting for gender and age and other covariates, all contrasts remained significant except for the clarinet and guitar (see Table 5).

PRMP Location

Number of Reported PRMP Locations

Twenty-five percent of children (n = 184) reported a PRMP at one location, 15% (110) reported PRMP at two locations, and 16% (114) reported PRMP at three or more locations (Fig. 4). There was no association between gender and reported number of PRMP locations (χ^2 = 1.345, *df* (2), p = 0.510), although there was for age. Children who reported three or more complaints were 0.5 years older than children who reported PRMP at one location (SE 0.22, p = 0.018). Children who reported the experience of PRMD recorded more PRMP locations than children who reported monthly PRMS (χ^2=15.512, *df* (2), p <0.001). This trend was significant for females (χ^2 = 22.03, *df* (2), p <0.001) but not males (χ^2 = 4.049, *df* (2), p = 0.132) (Fig. 5).

TABLE 2. Number of Children Playing Instruments at All and as Nominated Main, Second, and Third Instrument

Instrument	Played at All	Played as Main Instrument	Played as 2nd Instrument	Played as 3rd Instrument
Piano	304	130	160	14
Upper strings				
Violin	135	113	22	–
Viola	23	18	5	–
Lower strings				
Cello	58	50	7	1
Bass	24	18	6	–
Woodwind				
Clarinet	114	95	15	4
Flute	85	61	20	4
Oboe	15	13	2	–
Bassoon	11	7	4	–
Saxophone	48	36	11	1
Piccolo	2	–	2	–
Brass				
Trumpet	52	41	8	3
Trombone	32	23	7	2
Tuba	8	6	2	–
Euphonium	16	12	3	1
French horn	19	19	–	–
Baritone	4	3	1	–
Cornet	1	–	–	1
Guitar	108	63	31	14
Harp	1	1	–	–
Percussion	46	22	21	3
Other	3	–	3	–
Total	1109	731	330	48

Prevalence of PRMP in Different Locations

The most commonly reported locations for PRMPs were the right (24%) and left (23%) hands, followed by the neck (16%) and right shoulder (14%) (Table 6). Females reported more PRMP at all locations than males, with the exception of the mouth (Table 6), and there were significant differences at the neck (18.7% vs 11.4% F:M; $\chi^2 = 6.680$, df (1), $p = 0.010$), mid-back (10.9% vs 6.3%; $\chi^2 = 4.328$, df (1), $p = 0.037$), right shoulder (17.0% vs 8.1%; $\chi^2 = 11.281$, df (1), $p = 0.001$), and left shoulder (16.1% vs 5.5%; $\chi^2 = 17.76$, df (1), $p < 0.001$).

Spinal PRMP (neck, mid-back, and low back) increased with age (Fig. 6 illustrates neck PRMP across childhood). Gender-adjusted odds ratios showed the risk for neck, mid-back, and low back PRMP increased by 27%, 23%, and 38%, respectively, for each additional year of age (95% CI 1.13–1.60, p <0.001–0.006). There was no significant interaction effect between age and gender ($0.65 < p < 0.718/p = 0.651$–$0.718$).

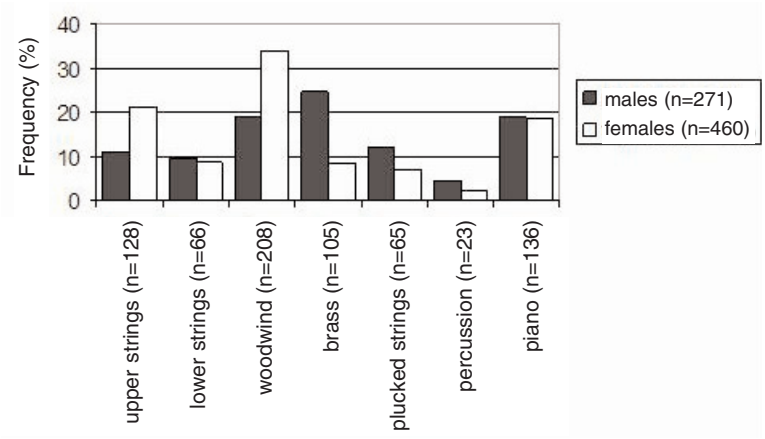

FIGURE 2. Main instrument groups played and gender.

TABLE 3. Prevalence Estimates and 95% Confidence Intervals (95% CI) for PRMP Related to Specific Instruments and Instrument Categories*

Instrument Type	Lifetime PRMS		Monthly PRMS		PRMD	
	Prevalence Proportion	95% CI	Prevalence Proportion	95% CI	Prevalence Proportion	95% CI
Piano (*n*=130)	0.52	0.44–0.61	0.44	0.35–0.52	0.18	0.11–0.24
Upper strings (*n*=131)	0.66	0.58–0.74	0.56	0.47–0.64	0.30	0.22–0.38
Violin (*n*=113)	0.65	0.57–0.74	0.54	0.45–0.63	0.29	0.21–0.38
Viola (*n*=18)	0.67	0.45–0.88	0.67	0.45–0.88	0.33	0.12–0.55
Lower strings (*n*=68)	0.76	0.66–0.87	0.68	0.57–0.79	0.37	0.25–0.48
Cello (*n*=50)	0.72	0.60–0.84	0.64	0.51–0.77	0.36	0.23–0.49
Double bass (*n*=18)	0.89	0.74–1.00	0.78	0.59–0.97	0.39	0.16–0.61
Woodwind (*n*=212)	0.76	0.71–0.82	0.63	0.56–0.69	0.33	0.27–0.39
Clarinet (*n*=95)	0.71	0.61–0.80	0.59	0.49–0.69	0.32	0.22–0.41
Flute (*n*=61)	0.79	0.68–0.89	0.62	0.50–0.74	0.33	0.21–0.45
Oboe (*n*=13)	0.85	0.65–1.04	0.54	0.27–0.81	0.23	0.00–0.46
Bassoon (*n*=7)	0.71	0.38–1.05	0.57	0.20–0.94	0.29	0.00–0.62
Saxophone (*n*=36)	0.86	0.75–0.97	0.78	0.64–0.91	0.42	0.26–0.58
Brass (*n*=104)	0.58	0.48–0.67	0.52	0.42–0.62	0.33	0.24–0.42
Trumpet (*n*=41)	0.59	0.43–0.74	0.54	0.38–0.69	0.34	0.20–0.49
Trombone (*n*=23)	0.65	0.46–0.85	0.52	0.32–0.73	0.30	0.12–0.49
Tuba (*n*=6)	0.50	0.10–0.90	0.50	0.10–0.90	0.17	0.00–0.46
French horn (*n*=19)	0.63	0.41–0.85	0.58	0.36–0.80	0.42	0.20–0.64
Euphonium (*n*=12)	0.42	0.14–0.70	0.33	0.07–0.60	0.25	0.01–0.50
Baritone (*n*=3)	0.33	0.00–0.87	0.67	0.13–1.00	0.33	0.00–0.87
Guitar (*n*=63)	0.71	0.60–0.83	0.56	0.43–0.68	0.32	0.20–0.43
Percussion (*n*=22)	0.68	0.49–0.88	0.59	0.39–0.80	0.32	0.12–0.51

*Note that analyses were performed on instruments as categories (e.g., upper strings and lower strings) and then on all individual instruments (e.g., violin, viola).

Upper limb PRMP showed variable patterns with age. Problems increased with age for the left shoulder (gender-adjusted odds ratio showed the risk for left shoulder PRMP increased by 14% for each additional year of age: 95% CI 1.01–1.29, $p = 0.038$) and right hand/elbow (gender-adjusted odds ratio showed the risk for right hand/elbow PRMP increased by 14% for each additional year of age: 95% CI 1.04–1.25, $p = 0.007$, Fig. 6). Problems peaked in mid-childhood for left hand/elbow, and there was no change with age for right shoulder ($p = 0.672$). There was no significant interaction effect between age and gender for any upper limb PRMP ($p = 0.083$–0.907).

Mouth PRMP also increased with age (gender-adjusted odds ratio showed the risk for mouth PRMP increased by 22% for each additional year of age: 95% CI 1.05–1.43, $p = 0.012$). Lower limb PRMP were very low across all age groups.

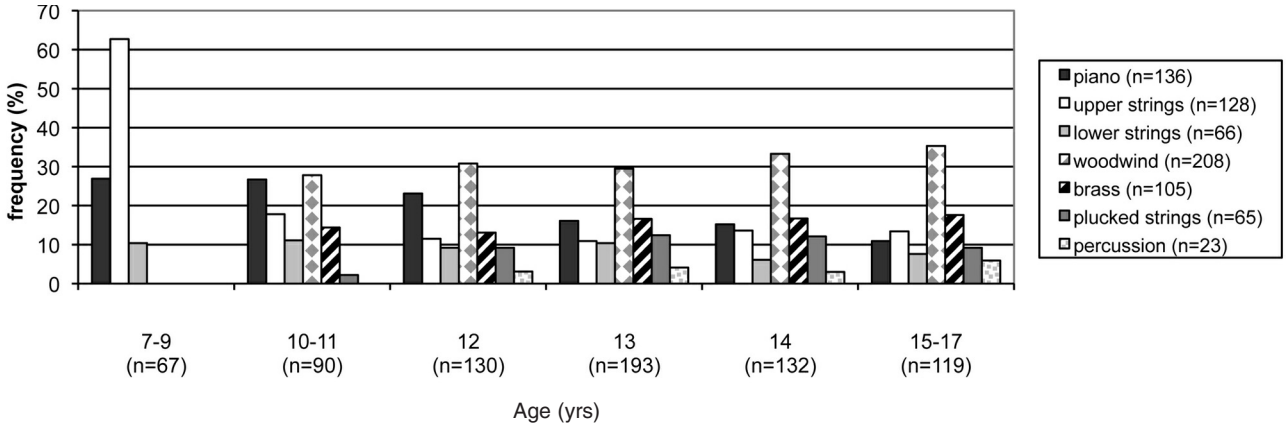

FIGURE 3. Main instrument groups played across age groups.

TABLE 4. Unadjusted Logistic Regression Odds Ratio (OR) Estimates and 95% CI for All Independent Variables for the Three Outcome Measures of PRMP

Covariate	Lifetime PRMS			Monthly PRMS			PRMD		
Unadjusted OR	OR	95% CI	*p* Value	OR	95% CI	*p* Value	OR	95% CI	*p* Value
Gender (female)	1.38	1.01–1.89	0.046	1.56	1.15–2.11	0.004	1.46	1.04–2.04	0.028
Age (yrs)	1.23	1.14–1.33	<0.001	1.19	1.11–1.29	<0.001	1.19	1.08–1.29	<0.001
Total practice time (hrs/wk)	1.05	1.01–1.10	0.014	1.07	1.03–1.11	0.001	1.04	0.99–1.08	0.070
No. of instruments played									
1	1.0			1.0			1.0		
2	1.09	0.79–1.52	0.595	1.16	0.85–1.59	0.336	1.23	0.88–1.71	0.227
3	0.58	0.32–1.07	0.079	0.68	0.37–1.23	0.202	0.84	0.42–1.66	0.607
Instrument*									
Piano (*n*=130)	1.0			1.0			1.0		
Upper strings (*n*=131)	1.74	1.06–2.87	0.029	1.61	0.99–2.63	0.056	1.97	1.10–3.54	0.023
Violin (*n*=113)	1.73	1.03–2.91	0.038	1.50	0.91–2.49	0.115	1.92	1.05–3.52	0.035
Viola (*n*=18)	1.82	0.65–5.15	0.257	2.56	0.91–7.24	0.076	2.33	0.79–6.84	0.125
Lower strings (*n*=68)	2.96	1.54–5.72	0.001	2.68	1.45–4.95	0.002	2.71	1.39–5.27	0.003
Cello (*n*=50)	2.35	1.16–4.75	0.018	2.28	1.16–4.47	0.017	2.62	1.26–5.44	0.010
Double bass (*n*=18)	7.29	1.61–33.01	0.010	4.48	1.40–14.36	0.012	2.96	1.04–8.45	0.043
Woodwind (*n*=212)	2.95	1.85–4.72	<0.001	2.16	1.38–3.36	0.001	2.29	1.35–3.91	0.002
Clarinet (*n*=95)	2.18	1.25–3.82	0.006	1.84	1.08–3.14	0.026	2.15	1.15–4.01	0.016
Flute (*n*=61)	3.37	1.67–6.80	0.001	2.12	1.14–3.95	0.018	2.27	1.13–4.57	0.022
Oboe (*n*=13)	5.02	1.07–23.52	0.041	1.49	0.48–4.69	0.492	1.40	0.36–5.47	0.633
Bassoon (*n*=7)	2.28	0.43–12.18	0.335	1.71	0.37–7.94	0.495	1.86	0.34–10.19	0.474
Saxophone (*n*=36)	5.65	2.07–15.45	0.001	4.48	1.90–10.58	0.001	3.32	1.49–7.40	0.003
Brass (*n*=104)	1.24	0.74–2.09	0.411	1.38	0.82–2.32	0.219	2.26	1.23–4.15	0.009
Trumpet (*n*=41)	1.29	0.63–2.62	0.486	1.48	0.73–3.00	0.273	2.41	1.10–5.30	0.028
Trombone (*n*=23)	1.71	0.68–4.31	0.256	1.40	0.58–3.40	0.461	2.04	0.75–5.51	0.162
Tuba (*n*=6)	0.91	0.18–4.69	0.912	1.28	0.25–6.59	0.767	0.93	0.10–8.35	0.949
French horn (*n*=19)	1.56	0.579–4.22	0.378	1.76	0.67–4.67	0.255	3.38	1.23–9.35	0.019
Euphonium (*n*=12)	0.65	0.20–2.16	0.483	0.64	0.18–2.23	0.484	1.55	0.40–6.18	0.534
Baritone (*n*=3)	0.46	0.04–5.15	0.526	2.56	0.23–28.96	0.447	2.33	0.20–26.75	0.498
Guitar (*n*=63)	2.28	1.20–4.35	0.012	1.60	0.87–2.93	0.128	2.16	1.08–4.34	0.030
Percussion (*n*=22)	1.95	0.75–5.11	0.172	1.85	0.74–4.63	0.189	2.17	0.80–5.92	0.130

*Note that analyses were performed on instruments as categories and then on individual instruments. For guitar and percussion, values for both analyses were identical.

Instrument Type and PRMP location

The prevalence of PRMP in different locations for each type of instrument is illustrated in Figure 7. Upper string players reported most problems in the neck (25%), followed by the left hand/elbow (24.2%) and left shoulder (22.7%). Lower string players reported most problems in the right shoulder (34.8%), right hand/elbow (33.3%), and left hand/elbow

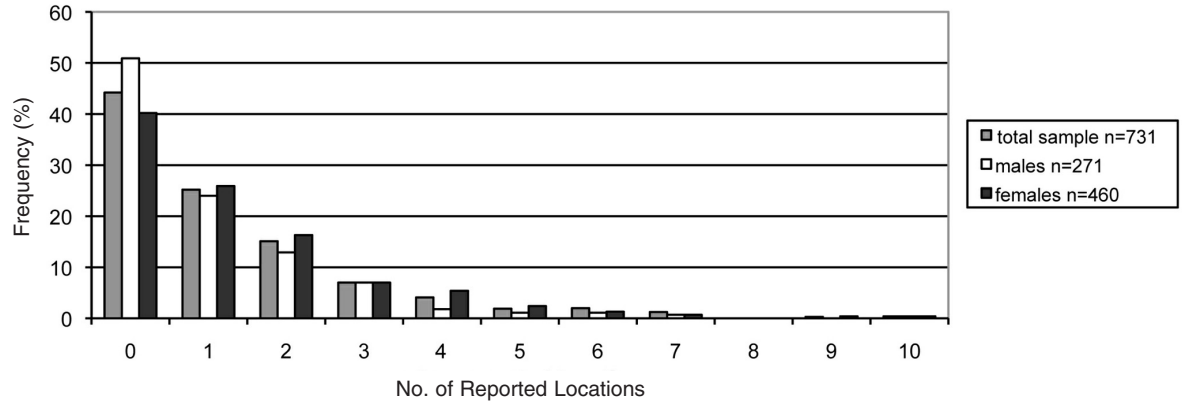

FIGURE 4. Number of reported PRMP locations, by gender (no significant differences, $p = 0.510$).

TABLE 5. Adjusted Logistic Regression Odds Ratio (OR) Estimates and 95% CI for Multivariate Models Including All Independent Variables for the Three Outcome Measures of PRMP

Covariate	Lifetime PRMS			Monthly PRMS			PRMD		
Unadjusted OR	OR	95% CI	*p* Value	OR	95% CI	*p* Value	OR	95% CI	*p* Value
Gender (female)	1.39	0.97–2.00	0.057	**1.67**	1.17–2.37	0.004	**1.62**	1.10–2.38	0.014
Age (yrs)	**1.22**	1.10–1.35	<0.001	**1.17**	1.06–1.28	0.002	**1.17**	1.06–1.30	0.003
Total practice time (hrs/wk)	1.04	0.99–1.09	0.140	**1.06**	1.01–1.11	0.025	1.01	0.97–1.06	0.614
No. of instruments played									
1	1.0			1.0			1.0		
2	1.02	0.70–1.49	0.916	1.01	0.76–1.53	0.66	1.26	0.87–1.81	0.222
3	**0.45**	0.21–0.89	0.022	**0.44**	0.22–0.89	0.022	0.68	0.31–1.49	0.332
Instrument*									
Piano (*n*=130)	1.0			1.0			1.0		
Upper strings (*n*=131)	**2.02**	1.18–3.47	0.010	1.67	0.99–2.83	0.053	**1.91**	1.04–3.50	0.038
Violin (*n*=113)	**2.13**	1.20–5.42	0.009	1.62	0.93–2.80	0.087	**1.94**	1.03–3.67	0.041
Viola (*n*=18)	1.38	0.47–4.05	0.560	1.89	0.65–5.53	0.245	1.65	0.55–4.95	0.376
Lower strings (*n*=68)	**3.30**	1.64–6.63	0.001	**2.93**	1.53–5.60	0.001	**2.74**	1.37–5.46	0.004
Cello (*n*=50)	**2.55**	1.20–5.42	0.015	**2.39**	1.17–4.87	0.017	**2.61**	1.22–5.57	0.013
Double bass (*n*=18)	**8.22**	1.77–38.16	0.007	**5.47**	1.65–18.15	0.005	**3.15**	1.07–9.26	0.037
Woodwind (*n*=212)	**2.56**	1.55–4.21	0.001	**1.78**	1.11–2.87	0.017	**1.85**	1.07–3.23	0.029
Clarinet (*n*=95)	**1.89**	1.04–3.42	0.036	1.54	0.87–2.72	0.137	1.71	0.89–3.27	0.106
Flute (*n*=61)	**2.86**	1.35–6.07	0.006	1.65	0.85–3.20	0.139	1.72	0.83–3.54	0.145
Oboe (*n*=13)	4.28	0.89–20.37	0.068	1.22	0.38–3.92	0.737	1.09	0.27–4.33	0.903
Bassoon (*n*=7)	1.37	0.25–7.54	0.719	0.99	0.21–4.81	0.995	1.14	0.20–6.39	0.882
Saxophone (*n*=36)	**4.83**	1.71–13.65	0.003	**4.01**	1.63–9.86	0.002	**3.11**	1.35–7.18	0.008
Brass (*n*=104)	1.10	0.63–1.93	0.737	1.37	0.78–2.40	0.272	**2.27**	1.20–4.29	0.012
Trumpet (*n*=41)	1.17	0.54–2.54	0.690	1.59	0.74–3.45	0.233	**2.40**	1.03–5.57	0.042
Trombone (*n*=23)	1.73	0.65–4.64	0.277	1.78	0.68–4.66	0.244	2.71	0.95–7.74	0.062
Tuba (*n*=6)	0.44	0.06–3.03	0.406	0.62	0.09–4.35	0.632	0.78	0.08–7.74	0.832
French horn (*n*=19)	1.40	0.50–3.92	0.522	1.64	0.59–4.54	0.342	3.08	1.08–8.76	0.035
Euphonium (*n*=12)	0.56	0.16–1.94	0.361	0.57	0.16–2.07	0.389	1.33	0.33–5.46	0.691
Baritone (*n*=3)	0.56	0.05–6.67	0.648	2.99	0.25–36.41	0.389	3.08	0.26–36.68	0.374
Guitar (*n*=63)	1.97	0.99–3.89	0.051	1.41	0.74–2.69	0.292	1.78	0.86–3.72	0.122
	1.99	1.01–3.94	0.048	1.45	0.76–2.77	0.261	1.81	0.87–3.78	0.115
Percussion (*n*=22)	1.65	0.61–4.46	0.325	1.61	0.62–4.20	0.328	1.65	0.57–4.79	0.361
	1.68	0.62–4.55	0.310	1.66	0.63–4.34	0.303	1.66	0.57–4.86	0.352

*Instruments were analyzed both separately and in categories. Significant covariates appear in boldface.

(28.8%). Plucked strings reported most problems in the left hand/elbow (38.5%) and right hand/elbow (33.8%).

Upper strings and plucked strings demonstrated significantly higher odds ratios (95% CI) for the risk of neck PRMP than lower strings: OR = 7.00 (2.06–23.84), $p = 0.002$ vs 3.82 (1.00–14.58), $p = 0.050$. Plucked strings demonstrated significantly higher odds ratios (95% CI) for the risk of right hand/elbow [3.13 (1.53–6.40), p=0.002] and left hand/elbow [1.96 (1.03–3.72), $p = 0.04$] PRMP compared to upper strings. Lower strings demonstrated significantly higher odds ratios (95% CI) for right hand [3.06 (1.50–6.24), $p = 0.002$], left hand [3.18 (1.12–9.020), $p = 0.030$], and right shoulder [2.89 (1.44–5.79), $p = 0.003$] PRMP compared to upper strings.

Woodwind players reported most problems in the right hand/elbow (30.3%), neck (18.8%), left hand/elbow (17.8%), and mouth (12.5%). Brass players reported most problems in the mouth (17.1%) and left hand/elbow (16.2%), with lower prevalence rates in all other locations. Percussionists reported most problems in the right hand/elbow (26.1%), left hand/elbow (21.7%), and neck (21.7%), with no reported problems in either shoulder. Piano players reported most problems in the left hand/elbow (25.7%) and right hand/elbow (23.5%) and neck (11.8%) and lower prevalence rates in other locations.

Woodwind and piano players demonstrated significantly higher odds ratios (95% CI) for the risk of right hand/elbow PRMP [3.08 (1.60–5.90), $p = 0.001$ and 2.18 (1.08–4.39), $p = 0.030$, respectively] than brass instrumentalists.

Overall Models for PRMP in Each Location

Final models were created to examine the independent association of all covariates for PRMP in each location. Age and gender were significant predictors for some upper limb locations only. Instrument type and number of PRMP locations were significant independent predictors for

PRMP in most locations. Even after adjusting for other covariates, similar statistically significant patterns of differences were observed between instrument type and PRMP location (Table 7).

DISCUSSION

This is the first study in children and adolescents to take account of gender and age in establishing relevant risk factors for the development of PRMP. Females and older children were more likely to experience problems. When adjusting for other covariates, increased time spent playing was associated with an increased odds of monthly PRMS, playing three instruments was associated with a reduced odds of monthly PRMS, and the odds of all PRMP varied significantly with the type of instrument. Age, gender, instrument type, playing time, number of years the main instrument had been played, and number of PRMP were significant independent predictors for PRMP in certain locations.

Gender and Age

This study found that children experienced PRMS at rates similar to adults, and alarmingly, 30% had experienced a PRMD. Female children and adolescents were at more risk of developing problems than their male counterparts. This finding concurs with studies of adult musicians[3,4,18,19] and of spinal pain in adults[77,78] and children.[79–82] The consistency of higher risk for a broad range of musculoskeletal disorders in females suggests that there may be consistent mechanisms. Clearly, this group of children should be monitored for the development of problems and managed early to prevent more severe problems.

Problems were experienced in the very young, and the risk for development of problems increased with age after accounting for gender. It is clear from the pain literature that episodes of adolescent neck and back pain are associated with an increased risk for the experience of neck and back pain in adulthood.[1,34,35] It is therefore imperative that children be educated with respect to potential problems and be encouraged to discuss the experience of any problems as they arise. In this way, the child can be examined, assessed for risk factors, and managed in the most effective manner to prevent the development of disabling disorders as their music studies progress.

TABLE 6. Prevalence of PRMP by Locations

	Total		Males		Females	
	No.	%	No.	%	No.	%
Neck	117	16.0	31	11.4	86	18.7*
Mid-back	67	9.2	17	6.3	50	10.9*
Low back	81	11.1	25	9.2	56	12.2
Left shoulder arm	89	12.2	15	5.5	74	16.1*
Left hand elbow	169	23.1	60	22.1	109	23.7
Right shoulder arm	100	13.7	22	8.1	78	17.0*
Right hand elbow	176	24.1	60	22.1	116	25.2
Left leg	15	2.1	7	2.6	8	1.7
Right leg	9	1.2	3	1.1	6	1.3
Mouth	61	8.3	29	10.7	32	7.0

*Significant differences ($p < 0.05$) between genders.

Music Exposure

Playing time was associated with monthly PRMS in the multivariate model. This is consistent with an increase in hours of exposure increasing the risk of developing musculoskeletal disorders reported in the occupational literature.[83,84] Playing time therefore needs to be carefully managed for child instrumentalists to minimize their risk of PRMP.

While no prior reports of the association between the number of instruments played and PRMP were found, we expected an increase in risk due to increased exposure time. This study found tthat children who played three instruments did spend more time practicing than other students, and time spent practicing was (independently) associated with monthly problems. However, playing three instruments was associated with a reduced risk of problems. Students in

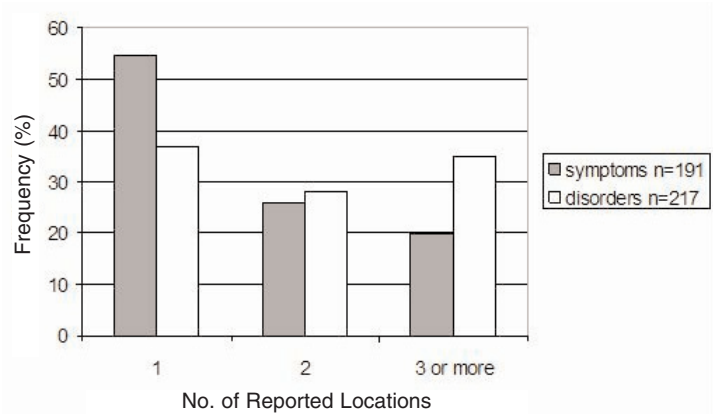

FIGURE 5. Number of reported PRMP locations in children who reported just symptoms (PRMS) versus disorders (PRMD).

TABLE 7. Significant Predictors of PRMP at Different Locations*

Covariate	Neck	Mid-back	Low Back	Left Shoulder	Left Hand	Right Shoulder	Right Hand	Mouth
Age	–	–	–	–	7.9 p=0.005	–	–	–
Gender	–	–	–	11.5 p=0.001	–	6.1 p=0.014	–	5.6 p=0.018
Instrument type	23.7 p=0.001	–	–	19.6 p=0.003	15.0 p=0.020	9.1 p=0.003	20.3 p=0.002	19.8 p=0.003
No. of instruments played	–	–	–	–	–	–	–	–
No. of PRMP locations	73.2 p<0.001	60.8 p<0.001	57.9 p<0.001	33.7 p<0.001	66.9 p<0.001	50.1 p<0.001	49.2 p<0.001	–
Playing time	5.4 p=0.021	–	–	5.8 p=0.016	–	–	–	–
Years playing main instrument	–	–	11.8 p=0.001	–	–	–	–	–

*Wald statistic and p value.

our study who played more than one instrument played different instruments (i.e., from a different instrument category) which may have had different physical task demands. Playing three instruments may therefore have provided physical variety which reduced risk. This inverse relationship has been reported in occupational health literature, where variation in exposure decreased the risk for work-related musculoskeletal disorders.[40–43] On the basis of this study, education guidelines should encourage different instrument types be played as a second or third instrument.

This was the first study to comprehensively establish risk associations between instrument/instrument category and PRMP in child instrumentalists. In this study, piano was the most commonly played instrument as a main, second, or third instrument, in line with prior reports.[6,8,13,28,85] Interestingly, the piano was associated with the least problems in our study. The piano requires left and right hand and finger movements, with the elbow and shoulder in reasonable, symmetrical postures. This may explain why it was less associated with problems.

In contrast, Fry and Rowley[13] reported piano (along with the cello) to be associated with the most problems in children. Failure to account for important covariates may have been the reason they reported different findings. Among adult musicians, the piano/keyboard has often been associated with a greater risk of PRMP compared to other instrument groups. At professional and tertiary levels, various practice habits may influence the development of problems, such as the difficulty/type of repertoire played, duration of practice sessions, and frequency of practice sessions. It may be that the cumulative repetitions and prolonged postures of more extensive adult playing times and less physical variation are the reason adults have more problems with piano/keyboards than did the children in our study.

Upper and lower string players displayed significantly higher odds than piano players for all PRMP in this study. Dis-

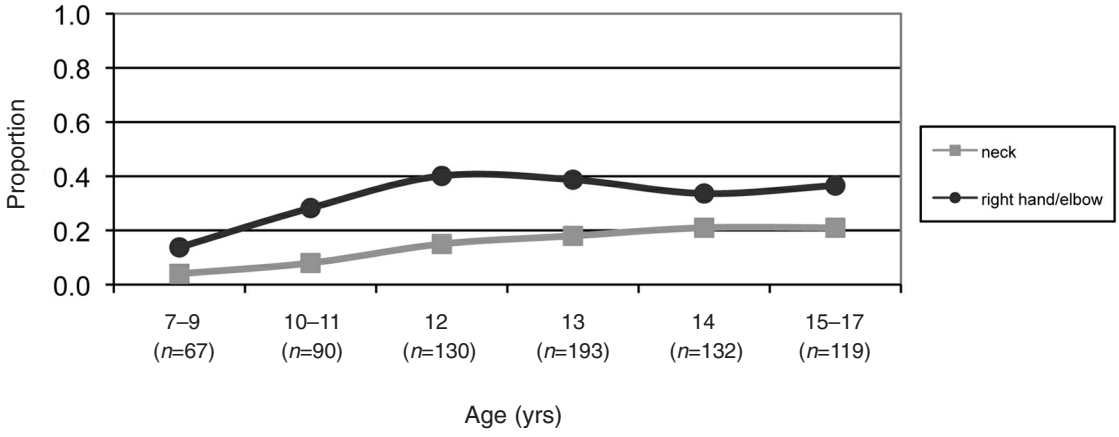

FIGURE 6. Proportion estimates for neck and right-hand/elbow PRMP across age groups.

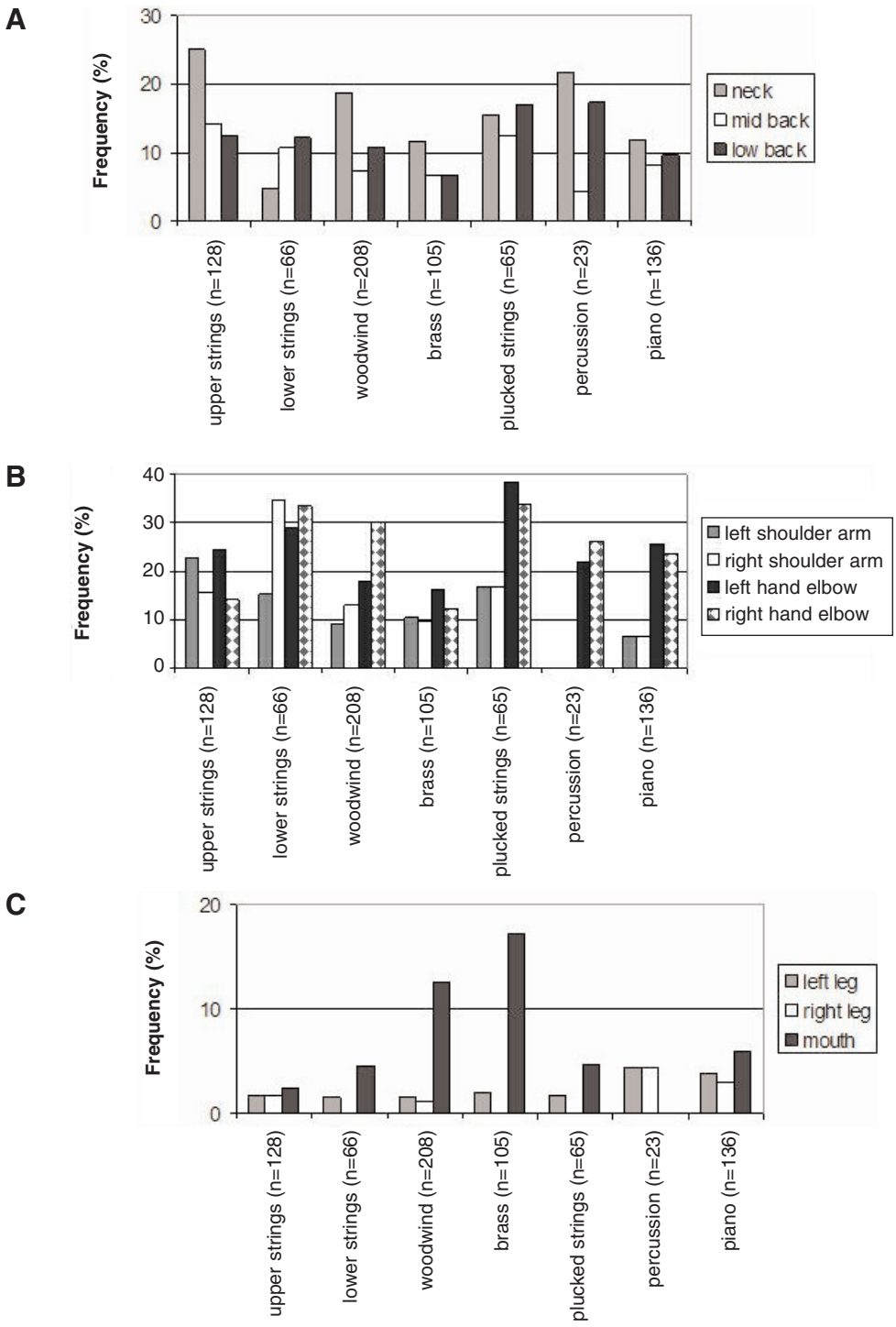

FIGURE 7. Prevalence of PRMP across instrument categories: A, neck/back; B, upper limb; C, lower limb and mouth.

parity between the child and instrument size has been postulated as a reason for increased prevalence of PRMPs in child string players.[15] In this study, upper and lower string players displayed significantly higher odds than piano players for PRMP, though when lower strings were contrasted to upper strings, there was no significant increase in risk (OR 1.41–1.73; p = 0.280–0.109). In adults, string instruments in general, and bowed stringed instruments specifically, have been associated with more upper limb problems than keyboard, percussion, woodwind, and brass.[55] The degree of coordination required for very different actions of the left and right upper limb in playing a bowed string instrument may explain why these instruments are associated with more problems.[86]

Woodwind players, and saxophone players in particular, displayed significantly higher odds than piano players for all PRMP in this study. Fry and Rowley[13] reported very high

PRMP prevalence in children playing clarinet and flute, although the small sample size precluded accurate estimation of population prevalence. While appropriately sized woodwind and brass instruments are supplied through the School of Instrumental Music, the weight of the instruments on the developing musculoskeletal system may place the child at risk for developing problems. In adults, woodwind instruments have been associated with PRMP but with lower risk than string instruments.[20,50] Among tertiary music students, woodwind instruments were a similar risk for PRMP as keyboard and string instruments.[5,6,57]

Brass players, and trumpet players in particular, displayed significantly higher odds than piano players for PRMD in this study. Potential explanatory factors for this finding may be child–instrument size mismatch, the heavy instrument weight, and the difficulty of technique required to play the trumpet. In adults, the unique physical demands required to play various brass instruments (i.e., to hold and position the instrument, produce and maintain blowing pressures, and manipulate valves and or slides) are thought to contribute to the experience of PRMP.[58]

On the basis of this study, close monitoring of children playing instruments with the highest odds of PRMP, such as cello, bass, saxophone, and trumpet, is recommended. Teachers and parents need to be informed of prevention strategies for PRMPs associated with these instruments.

Location of PRMP

This was the first study to document the prevalence of PRMP location in children and its association with symptoms versus disorders. Children who reported the experience of PRMD recorded more locations than those who reported PRMS. No study of adults which investigated this relationship was found. The final regression models demonstrated that the number of location where PRMP was experienced was a significant independent factor for predicting risk of developing problems in other locations. Once problems arise, the intricate balance and coordinated movement required for performance are interrupted and a cascade effect may promote problems elsewhere. It is imperative that children be assessed and treated appropriately to avoid compensatory mechanisms that inevitably produce less efficient performance and increase risk of further problems.

No study was found which had previously investigated the location of PRMP and the association with gender, across childhood and type of instruments. This study identifies that female gender was a significant predictor for left and shoulder problems, age was a significant predictor for left hand/elbow pain, and instrument type and number of PRMP locations were significant predictors for neck, left and right shoulder and hand/elbow, and mouth PRMP locations. The necessity of combined static postures distally and dynamic postures proximally in one upper extremity and for the converse (static postures proximally and highly repetitive movements distally) in the contralateral limb represent demands that are unique to the type of instrument for the instrumentalist. Regardless of other factors such as repertoire and the potential for children to adapt to their instruments, we have clear evidence that instrument type is an important risk factor for the development of PRMP in children and adolescents, and prevention initiatives must be implemented to avoid more disabling disorders later and potential career termination due to problems.

Generally, the patterns of location of problems in this study are disconcertingly similar to those reported in the literature for adults. High prevalence rates of upper limb problems appear early and remain high across childhood. Studies on neck and shoulder pain and leisure activities among high school students have reported that hobbies involving dynamic loading of the shoulder, such as racquet sports, decreased the risk for neck and shoulder pain. Ongoing analyses will investigate the participation in physical activities, hand-intensive activities, and information technology use and their association with PRMP.

In adult piano players, hand problems are most commonly reported, with the right more affected than the left. Repetitive techniques required for complex repertoires and the force applied to keys are thought to be contributing factors.[45,60] In our study, the left hand was affected marginally more than the right. It may well be that children and adolescents have learned how to abduct the thumb and little finger of the right hand, reaching keys with relative ease. However, attention to left hand technique and necessary adaptation may result in the experience of symptoms. As mentioned, children in this study may not be playing complex repertoire that adult pianists perform and therefore are less likely to have associated problems in the right hand.

The left hand/elbow, left shoulder, and neck were the most commonly reported problem locations for upper strings players in this study, and this is consistent with the patterns seen in adults. The asymmetrical and sustained posture of the neck and left shoulder, despite adequately sized instruments and the propensity for adaptation to the instrument, may contribute to these problems. The extreme flexion of the left wrist, hand, and fingers and the stretching of fingers to reach the strings (especially the small fourth and fifth fingers) as well as the force necessary to depress strings may increase the risk for developing problems in the left hand.[45]

In lower strings players, the right shoulder, right hand/elbow, and left hand/elbow were the most commonly reported problems in our study. This is again in agreement with the adult literature. Requirements of the left hand and wrist for cello and bass are similar to upper strings, and though not as flexed, repetitive and forceful movements are required, which may explain the pattern of involvement. However, the left shoulder and elbow are not sustained in extreme positions and subsequently not as affected as in upper strings.

The right bowing shoulder and hand were often involved in lower strings players. The hand is affected perhaps owing to the bow grip. The right shoulder is involved probably due to the repetitive range of motion and the bow reaction forces

from contact with the strings[60] and further due to the potentially increased load on the rotator cuff due to the high static handgrip force on the bow.[72] We expected children who played bass to be at greater risk of spinal pain and left shoulder pain given the potential for instrument mismatch in the developing child; however, this was not the case, and strategies implemented by the School for Instrumental Music may be successfully helping to prevent mismatch problems for the growing child.

For plucked strings, left and right hand/elbows were affected, the left moreso than the right. The shoulders were affected equally, and the low back was the most commonly reported spinal pain. This again is in agreement with the adult literature. In our study, the guitar represented the majority of plucked string instruments. As mentioned previously, the way in which the guitar is held and played is associated to the development of problems.[60] The sustained, asymmetric postures of the left wrist, repetition and force of left hand and left finger movements, and the techniques and associated forces through the right wrist, hand, and fingers contribute to bilateral hand problems in the child, even with appropriately sized guitars. Our study did not seek information with respect to a seated or standing position, or the use of a neck strap; however, the use of neck straps could be encouraged, and alternating seating and standing postures recommended to help prevent spinal pain.

Woodwinds players in our study had right hand/elbow problems most commonly, followed by neck and left hand/elbow problems. As mentioned previously, problems generally arise due to the support of the instrument—right thumb for clarinetists and oboists, left hand for flautists—and due to the frequency and difficulty of repetitive finger movements. External supports such as a neck strap are used with some larger instruments like the bassoon and bass clarinet, though not with the smaller instruments, and the majority of weight is taken through the right thumb. It may be important to recommend use of neck strap in the growing child and assess the feasibility of a splint for the thumb to assist in support of the instrument. Preventative exercises to strengthen thumb stabilizers (abductor pollicis longus and adductor pollicis) should also be considered. In the child with underlying thumb hypermobility, education with respect to the use of supportive aids may be necessary as an interim strategy or long-term intervention.

Brass instrumentalists had mouth problems most commonly, followed by left and right hand/elbow, neck, and left shoulder problems, consistent with adult findings reported by Chesky et al.[58] Clearly embouchure issues need to be addressed early in children to prevent serious dental and facial problems from occurring, especially as such problems contribute to the child's perceived physical appearance, self-esteem, and ability to tackle issues in adolescence.

Percussionists in our study had problems most commonly in the right and left hand/elbow, followed by the neck and low back. The adult literature describes problems pertaining to percussionists as unique to the variety of instruments in this category. Risks may develop from how an instrument is held and jarring from impact of the hands/upper limb, the position of grasp/grip, the repertoire, number of repetitions used, and the properties of instrument sticks or whatever is used to strike the instrument (e.g., cymbals).[87] In our study, children demonstrated patterns of involvement probably due to the weight of the instruments and unique playing postures for individual instruments.

Sustained awkward postures and the repetitive and forceful movements necessary to play instrumental music present challenges for the developing musculoskeletal system, especially during periods of growth. To prevent and minimize PRMP development during childhood, there needs to be some flexibility with respect to playing posture, transition to larger sized instruments, and the provision and revision of external supports for the child and adolescent instrumentalist.

Limitations and Strengths

This study has several limitations related to its design. As a cross-sectional study, the strongest evidence it can provide is of association. Using self-reported measures of PRMS and PRMD may inflate prevalence rates compared to physical examination. While the current analysis has provided unique information on the prevalence of PRMS and PRMD in children and the associations with playing time and the number and type of instruments played, further analysis will need to consider other aspects of music habits and other activities, such as the use of information technology and participation in physical activity. The study strengths include its large, representative sample, clear case definitions, and assessment of the independent effects of age and gender along with various music exposure factors.

While longitudinal studies are needed to determine the true incidence of PRMP and better establish associated risks, this study has highlighted important evidence for the health of the child and adolescent instrumentalist. Music educators, parents, health care practitioners, and last but certainly not least, the child musician need to be aware of the high risk of PRMP and address identified risk factors. This will help ensure the longevity of a music career for the individual and benefit the community as a whole.

CONCLUSION

Gender, age, playing time, and type of instrument played were associated with the reported prevalence and location of PRMS and PRMD in children learning instrumental music. The high prevalence of both PRMS and PRMD in children warrants further evaluation of risks to inform teachers, parents, and children on prevention initiatives and to avoid the development of chronic disorders as these musicians grow into adulthood.

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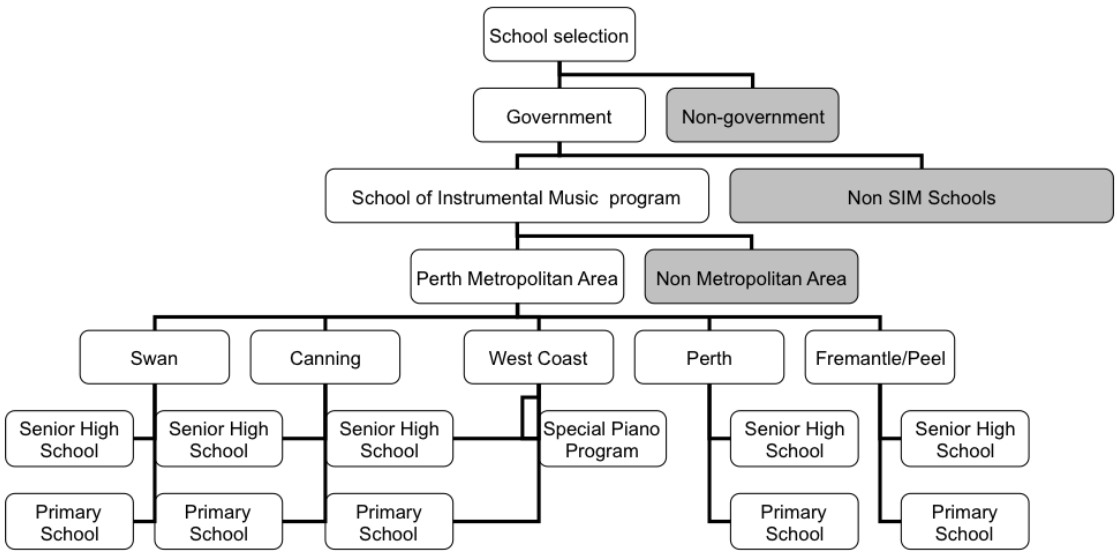
APPENDIX



APPENDIX 1. Process of school selection.