Musicians’ Playing-Related Musculoskeletal Disorders: An Examination of Risk Factors

C. Zaza, PhD,1* and V.T. Farewell, PhD2

Several studies have shown that playing-related musculoskeletal disorders (PRMDs) present a significant health problem for musicians. To examine physiological, psychological, and behavioral risk factors of musicians’ PRMDs, data for a case-control analysis were collected from classically-trained professional and university student musicians in the Canadian province of Ontario in 1994. Two-hundred and eighty-one subjects completed a self-report questionnaire and hypermobility and hand-span measurements. Cases were identified according to an operational PRMD definition developed by musicians and health care professionals in a qualitative study. Logistic regression was used to compare data from 44 prevalent PRMD cases who had no previous history of a PRMD, and 90 controls who had never experienced a PRMD. Data from all subjects were analyzed to examine the role of a prior PRMD on the risk of a current PRMD. This study suggests that females and string players were at a higher PRMD risk. A number of other individual characteristics were also important determinants of the development of a PRMD. Warming up before and taking breaks during practice sessions protected the subject from a PRMD. Given the high proportion of musicians who experience PRMDs, prevention programs are warranted. Am. J. Ind. Med. 32:292–300, 1997. © 1997 Wiley-Liss, Inc.

KEY WORDS: epidemiology; musculoskeletal system; music; occupational health; case-control study

INTRODUCTION

Besides general health problems, many musicians experience adverse physical conditions as a result of playing their instrument(s); most common are playing-related musculoskeletal disorders (PRMDs). These and other conditions typically affect the neck, back, upper extremities, and facial musculature. The medical literature has sporadically documented musicians’ PRMDs since the late 1800s [DeWatteville, 1885; Gowers, 1888; Graham, 1888; Harman, 1888]. Since the 1980s, performing arts medicine has grown to international proportions, and the profusion of “Musicians’ Clinics” is now worldwide. Cross-sectional surveys of professional musicians [Caldron et al., 1986; Fry, 1986; Hiner et al., 1987; Fishbein et al., 1988], university music students [Fry, 1987; Hartsell and Tata, 1991; Larsson et al., 1993; Pratt et al., 1992; Revak, 1989; Roach et al., 1994; Zaza, 1992], and primary and secondary school-age music students [Fry et al., 1988; Fry and Rowley, 1989; Grieco et al., 1989; Lockwood, 1988; Shoup, 1995] report prevalence figures from 5% to 80%. A meta-analysis to derive a summary estimate of prevalence is not possible due to the heterogeneity of studies. The only published case-control study compared 48 pairs of university music students, matched on gender, academic year, and instrument; however, a multivariate analysis of these data was not reported [Manchester and Park, 1996].

The most consistently reported finding is that females are more affected by PRMDs than males [Fishbein et al., 1988; Fry, 1987; Fry et al., 1988; Larsson et al., 1993;
An increased PRMD risk for string players [Caldron et al., 1986; Fishbein et al., 1988; Larsson et al., 1993; Lockwood, 1988; Manchester, 1988; Manchester and Flieder, 1991] and keyboard players [Fry and Rowley, 1989; Manchester, 1988; Manchester and Flieder, 1991; Zaza, 1992] has also been reported. Aside from gender and instrument group, various playing-related behaviors have been cited as risk factors, most notably, abrupt increases in total practice time or changes in repertoire, teacher, or instrument [Fry, 1987; Newmark and Lederman, 1987; Manchester and Flieder, 1991; Revak, 1989]. Not one of the studies reported in the performing arts medicine literature has examined interactions between physical, psychological, and playing-related behavioral factors. The inferences regarding these suspected risk factors are attenuated by several methodological weaknesses in many of the studies, including low response rates, suspicion of response bias, lack of outcome definition, and measurement bias. This literature has been critically reviewed elsewhere [Zaza, 1995].

Further information regarding the risk factors for PRMDs is found in the occupational medicine literature, since the musculoskeletal conditions which disable musicians are also prevalent in workers in other occupations. Extensive research on several groups shows that force, repetition, and posture are associated with an increased risk of work-related musculoskeletal disorders [Moore et al., 1991; Armstrong and Silverstein, 1987; Stock, 1991]. There is strong evidence to suggest that a causal relationship exists for force and repetition [Silverstein et al., 1986; Stock, 1991].

The aim of this study was to investigate individual and joint effects of physical, psychological, and behavioral factors on first-episode PRMD risk and on recurrent PRMD risk in adult, classically trained musicians. Rather than dealing with a specific risk factor (e.g., gender) for a particular disorder (e.g., tendinitis) in one instrumentalist (e.g., cellists), this study was designed to investigate global risk factors for PRMDs in several different instrumentalists. This approach is consistent with several studies of work-related musculoskeletal disorders which use aggregate outcomes (e.g., upper-extremity cumulative trauma disorders) [Armstrong and Silverstein, 1987; Feuerstein and Fitzgerald, 1992; Harber et al., 1993; Stock, 1991].

**MATERIALS AND METHODS**

Data were collected from 281 classically trained professional musicians and university music students in Ontario. All subjects gave their written informed consent, and the study protocol received ethics approval from the Office of Human Research at the University of Waterloo, where the study was based.

**Outcome Definition**

In the absence of objective “gold standard” criteria for the diagnosis of PRMDs, an operational definition of PRMDs was warranted. Study subjects were identified as cases if they responded “yes” to the self-report case definition question: “Currently, do you have a 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)?” Subjects who responded “no” were identified as controls. Cases and controls were also asked if they had ever experienced a PRMD. This operational definition was developed by 27 musicians and three health professionals in a separate qualitative study which showed that musicians clearly distinguish between mild, transient aches and pains, and a PRMD [Zaza, 1995, 1996]. According to musicians, PRMDs are serious chronic problems affecting their usual level of playing, are beyond their control, and are determined individually [Zaza, 1995, 1996]. Thus, this PRMD case definition excludes mild symptoms.

**Subject Accrual**

To identify musicians interested in participating in the study, potential subjects were given a one-page self-report demographic form, which also contained exclusion criteria. Cases and controls were identified in the community and survey methods were used for data collection because of the expected high proportion of musicians with PRMDs.

In order to exclude musicians with health problems not caused by playing (e.g., broken arm from a fall), a list of medical conditions that would affect the musculoskeletal system (e.g., arthritis) and a question regarding accidents in the last 12 months (e.g., motor vehicle accident) were presented on the one-page self-report form. Musicians who indicated one of the specified non-playing-related problems were excluded from the study. Eligible participants were given a self-report questionnaire to complete and return to the principal investigator (PI). Hand span and hypermobility were measured by the blinded PI. Since this study compares a large group of injured musicians who reported on pre-PRMD status with musicians who do not have a PRMD, it effectively becomes a case-control study. As Breslow and Day state [1980], case-control techniques for subject accrual and questionnaire administration may resemble a multisite survey.

Ten sites were invited to participate in the study, including three post-secondary music schools, six professional orchestras, and one professional music teacher’s organization. The study was introduced to approximately 475 musicians by a brief announcement made by one of the authors (CZ) at each location. When this method was not possible, the musicians received an introductory letter, followed by a telephone call. Of the 352 who agreed to
participate, 36 were excluded and 35 did not return their questionnaires, leaving 281 subjects in the sample, a response of 66.7% (317/475). Data on the non-respondents were collected on the one-page form whenever possible.

**Data Collection**

Variables were included for exploratory purposes (i.e., to examine the role of factors not previously investigated in musicians) and for verification of evidence from other studies.

The 36-page Playing-Related Health Questionnaire included five categories of questions: 1) Physical and Demographic Variables, 2) Psychological Variables, 3) Practice Behaviors and Other Playing-Related Variables, 4) Non-Music Related Variables, and 5) Instrument Groups. In addition to reporting current status and behaviors, cases also responded to questions regarding pre-PRMD playing-related behaviors. Physical and demographic characteristics included age, gender, body size measured by body mass index (BMI) calculated from self-report height and weight, hand span, and hypermobility (the ability of a joint to extend beyond the normal range of motion). Hand span and hypermobility, also called hyperlaxity, were measured by the PI, who was blinded as to the subjects’ case-control status. To measure hand span, subjects consecutively placed each hand, outstretched as wide as possible without causing pain, on a blank sheet of paper set on a flat surface. The PI traced the subjects’ hands, marked the distance between the tip of the little finger to the tip of the thumb with a drafting precision instrument similar to a compass, and recorded the measurement in millimeters. The PI measured hypermobility according to a standard protocol developed by Carter and Wilkinson [Carter and Wilkinson, 1964; Klemp et al., 1984], which involves assessing the subjects’ ability to perform the following maneuvers on both right and left sides, where applicable: 1) passive dorsiflexion of the little fingers beyond 90°, 2) passive apposition of the thumbs to the flexor aspects of the forearms, 3) hyperextension of the elbows beyond 10°, 4) hyperextension of the knees beyond 10°, and 5) forward flexion of the trunk, with knees straight, so that the palms of the hands rest easily on the floor. All but the fourth maneuver were measured, as it was not possible to view the knees of most subjects. The commonly used modification developed by Beighton [1973], which involves extension of the wrist and metacarpal phalanges, was also measured. A joint was considered hypermobile if the subject was able to perform the above maneuver. A total hypermobility score was calculated by summing the total number of hypermobile joints. The total score was dichotomized such that individuals with five or more hypermobile joints (i.e., a score of >5/9) were considered hypermobile, and those with 0 to 4 hypermobile joints were considered to be not hypermobile.

Psychological characteristics were measured because of their potential to contribute to the risk of a PRMD; for example, by leading to increased repetition, force, and/or muscle tension. Perfectionism, trait anxiety, compulsivity, and affect were measured on standardized validated scales. Fifteen items from the Multidimensional Perfectionism Scale [Hewitt et al., 1991; Hewitt et al., 1989] were used to measure perfectionism. Trait anxiety was measured by the A-Trait scale of the State Trait Anxiety Inventory [Spielberger et al., 1970]. Physical and psychological symptoms of performance anxiety were measured based on previous research [Bartel and Thompson, 1994]. Kagan and Squires’ Compulsiveness Inventory was used to measure general non-pathological compulsiveness [Corcoran and Fischer, 1987]. Since compulsivity during practice sessions might be missed on the Compulsiveness Inventory, five items on this scale were presented a second time, each prefaced by the phrase ‘When practicing your instrument...’ Two total scores were calculated and examined in multivariate analyses: one from the original Compulsiveness Inventory, and the other from the five items relating to practice behavior. The Positive Affect Negative Affect Schedule was used to measure affect [Watson et al., 1988]. General life stress and work or study stress were measured by five-point Likert scales (5 = very stressful, 1 = not stressful at all). Finally, eight statements regarding attitudes toward playing and pain were presented with seven-point Likert scales for each. Playing-related factors included musical warmup (e.g., playing slow scales), physical warmup (e.g., stretching exercises), breaks, practice time, recent changes, and other factors.

To reduce the problem of reverse causality, immutable physical factors and personality characteristics which are considered stable and unlikely to change because of a PRMD were mainly selected for measurement, and the questionnaire sought pre-PRMD information from cases.

**ANALYSIS**

Figure 1 illustrates the PRMD status and history of the subjects, and the two analyses presented in this paper. The
first compares 44 cases with 90 controls to determine the risk of acquiring a PRMD in individuals who have no PRMD history (denoted the First Analysis). Data from the 62 cases and 81 controls with a prior history of PRMD were then added to the analysis, resulting in a comparison between the 110 cases and the 171 controls (denoted the Second Analysis). The presence or absence of a prior PRMD was determined by self-report on the questionnaire and the analysis was stratified on this variable. The stability of the findings in both the prior PRMD and no-prior PRMD strata was investigated by the inclusion of interaction variables involving prior PRMD and the other potential risk factors. In the extreme case of including all such interactions, this latter analysis would be equivalent to undertaking separate analyses in the strata.

Individual and combined effects of the explanatory variables on the risk of a PRMD were examined in logistic regression, using the Egret software package [Egret, 1993]. The conventional .05 significance level was used as a guide to determine the statistical significance of the relationship between the explanatory variables in the model and the dependent variable (prevalent PRMD). For ease of presentation, a variable will be described as “significant” if the test for a non-zero coefficient for the variable is significant. Each variable in the five categories was fit individually in a logistic regression model. The multivariate model was constructed using two procedures, of which both produced the same results: 1) statistically significant variables from each of the five categories described above were combined in one step, into one model; 2) statistically significant variables from the first category were fit into an initial model, which was then extended to include variables from the second category. This procedure was repeated to include the variables from all five categories. In both strategies, variables which might potentially confound other associations, even if not shown to be significant in univariate analyses, were examined in multivariate analyses (e.g., instrument groups, gender, age). Interactions between all of the variables in the multivariate model as well as interactions with other selected variables were systematically examined.

RESULTS

First Analysis

Univariate Analyses

Forty-four cases with first-episode PRMD were compared with 90 controls who had no history of PRMD. The mean duration of PRMD for cases with no prior PRMD history was 2.8 years (range = 1 year to 44 years; standard deviation = 6.9 years). Table I summarizes results from the univariate analyses. The only physical/demographic variable to approach statistical significance in univariate

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cases</th>
<th>Controls</th>
<th>Unadjusted odds ratio</th>
<th>P value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Gender</td>
<td>27/44</td>
<td>42/90</td>
<td>1.815</td>
<td>0.112</td>
<td>.8706-3.784</td>
</tr>
<tr>
<td>(61%)</td>
<td>(47%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>28.7</td>
<td>32.8</td>
<td>1.003</td>
<td>0.364</td>
<td>.9968-1.009</td>
</tr>
<tr>
<td>Number Years Played</td>
<td>17.6</td>
<td>22.2</td>
<td>0.9721</td>
<td>0.068</td>
<td>.9430-1.002</td>
</tr>
<tr>
<td>BMI</td>
<td>24.6</td>
<td>23.7</td>
<td>1.065</td>
<td>0.208</td>
<td>.9655-1.175</td>
</tr>
<tr>
<td>Strings</td>
<td>15/44</td>
<td>17/90</td>
<td>2.221</td>
<td>0.056</td>
<td>.9814-5.027</td>
</tr>
<tr>
<td>(34%)</td>
<td>(19%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypermobility</td>
<td>1.25</td>
<td>1.7</td>
<td>0.3203</td>
<td>0.151</td>
<td>.6775E-01-1.515</td>
</tr>
<tr>
<td>Trait Anxiety Performance</td>
<td>43.8</td>
<td>38.8</td>
<td>1.061</td>
<td>0.005</td>
<td>1.018-1.105</td>
</tr>
<tr>
<td>Work/Study Stress</td>
<td>5.98</td>
<td>5.1</td>
<td>1.118</td>
<td>0.095</td>
<td>.9806-1.275</td>
</tr>
<tr>
<td>General Life Stress</td>
<td>3.8</td>
<td>3.2</td>
<td>1.660</td>
<td>0.007</td>
<td>1.152-2.393</td>
</tr>
<tr>
<td>Stress</td>
<td>3.7</td>
<td>3.2</td>
<td>1.508</td>
<td>0.023</td>
<td>1.060-2.146</td>
</tr>
<tr>
<td>Musical Warmup</td>
<td>24/44</td>
<td>65/90</td>
<td>0.4615</td>
<td>0.044</td>
<td>.2177-.9786</td>
</tr>
<tr>
<td>Physical Warmup</td>
<td>3/44</td>
<td>16/90</td>
<td>0.3384</td>
<td>0.10</td>
<td>.9308E-01-1.230</td>
</tr>
<tr>
<td>Other Change</td>
<td>13/44</td>
<td>6/90</td>
<td>5.871</td>
<td>&lt;.001</td>
<td>2.052-16.80</td>
</tr>
<tr>
<td>Professional Musician Status</td>
<td>18/44</td>
<td>51/90</td>
<td>0.5294</td>
<td>0.088</td>
<td>.2548-1.100</td>
</tr>
<tr>
<td>(41%)</td>
<td>(57%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

analyses was the number of years playing the main instrument. Work/study stress, general life stress, and trait anxiety were the only significant psychological variables, and musical warmup and the variable “other changes” were the only significant playing-related behaviors. The variable “other changes” represents a range of playing-related changes listed by subjects on the questionnaire. None of the non-music-related activities (i.e., computer use, six activities of daily living, leisure activities/hobbies) were significant PRMD predictors. All instrument groups were examined in one model, using keyboardists as the reference group to facilitate ease of interpretation, as this group was large and more homogeneous than the other instrument groups. The use of a different reference group did not alter the findings. An examination of the instrument classification variable via a deviance test which compared a model with this classification to one with a grand mean alone did not establish global significance.

TABLE I. Univariate Logistic Regression Results (First Analysis) in Survey of Musicians

Musicians’ Musculoskeletal Disorders 295
The best-fitting multivariate regression model is shown in Table II. In the multivariate analysis with no interaction effects, string players had over four times the risk of developing a PRMD compared with non-string players. Females were more likely to have a PRMD compared with males. An increase in BMI was associated with an increase in PRMD risk. More years of playing an instrument was protective. Although age was correlated with the number of years a musician played ($r = .938$), it was not significant in multivariate analyses. To avoid multi-collinearity in the regression model, only trait anxiety (and not work/study stress) was included. In multivariate analysis, trait anxiety approached statistical significance (.088) in the main effects model, but this was lost in the final model. Whereas musical warmup was protective of injury, “other changes” significantly increased PRMD risk. Table III lists subjects’ responses for the variable “other changes.” Because the interpretation of this variable is difficult, if not impossible, it was not retained for further analysis despite the magnitude of its effect.

## Second Analysis

### Univariate Analyses

The second analysis compares all cases with all controls. Table IV shows the results of univariate analyses, controlling for the variable past PRMD. Of the physical and demographic variables, only hypermobility was significant. The psychological variables trait anxiety, performance anxiety, occupational stress, and general life stress were also significant. Statistically significant practice behaviors included breaks, physical warmup, and “other changes”; musical warmup approached statistical significance.

### Multivariate Analyses

Variables shown to be significant in the first analysis were retained in this model (see Table V). The interaction between strings and number of years played (significant in the first analysis) was not significant in this model, and,

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### TABLE II. Best-fitting Logistic Regression Model in the First Analysis of PRMD

<table>
<thead>
<tr>
<th>Variable</th>
<th>P value</th>
<th>Odds ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>% GM (intercept)</td>
<td>0.002</td>
<td>.2895E-02</td>
<td>.6614E-04–.1268</td>
</tr>
<tr>
<td>Strings</td>
<td>0.007</td>
<td>4.692</td>
<td>1.517–14.52</td>
</tr>
<tr>
<td>Number Years Played</td>
<td>0.010</td>
<td>0.9506</td>
<td>.9145–.9882</td>
</tr>
<tr>
<td>Gender</td>
<td>0.034</td>
<td>2.838</td>
<td>1.079–7.463</td>
</tr>
<tr>
<td>BMI</td>
<td>0.009</td>
<td>1.187</td>
<td>1.045–1.348</td>
</tr>
<tr>
<td>Trait Anxiety</td>
<td>0.088</td>
<td>1.041</td>
<td>.9941–1.09</td>
</tr>
<tr>
<td>Musical Warmup</td>
<td>0.030</td>
<td>.3715</td>
<td>.1518–.9096</td>
</tr>
</tbody>
</table>

Deviance on 121 DF = 131.598

BMI = body mass index.

### TABLE III. Response Items from Cases and Controls for "Other" Playing-Related Changes

<table>
<thead>
<tr>
<th>Cases</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>— Posture while playing</td>
<td>— Method of vibrato production</td>
</tr>
<tr>
<td>— Rotated seating for section players</td>
<td>— Transition from full-time student to professional musician</td>
</tr>
<tr>
<td>— Intensive exercise regime (e.g., bicycling)</td>
<td>— Broken arm, wrist</td>
</tr>
<tr>
<td>— Practiced less regularly in between work</td>
<td>— Practiced flute frequently with one-pound weights on each wrist...quite successful with no adverse stress</td>
</tr>
<tr>
<td>— Lots of new subs in [ensemble name]</td>
<td>— Changed cities and life in general</td>
</tr>
<tr>
<td>— Evolved slowly</td>
<td>— Still playing but private study has become far less frequent</td>
</tr>
<tr>
<td>— Change of school (actually alternating from school to work)</td>
<td>— Health: began to get in shape</td>
</tr>
<tr>
<td>— Auditions</td>
<td>— Moved to principal trumpet from section</td>
</tr>
<tr>
<td>— Family problems producing stress</td>
<td>— Overall schedule due to change of work situation</td>
</tr>
</tbody>
</table>

### TABLE IV. Univariate Logistic Regression Results Controlling for Past PRMD (Second Analysis)

<table>
<thead>
<tr>
<th>Variable</th>
<th>% or mean</th>
<th>Cases</th>
<th>Controls</th>
<th>Adjusted OR</th>
<th>P value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strings</td>
<td>43/110</td>
<td>49/171</td>
<td>1.485</td>
<td>0.135</td>
<td>.8836–2.496</td>
<td></td>
</tr>
<tr>
<td>Female Gender</td>
<td>66/110</td>
<td>89/171</td>
<td>1.416</td>
<td>1.66</td>
<td>.8654–2.316</td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>24.98</td>
<td>23.98</td>
<td>1.046</td>
<td>0.163</td>
<td>.9819–1.115</td>
<td></td>
</tr>
<tr>
<td>Hyperlaxity</td>
<td>5/110</td>
<td>23/171</td>
<td>0.3014</td>
<td>0.19</td>
<td>.1105–8.215</td>
<td></td>
</tr>
<tr>
<td>Number Years Played</td>
<td>21.4</td>
<td>22.5</td>
<td>0.9926</td>
<td>0.452</td>
<td>.9736–1.012</td>
<td></td>
</tr>
<tr>
<td>Trait Anxiety</td>
<td>4.32</td>
<td>4.09</td>
<td>1.031</td>
<td>0.019</td>
<td>1.005–1.057</td>
<td></td>
</tr>
<tr>
<td>Performance Anxiety</td>
<td>6.2</td>
<td>5.4</td>
<td>1.087</td>
<td>0.040</td>
<td>1.004–1.177</td>
<td></td>
</tr>
<tr>
<td>Work/Study Stress</td>
<td>3.68</td>
<td>3.34</td>
<td>1.411</td>
<td>0.007</td>
<td>1.098–1.812</td>
<td></td>
</tr>
<tr>
<td>General Life Stress</td>
<td>3.5</td>
<td>3.28</td>
<td>1.252</td>
<td>0.060</td>
<td>.9908–1.583</td>
<td></td>
</tr>
<tr>
<td>Musical Warmup</td>
<td>66/110</td>
<td>119/171</td>
<td>0.6397</td>
<td>0.088</td>
<td>.3830–1.068</td>
<td></td>
</tr>
<tr>
<td>Breaks</td>
<td>60/110</td>
<td>119/171</td>
<td>0.5343</td>
<td>0.015</td>
<td>.3217–8.873</td>
<td></td>
</tr>
<tr>
<td>Physical Warmup</td>
<td>9/110</td>
<td>32/171</td>
<td>0.3837</td>
<td>0.017</td>
<td>.1745–.8436</td>
<td></td>
</tr>
<tr>
<td>Other Changes</td>
<td>24/110</td>
<td>9/171</td>
<td>5.685</td>
<td>&lt;.001</td>
<td>2.493–12.97</td>
<td></td>
</tr>
</tbody>
</table>

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therefore, was not retained. In this analysis, hypermobility, physical warmup, and breaks were protective of a PRMD. All interactions between past PRMD and the other variables in the model were not found to be significant.

**DISCUSSION**

**Interpretation of Findings and Consistency with Other Studies**

The objective of this case-control study was to examine physical, psychological, and behavioral risk factors for PRMDs. Although all three types of variables were associated with PRMD risk, physical and demographic factors dominated in the explanation of PRMD risk, including gender, instrument, BMI, and the number of years the musician had played his or her instrument. This study confirmed previous findings that females and string players are at higher PRMD risk. The only other study to have measured BMI [Roach et al., 1994] did not find an association between BMI and PRMD risk. It is difficult to interpret the meaning of the increased risk associated with BMI, since the risk of some medical conditions associated with BMI may be curved and/or non-monotonic rather than linear (i.e., a BMI <20, and >25 may confer a higher risk). Also BMI is primarily an indication of whether an individual is at the appropriate weight for their body size, and does not indicate body composition or differentiate between weight from muscle mass and weight from fat. Many of the responses for the item “other changes” (Table III) represent a sudden change in playing time and/or a change in other playing-related factors. Considering the varying nature of responses to this open-ended item, further investigation of playing-related changes is warranted.

It is interesting to note that while performing a musical warmup was protective of a first-episode PRMD, it did not predict risk of recurrent PRMD. Likewise, taking breaks during practice sessions did not predict first-episode PRMD risk, but was protective of a recurrent PRMD. Since the data in Tables VI and VII represent pre-PRMD behaviors for cases, the likelihood of reverse causality may be decreased. There is evidence to suggest that musicians who experience a PRMD change some, but not all, of their practice behaviors as a result of their injury.

**Strengths and Limitations**

A principal strength of this case-control study was that it provided the opportunity to examine males and females performing the same tasks. This was true for all instrument groups except the guitarists, all nine of whom were male, and the harpists, all eight of whom were female. The ability to examine males and females performing identical work tasks is rare in many occupations [Silverstein et al., 1986; Stock, 1991; Viikari-Juntura, 1992]. Another strength was that this study allowed for a more comprehensive examination of PRMD risk by examining the individual and combined effects of physical, psychological, and playing-related behavioral factors. The identification of cases and controls was also comprehensive, in that several sites participated in this study. Through blinding of the PI during physical measurements, the use of a self-report questionnaire, and the use of a case definition developed by musicians and health care professionals in a separate study, the effect of researcher bias in this study was minimized. Despite the small sample
size in the first analysis, there was sufficient power to
demonstrate some important effects. The assumption that
work-related musculoskeletal disorders share a common
etiology is supported by the fact that several risk factors
were demonstrated for the aggregate outcome, PRMD. It is
recognized, however, that grouping many disorders into one
outcome may have decreased the ability to identify variables
which are risk factors for some conditions but not others.
Nevertheless, grouping several disorders into one outcome
is common practice in the occupational medicine literature
[Feuerstein and Fitzgerald, 1992; Stock, 1991].

The findings of this study support the use of an
operational case definition developed by the population of
interest through qualitative research methods. The suitability
of using such a case definition was reinforced by the fact that
findings from other studies were corroborated with the use
of this case definition. Thus, the operational case definition
was not only meaningful to musicians, it was also effective
for research purposes.

Perhaps the greatest limitation of the current study was
the fact that force, repetition, and posture were not measured
directly. The complex and changing nature of the musician’s
job presents obstacles to the quantification of force and
repetition. Although not measured directly, inferences regarding posture can be made by considering the positions
required to play each instrument in general. The higher risk
for string players may reflect the awkward asymmetrical posture and static loading required to play the violin, viola,
cello, and double bass.

Although the use of incident cases generally leads to a
better estimation of risk [Breslow and Day, 1980; Schlessel-
man, 1982], the gradual onset and chronic nature of PRMDs
makes it difficult if not impossible to identify truly incident
PRMD cases. Thus, this study oversampled chronic cases. In
an attempt to minimize this weakness, first-episode PRMDs
were identified for analysis; however, even first-episode
PRMD cases were chronic. By distinguishing cases with a
first-episode PRMD from those with a history of PRMD, we
were able to look for differences between prognostic risk
factors for recurrence and etiologic risk factors. Because a
necessary time interval between a prior and current PRMD
was not defined, it is possible that subjects with a long-
standing PRMD might have considered it to be two separate
episodes rather than one long PRMD. Although such a
misclassification error is theoretically possible, the qualita-
tive study suggests that it is not likely based on the
musicians’ definition of a PRMD.

Several potential biases may have influenced the study’s
findings. The non-response bias was assessed by examining
the available data from 85 non-respondents; these indicated
that the primary reason for non-participation was a busy
schedule. Participants also reported having busy schedules.

However, given that 52 of the non-respondents were con-
trols and 15 were cases (18 non-respondents did not specify
their status) a non-response bias cannot be ruled out. Recall
bias also cannot be ruled out, since fewer controls reported
events during the previous year compared with cases. Also,
recall may have differed for cases with a longstanding
PRMD compared with cases reporting a recently developed
PRMD. Although recall bias may be unavoidable with prevalent cases, if the PRMD latency period is lengthy
accuracy in recalling exposures may not be improved even
in incident cases [Schlesselman, 1982]. Even if present,
however, recall bias would not have affected the unmodifiable physical and demographic factors, for which there is the
strongest evidence in this study.

It is unavoidable that musicians who have permanently
stopped playing because of a PRMD were missed in this
study. Therefore, it is possible that the decrease in PRMD
risk associated with the number of years played may be due
to the fact that more experienced musicians with severe
PRMDs were no longer in the target population and could
not, therefore, be included in the study. As such, the survival
bias cannot be ruled out. The presence of a selection bias
was addressed by examining the variability of PRMD
severity in the study sample. Since we found varying
degrees of PRMD severity in the sample, it is unlikely that
the sample was biased toward very mild or very severe
cases. Error or bias due to misclassification was extensively
investigated in the case definition development studies
[Zaza, 1995; Zaza, 1996]. These studies showed that musi-
cians know when and how their playing is affected by a
PRMD, and that the case definition leads to accurate
classification of PRMD status. Therefore, while it is theoreti-
cally possible, bias due to misclassification is considered to
be unlikely in this study.

Prevention

Because PRMDs often lead to long-term morbidity and
disability and are highly prevalent, prevention efforts can be
justified so long as they are cost-effective, are based on
population-based research, and are unlikely to cause harm
[Zaza, 1993]. Although several unmodifiable risk factors
have been identified in this study and in other studies,
modifiable playing-related behaviors were also shown to
affect the risk of acquiring a PRMD. A musical warmup and
taking breaks should be incorporated into musicians’ prac-
tice routines because of their suggested roles in preventing
PRMD risk, and because they are not likely to cause harm,
and may even benefit the learning process. The evaluation of
the effectiveness of prevention programs may further clarify
the etiology of PRMDs.
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REFERENCES


