# Risk Factors for Piano-related Pain among College Students

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**Abstract**—Although pianists commonly report pain and musculoskeletal problems from playing, the related research literature on this topic is limited. The purpose of this study was to investigate the relationships between pain and several independent playing-related and anthropometric variables. Subjects included 35 piano majors attending a large college of music. Subjects were assessed with a questionnaire, bilateral anthropometric measurements of the upper arm and hand, and upper-extremity performance tests for range of motion, isometric strength, and rotation speed. Finger mobility, including active digit-to-digit span, was assessed using digital photography. Four questions regarding pain associated with piano were treated as dependent variables and used for correlation and regression analyses with other variables. A five-factor model emerged and each model was statistically significant. In addition to accounting for a large amount of variance associated with the dependent variables, results highlighted the importance of right 3–4 span (flexibility/mobility). This specific risk factor is rarely mentioned in the performing arts medicine literature. Additional studies are highly warranted for replication and for determining the clinical and pedagogical relevance of this finding. *Med Probl Perform Art* 2006; 21:118–125.

Research in performing arts medicine suggests that musicians experience pain and upper extremity musculoskeletal problems from playing the piano.[1–8] Studies point to age as an important factor and indicate that females tend to report more problems than males.[1–5] Hand size represents an important factor, and general anthropometric differences by gender may account for increased prevalence rates among females.[4,9]

Sakai[3] has argued that technical demands, such as playing octaves, chords, and *fortissimo,* increase risk and are responsible for the majority of the hand and forearm problems. Wolf et al.[10] also suggested that musculoskeletal problems are caused by playing loudly with high force and from using finger positions with high tendon and joint forces. Together, these studies imply that medical problems associated with piano performance involve a group of factors, including age, gender, hand size, technical requirements, biomechanical forces, and posture.

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There are limitations associated with this literature, and additional investigations are warranted. Bragge[11] indicated in his review of the literature that there are several methodologic limitations including statistical significance testing and that there is no consensus among authors regarding risk factors. Brandfonbrener[12] highlighted the need for studies regarding individual physical variants and argued that arm segment lengths, hand widths, and finger lengths and proportions "are all-important considerations as risk factors."

The published information regarding joint mobility, especially lateral movements of fingers, remains inconclusive. De Smet[4] reported that digit-to-digit span between the thumb and index finger is proportional to hand span and suggested a general correlation between these factors, whereas Wagner[9] reported weak correlations for within-hand digit-to-digit span characteristics. The related literature remains unclear as to whether non-thumb digit-to-digit spans are correlated with hand span and, most importantly, whether they are correlated with pain associated with performing piano. The purpose of this study was to investigate risk factors for piano-related pain among college students.

## METHODS

### Subjects

Following approval by the Institutional Review Board (IRB) of the University of North Texas, 35 piano performance majors at the university were recruited to participate in this study. Subjects were recruited through personal contact by the investigator, and they were compensated for their time.

### Procedure/Research Design

The investigation included the following procedures. During the first meeting, the IRB consent form was presented to, reviewed, and signed by the subject. A questionnaire was administered. During a second meeting, extensive upper arm and hand anthropometric measurements were taken, along with a battery of bilateral upper-extremity performance tests for range of motion, isometric strength, and rotation speed.

#### Questionnaire

The questionnaire consisted of three sections: demographics and musical background, practice habits, and med-

ical problems. The section on medical problems was divided into two subsections. The first subsection focused on pain associated with playing the piano as indicated in the following questions.

- Do you experience pain when playing?
- Do you experience pain after playing?
- Does pain stop you from playing the piano?
- How much of your playing is affected by your pain?

In this study, pain was conceptualized as one set of symptoms of a possible cluster of inter-related symptoms associated with playing-related musculoskeletal disorders (PRMD) as defined by Zaza et al.[13] Each question was presented with a visual analogue scale (VAS) anchored with adjective descriptors representing the full range of possible responses (i.e., never to always). Subjects were instructed to mark responses along the 10-cm line. The VAS is a reliable and valid approach for measuring pain.[14–16] To determine the number of painful sites, subjects also were asked to mark the locations of pain on dorsal and palmer graphic representations of hands and on the front and back graphic representations of the torso.

The second subsection asked about general problems with nonmusculoskeletal issues, including problems with anxiety, stage fright, depression, fatigue, etc. Subjects marked either no problem, mild, or severe for each problem.

### Anthropometric Measurements

A cloth measuring tape was used to take a series of bilateral upper extremity anthropometric measures, including upper arm length (tip of the acromion to the lateral joint interspace of the elbow), forearm length (lateral joint interspace of the elbow to the lateral joint interspace of the wrist), hand length (dorsal joint interspace of the wrist to the tip of phalange 3), and wrist circumference (along the line connecting the most distal portions of the ulna and radius). Industry-standard jewelers' rings were used for measuring the circumference of digit 2 at the proximal interphalangeal (PIP) joint.

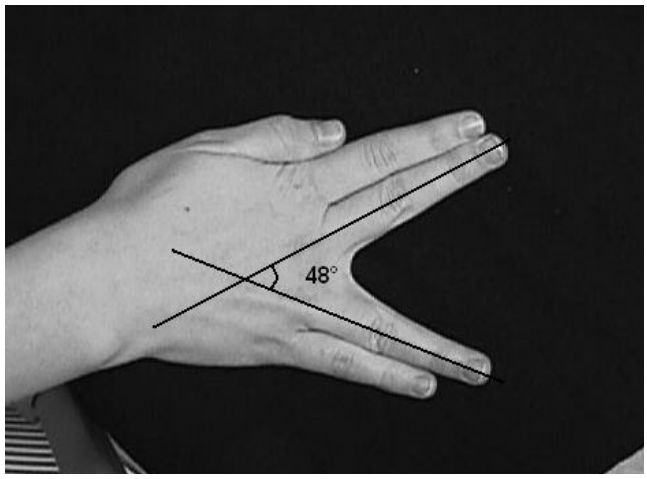


***FIGURE 1.*** Maximum digit-to-digit span for digits 3–4 (right hand).

Hand volumes were measured using the displacement method, inserting each hand into a water volumeter up to the distal prominence of the ulna (ulnar head). Hand span was measured on a flat ruler by placing the tip of the thumb at the point 0. Digit-to-digit span was measured using a digi-

***TABLE 1:*** **Demographic Characteristics and Music Background Data of Study Participants (*n* = 35)**

| **Demographics** | **No.** | **%** |
|---|---|---|
| Gender | | |
| Males | 8 | 22.9 |
| Females | 27 | 77.1 |
| Marital status | | |
| Single | 29 | 82.9 |
| Married | 6 | 17.1 |
| Race | | |
| Caucasian | 14 | 40.0 |
| Asian | 20 | 57.1 |
| Hispanic | 1 | 2.9 |

| **Variables** | **Minimum** | **Maximum** | **Mean** | **SD** |
|---|---|---|---|---|
| Age (yrs) | 21 | 41 | 27.17 | 4.99 |
| No. of children | 0 | 2 | 0.11 | 0.40 |
| Average amount of sleep (hrs/day) | 4 | 9 | 7.24 | 0.97 |
| Average amount of exercise (hrs/week) | 0 | 7 | 2.00 | 2.07 |
| Average travel (days/mo) | 0 | 25 | 2.91 | 4.59 |
| Age started piano (yrs) | 3 | 13 | 6.04 | 2.30 |
| Years of private lessons | 7.5 | 30 | 19.37 | 5.21 |
| Years of college piano | 2 | 20 | 7.33 | 4.27 |
| Size of hands (subjective)* | 0.10 | 10 | 4.78 | 2.51 |

*Subjects answered on VAS (0–10 cm).

*TABLE 2*: **Practice Habits**

| | Minimum | Maximum | Mean | SD |
|---|---|---|---|---|
| Practice hrs per wk | 3.0 | 42.0 | 24.83 | 8.46 |
| Lesson hrs per wk | 0 | 6.0 | 1.20 | 0.96 |
| Accompanying hrs per wk | 0 | 20.0 | 5.66 | 5.00 |
| Chamber music/ensemble hrs per wk | 0 | 6.0 | 1.11 | 1.62 |
| Teaching hours per week | 0 | 25.0 | 5.49 | 7.45 |
| Keyboard-related activities hrs per wk | 0 | 13.0 | 2.03 | 2.96 |
| No. of performances in school per semester | 0 | 40.0 | 5.28 | 7.29 |
| No. of performances outside school per semester | 0 | 20.0 | 3.13 | 4.29 |
| Practice hrs on upright piano per wk | 0 | 42.0 | 4.79 | 9.19 |
| Practice hrs on grand piano per wk | 0 | 55.0 | 23.23 | 12.74 |
| Do you warm-up before practice?* | 0 | 10.0 | 4.37 | 3.29 |
| Physical warm-up time spent (min) | 0 | 60.0 | 3.26 | 10.46 |
| Psychological warm-up time spent (min) | 0 | 60.0 | 2.03 | 10.23 |
| Musical warm-up time spent (min) | 0 | 45.0 | 17.71 | 13.07 |
| Do you take breaks during practice?* | 2.75 | 10.0 | 8.46 | 1.90 |
| How long are your breaks? (min) | 2.0 | 30.0 | 11.72 | 7.27 |
| How often do you take breaks? (hr) | 0.5 | 3.0 | 1.60 | 0.66 |
| Do you stop practice because of physical fatigue?* | 0 | 10.0 | 4.15 | 2.99 |
| Do you stop practice because of mental fatigue?* | 0 | 10.0 | 5.46 | 3.11 |
| Primary hand-related activities time spent (hrs/wk) | 0 | 19.0 | 3.67 | 3.99 |

*Subjects answered on VAS (0–10 cm).

*TABLE 3*: **Responses to Pain Questions and Nonmusculoskeletal Problems**

| **Pain Questions** | **Minimum** | **Maximum** | **Mean** | **SD** |
|---|---|---|---|---|
| Do you experience pain when playing? | 0 | 9.2 | 2.83 | 2.60 |
| Do you experience pain after playing? | 0 | 9.0 | 2.91 | 2.79 |
| Does pain stop you from playing? | 0 | 9.8 | 2.49 | 3.16 |
| How much of your playing is affected by pain? (%) | 0 | 100.0 | 29.91 | 25.82 |

| **Nonmusculoskeletal Problems** | **None** ***n*** **(%)** | **Mild** ***n*** **(%)** | **Severe** ***n*** **(%)** |
|---|---|---|---|
| Acquired dental malocclusion | 30 (85.7) | 3 (8.6) | 2 (5.7) |
| Acute anxiety | 27 (77.1) | 8 (22.9) | 0 (0) |
| Asthma | 32 (91.4) | 2 (5.7) | 1 (2.9) |
| Blackouts/dizziness | 32 (91.4) | 3 (8.6) | 0 (0) |
| Chest discomfort | 31 (88.6) | 4 (11.4) | 0 (0) |
| Chin rest sore | 34 (97.1) | 1 (2.9) | 0 (0) |
| Depression | 23 (65.7) | 12 (34.3) | 0 (0) |
| Earaches | 35 (100) | 0 (0) | 0 (0) |
| Eye strain | 25 (71.4) | 8 (22.9) | 2 (5.7) |
| Fatigue | 18 (51.4) | 14 (40.0) | 3 (8.6) |
| Headache | 21 (60.0) | 13 (37.1) | 1 (2.9) |
| Hearing loss | 34 (97.1) | 1 (2.9) | 0 (0) |
| Heart condition | 34 (97.1) | 1 (2.9) | 0 (0) |
| Hemorrhoids | 35 (100) | 0 (0) | 0 (0) |
| High blood pressure | 35 (100) | 0 (0) | 0 (0) |
| Inguinal hernia | 35 (100) | 0 (0) | 0 (0) |
| Loss of lip | 35 (100) | 0 (0) | 0 (0) |
| Loss of seal | 35 (100) | 0 (0) | 0 (0) |
| Mouth lesions | 34 (97.1) | 1 (2.9) | 0 (0) |
| Respiratory allergies | 28 (80.0) | 7 (20.0) | 0 (0) |
| Sleep disturbances | 27 (77.1) | 8 (22.9) | 0 (0) |
| Stage fright | 20 (57.1) | 14 (40.0) | 1 (2.9) |
| TMJ syndrome | 31 (88.6) | 4 (11.4) | 0 (0) |
| Ulcer | 33 (94.3) | 2 (5.7) | 0 (0) |
| Varicose veins | 35 (100) | 0 (0) | 0 (0) |
| Weight problems | 30 (85.7) | 4 (11.4) | 1 (2.9) |

*TABLE 4:* **Number of Pain Sites and Nonmusculoskeletal Problems**

| Total Sites/Problems | No. | % |
|---|---|---|
| **Pain Sites** | | |
| 0 | 3 | 8.6 |
| 1 | 7 | 20.0 |
| 2 | 4 | 11.4 |
| 3 | 4 | 11.4 |
| 4 | 9 | 25.7 |
| 5 | 1 | 2.9 |
| 6 | 1 | 2.9 |
| 7 | 2 | 5.7 |
| 8 | 2 | 5.7 |
| 10 | 1 | 2.9 |
| 14 | 1 | 2.9 |
| Total | 35 | 100.0 |
| **Nonmusculoskeletal Problems** | | |
| 0 | 5 | 14.3 |
| 1 | 7 | 20.0 |
| 2 | 5 | 14.3 |
| 3 | 2 | 5.7 |
| 4 | 4 | 11.4 |
| 5 | 3 | 8.6 |
| 6 | 3 | 8.6 |
| 7 | 2 | 5.7 |
| 8 | 3 | 8.6 |
| 11 | 1 | 2.9 |
| Total | 35 | 100.0 |

tal photographic (Sony Digital Mavica MVC-FD7) representation of the performers' hands on a flat surface against a black cloth. Four photographs were taken for each hand to measure maximum active digit-to-digit span between thumb–index, 2–3, 3–4, and 4–5 digits. Span angles were measured on the printed photograph as shown in Figure 1.

### Elements of Performance

Wrist range of motion, rotation speed, isometric strength, and pinch strength were measured bilaterally using the HPM Basic Elements of Performance XII System software and standardized protocol (Human Performance Measurement, Inc., Arlington, TX).

### Statistical and Analysis Methods

All statistical analyses were done using SPSS software. The four pain questions from the questionnaire were treated as dependent variables (criterion variables) and the rest of the variables were treated as independent variables (predictor variables).

The following statistical procedures were followed: 1) descriptive statistics for questionnaire, anthropometric data, and elements of performance data; 2) cross-correlations between independent variables and dependent variables; 3) inter-correlations of independent variables significantly corre-

*TABLE 5:* **Anthropometric Measures of Upper Extremity**

| Variable | Minimum | Maximum | Mean | SD |
|---|---|---|---|---|
| Height (cm) | 147.0 | 188 | 164.09 | 9.81 |
| Weight (kg) | 40.0 | 83 | 58.27 | 11.77 |
| Left upper arm length (mm) | 260 | 350 | 298.74 | 22.18 |
| Right upper arm length (mm) | 260 | 355 | 299.69 | 23.81 |
| Left forearm length (mm) | 215 | 288 | 245.97 | 22.00 |
| Right forearm length (mm) | 215 | 287 | 244.20 | 19.17 |
| Left hand length (mm) | 148 | 202 | 174.40 | 13.03 |
| Right hand length (mm) | 153 | 203 | 174.86 | 12.51 |
| Left wrist circumference (mm) | 135 | 181 | 153.77 | 12.40 |
| Right wrist circumference (mm) | 140 | 184 | 154.23 | 12.95 |
| Left index finger diameter (mm) | 15.3 | 21 | 17.70 | 1.47 |
| Right index finger diameter (mm) | 15.9 | 21.3 | 17.98 | 1.46 |
| Left hand volume (mL) | 187.5 | 500 | 335.71 | 98.34 |
| Right hand volume (mL) | 187.5 | 562.5 | 352.13 | 97.04 |
| Left hand span (mm) | 181.0 | 250 | 212.43 | 17.73 |
| Right hand span (mm) | 183.0 | 250 | 209.74 | 17.18 |
| Left max. interval on keyboard | 8 | 11 | 9.49 | 0.78 |
| Right max. interval on keyboard | 8 | 11 | 9.57 | 0.74 |
| BMI* | 16.12 | 27.46 | 21.50 | 3.02 |
| Left thumb-index span (deg) | 68 | 116 | 90.17 | 11.97 |
| Right thumb-index span (deg) | 64 | 114 | 87.03 | 10.63 |
| Left 2–3 span (deg) | 20 | 62 | 41.69 | 8.25 |
| Right 2–3 span (deg) | 17 | 54 | 39.17 | 8.03 |
| Left 3–4 span (deg) | 18 | 50 | 31.63 | 7.06 |
| Right 3–4 span (deg) | 10 | 48 | 29.69 | 8.40 |
| Left 4–5 span (deg) | 32 | 65 | 48.20 | 8.31 |
| Right 4–5 span (deg) | 18 | 64 | 45.49 | 8.59 |

*Body mass index, BMI = weight in kg / (height in cm)$^2$ × 10,000.

*TABLE 6:* **Basic Elements of Performance**

| Variables | Minimum | Maximum | Mean | SD |
|---|---|---|---|---|
| Range of motion left pronation (deg) | 61.7 | 153.9 | 101.28 | 20.21 |
| Range of motion left supination (deg) | 60.1 | 177.1 | 123.65 | 24.81 |
| Range of motion right pronation (deg) | 56.3 | 155.0 | 100.46 | 21.87 |
| Range of motion right supination (deg) | 92.9 | 175.8 | 131.87 | 22.90 |
| Rotation speed left pronation (deg/sec) | 331.0 | 1703.0 | 690.56 | 312.89 |
| Rotation speed left supination (deg/sec) | 277.5 | 1521.0 | 889.16 | 306.73 |
| Rotation speed right pronation (deg/sec) | 281.0 | 1374.0 | 655.80 | 275.89 |
| Rotation speed right supination (deg/sec) | 447.5 | 1487.0 | 885.89 | 268.75 |
| Isometric strength left pronation (N-m) | 2.3 | 21.1 | 6.53 | 3.70 |
| Isometric strength left supination (N-m) | 2.1 | 10.8 | 4.09 | 2.25 |
| Isometric strength right pronation (N-m) | 2.3 | 19.3 | 6.02 | 3.81 |
| Isometric strength right supination (N-m) | 2.4 | 13.0 | 6.45 | 2.28 |
| Pinch strength left (N) | 1.2 | 2.8 | 2.01 | 0.39 |
| Pinch strength right (N) | 1.0 | 5.0 | 2.29 | 0.83 |
| | **No.** | | % | |
| Hand dominance | | | | |
| Right | 33 | | 94.3 | |
| Left | 1 | | 2.9 | |
| Hyperlaxity | | | | |
| Yes | 6 | | 17.1 | |
| No | 29 | | 82.9 | |

lated with one or more dependent variable(s); 4) factor development for regression modeling by grouping together independent variables based on cross and inter-correlations with dependent variables; and 5) regression (Enter method) analysis for each dependent variable using one independent variable (highest correlation with dependent variable) from each factor.

## RESULTS

### Descriptive Analyses

The study participants ranged in age from 21 to 41 yrs (average, 27 yrs) and included 8 males (23%) and 27 females (77%). As shown in Table 1, the age at starting piano-playing ranged from 3 to 13 years. Over 50% of subjects reported Asian ethnicity.

Subjects reported an average of 24 hrs/week of practice time (Table 2). On average, subjects reported five school performances per semester and over 5 hrs of teaching per week.

Table 3 shows the responses to the four pain questions and responses to the nonmusculoskeletal problems. Eighty-six percent of subjects answered that they experienced pain when playing.

Nine subjects (25.7%) reported that they had musculoskeletal pain in four locations (Table 4). For nonmusculoskeletal problems, 20% of subjects answered that they had one problem.

The active digit-to-digit span data, shown in Table 5, indicates that the average left-hand span was larger than the right-hand span. Another tendency was that right-side anthropometric characteristics were generally larger than the left side, except for span and forearm length.

Almost 83% of subjects showed no signs of hyperlaxity (Table 6). The means of range of motion and rotation speed were greater for supination than for pronation. Left supination represented the weakest isometric strength measure.

### Cross- and Inter-correlations

Cross-correlations with independent variables showed many significant correlations with the four pain questions, as shown in Table 7. In general, anthropometric measurements were inversely correlated with the dependent variables.

Based on inter-correlations, variables were categorized into five groups (factors): 1) age/exposure, 2) size/strength/speed, 3) flexibility, 4) number of nonmusculoskeletal problems, and 5) number of musculoskeletal problems. Size, strength, and speed were significantly correlated and categorized into one factor. Hand span and range of motion were similarly treated, as shown in Table 8.

### Factor Identification

Factor identification for regression modeling resulted in a five factor set of independent variables for each of the four dependent variables. As shown in Table 9, the variable selected for each model to best represent the individual factors was not the same for each model. Conditions for choosing independent variables included 1) the highest correlations with each dependent variable, and 2) if this independent variable was significantly correlated with other variables selected for the model, the next or second highest correlated variable (indicated as *) was selected.

*TABLE 7:* **Variables Correlated with One or More Dependent Variables**

| Variables Significantly Correlated with Dependent Variables | Dependent Variables | | | |
|---|---|---|---|---|
| | Do you experience pain when playing? | Do you experience pain after playing? | Does pain stop you from playing the piano? | How much of your playing is affected by your pain? |
| Age | –0.161 | –0.044 | 0.412* | 0.214 |
| Age started piano | –0.153 | –0.288 | –0.234 | –0.467† |
| Years of private lessons | –0.029 | 0.137 | 0.314 | 0.372* |
| Height | –0.005 | –0.202 | –0.362* | –0.330 |
| Weight | –0.221 | –0.504† | –0.328 | –0.491† |
| BMI | –0.331 | –0.561† | –0.159 | –0.414* |
| Left upper arm length | –0.118 | –0.305 | –0.432† | –0.395* |
| Right upper arm length | –0.133 | –0.327 | –0.420* | –0.331 |
| Left forearm length | –0.007 | –0.221 | –0.313 | –0.356* |
| Right forearm length | –0.028 | –0.237 | –0.312 | –0.347* |
| Left wrist circumference | –0.321 | –0.583† | –0.374* | –0.550† |
| Right wrist circumference | –0.260 | –0.511† | –0.350* | –0.507† |
| Left index finger diameter | –0.357* | –0.589† | –0.426* | –0.434† |
| Right index finger diameter | –0.362* | –0.574† | –0.424* | –0.423* |
| Left hand volume | –0.170 | –0.374* | –0.250 | –0.326 |
| Right hand volume | –0.270 | –0.440† | –0.345* | –0.503† |
| Left hand span | –0.324 | –0.483† | –0.342* | –0.560† |
| Right hand span | –0.326 | –0.471† | –0.318 | –0.489† |
| Left interval on keyboard | –0.324 | –0.437† | –0.140 | –0.441† |
| Right thumb-index span | –0.165 | –0.164 | –0.323 | –0.368* |
| Right 3–4 span | –0.494† | –0.413* | –0.264 | –0.099 |
| ROM left pronation | –0.469† | –0.316 | –0.276 | –0.106 |
| ROM right pronation | –0.369* | –0.352* | –0.146 | –0.087 |
| Rotation speed left supination | –0.463† | –0.441† | –0.494† | –0.296 |
| Rotation speed right supination | –0.329 | –0.280 | –0.399* | –0.422* |
| Isometric strength left pronation | –0.314 | –0.376* | –0.268 | –0.385* |
| Isometric strength left supination | –0.252 | –0.345* | –0.271 | –0.389* |
| Isometric strength right pronation | –0.186 | –0.275 | –0.256 | –0.338* |
| Number of non-MS problems | 0.348* | 0.372* | 0.142 | 0.345* |
| Number of MS pain sites | 0.408* | 0.426* | 0.169 | 0.370* |

*Correlation is significant at the 0.05 level (2-tailed).
†Correlation is significant at the 0.01 level (2-tailed).

### Regression Analysis

As shown in Table 10, results from the regression analysis showed that each model was statistically significant ($p < 0.0005$ for models 1, 2, and 4 and $p < 0.005$ for model 3). The adjusted $R^2$ showed that variance accounted for ranged from 40% for model 3 to 60% for model 2.

For models 1 and 2, the β weight for factor 3, based on the right-hand 3–4 digit span variable, was the most or second strongest factor. As a follow-up analysis, the variable (right 3–4 span) was excluded from and then added to the regression model in order to observe the change of adjusted $R^2$. For model 1, the adjusted $R^2$ was increased from 0.361 to 0.549 by adding the right 3–4 span variable, and from 0.389 to 0.602 for model 2.

## DISCUSSION AND CONCLUSIONS

This study used a statistical approach to investigate risk factors for piano-related pain. Knowledge of these factors is needed to help understand why piano players report pain. Such information can be applied toward the development of effective preventative strategies and clinical responses to pain.

Results show that finger joint mobility, particularly right 3–4 span, is a risk factor for piano-related playing. This is an important finding because it has not been noted in previous studies. Consistent with reports for Pak[1] and De Smet,[4] this study also showed that age and size are important risk factors for pain. In this study, however, age was conceptualized as a factor or set of related variables due to significant inter-correlations. Similarly, size, strength, and speed were grouped into one factor. The data from this study indicated that time, or number of years, playing the piano is positively associated with problems. The negative association with size/strength/speed suggests that the piano players with smaller hands are at increased risk for problems. A positive association between factor 4 (number of nonmusculoskeletal problems) and the dependent variables suggests that a possible "overall health" factor may be involved.

*TABLE 8:* **Five Factors with Related Variables**

| |
|---|
| Factor 1—Age/exposure |
| Age |
| Age started piano |
| Years of private lessons |
| Factor 2—Size/strength/speed |
| Height |
| Weight |
| BMI |
| Upper arm length (L&R) |
| Forearm length (L&R) |
| Wrist circumference (L&R) |
| Index finger diameter (L&R) |
| Hand volume (L&R) |
| Hand span (L&R) |
| Maximum interval on keyboard (L) |
| Rotation speed (L&R supination) |
| Strength (L&R pronation & L supination) |
| Factor 3—Flexibility |
| Range of motion (L&R pronation) |
| Thumb-index span (R) |
| 3–4 span (R) |
| Factor 4—Number of Non-MS problem |
| Factor 5—Number of MS problems |

Together, as shown in model 2, five statistically independent factors accounted for about 60% of the variance in the dependent variable (adjusted $R^2$ = 0.602). Even though this study documents the apparent importance of right 3–4 span as a strong contributor to the overall variance associated with pain among pianists, 40% of the variance remains unaccounted for. As highlighted by Sakai,[3,5] biomechanical force and performance technique (octave and chords) are important factors to consider. Other factors, such as genetics and nutrition, also may be important to general and specific levels of vulnerability and susceptibility.

Because of the relevance associated with the right 3–4 span variable, this study needs to be replicated with larger and more diverse populations. The limitations associated with this study, including the small sample size and generally homogeneous level of performance ability among subjects pursuing a degree in piano performance, restrict generalizations from these findings.

Nevertheless, this study raises important questions for the field of performing arts medicine. Primarily, what are the developmental, pedagogical, and clinical implications for piano players with limited right 3–4 span? Considering that lateral movements of digits involve the metacarpophalangeal joint and extensor communis tendons, and that there are three distinct morphologic types of juncturae tendinum,[17] does pain implicate possible anatomical variants in the juncturae tendinum?

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*TABLE 9:* **Regression Model**

| | **Model 1 Do you experience pain when playing?** | **Model 2 Do you experience pain after playing?** | **Model 3 Does pain stop you from playing the piano?** | **Model 4 How much of your playing is affected by your pain?** |
|---|---|---|---|---|
| Factor 1 (Age / exposure) | Age | Years of college piano instruction* | Age | Years of private lessons* |
| Factor 2 (Size/strength/speed) | Rotation speed left supination | Left index finger diameter | Rotation speed left supination | Left hand span |
| Factor 3 (Flexibility) | Right 3–4 span | Right 3–4 span | Right thumb-index span | Right thumb-index span |
| Factor 4 (Non-MS problems) | Number of non-MS problems | Number of non-MS problems | Number of non-MS problems | Number of non-MS problems |
| Factor 5 (MS problems) | Number of MS location | Number of MS location | Number of MS location | Number of MS location |

*Second highest correlated variable.

***TABLE 10:*** **Regression Data**

| | Predictors | Beta | Adjusted $R^2$ | $F$ | $p$-Value |
|---|---|---|---|---|---|
| **Model 1** | | | 0.549 | 9.275 | 0.000 |
| Factor 1 | Age | –0.205 | | | |
| Factor 2 | Rotation speed left supination | –0.428 | | | |
| Factor 3 | Right 3–4 span | –0.430 | | | |
| Factor 4 | Number of non-MS problems | 0.184 | | | |
| Factor 5 | Number of MS problems | 0.263 | | | |
| **Model 2** | | | 0.602 | 11.287 | 0.000 |
| Factor 1 | Years of college piano instruction | –0.165 | | | |
| Factor 2 | Left index finger diameter | –0.540 | | | |
| Factor 3 | Right 3–4 span | –0.468 | | | |
| Factor 4 | Number of non-MS problems | 0.167 | | | |
| Factor 5 | Number of MS problems | 0.175 | | | |
| **Model 3** | | | 0.407 | 5.675 | 0.001 |
| Factor 1 | Age | 0.362 | | | |
| Factor 2 | Rotation speed left supination | –0.408 | | | |
| Factor 3 | Right thumb-index span | –0.316 | | | |
| Factor 4 | Number of non-MS problems | 0.203 | | | |
| Factor 5 | Number of MS problems | 0.074 | | | |
| **Model 4** | | | 0.447 | 6.500 | 0.000 |
| Factor 1 | Years of private lessons | 0.259 | | | |
| Factor 2 | Left hand span | –0.368 | | | |
| Factor 3 | Right thumb-index span | –0.164 | | | |
| Factor 4 | Number of non-MS problems | 0.227 | | | |
| Factor 5 | Number of MS problems | 0.235 | | | |


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