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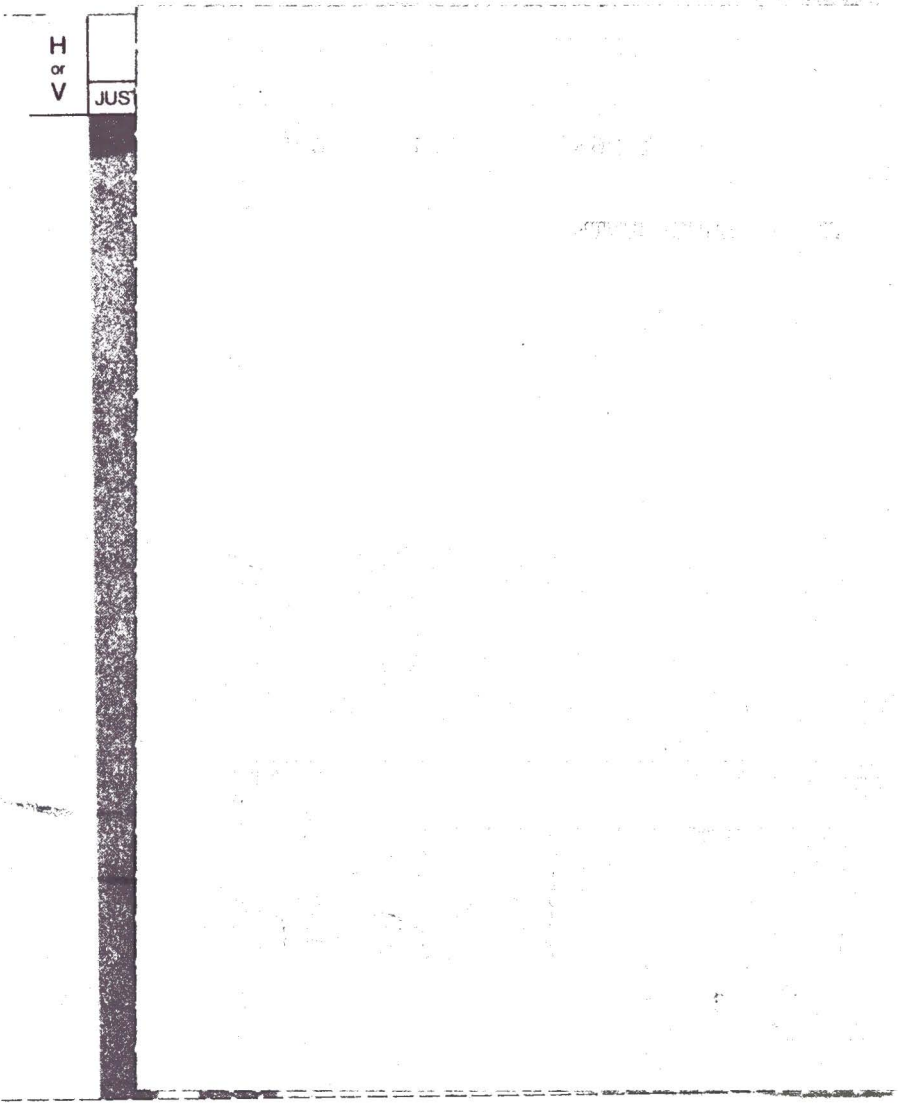
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Data were derived from the University of North Texas Musician Health Survey, involving keyboard instrumentalists. 455 keyboard instrumentalists were selected and musician type, daily playing time, gender, and age were examined as possible risk factors for musculoskeletal problems of the hand, finger, and wrist. Age was found to be a significant risk factor when all levels of pain were considered. Gender was found to be a significant risk factor for all levels of pain as well as severe pain. Musician type and daily playing time did not show statistical significance.

PREVALENCE OF HAND, FINGER, AND WRIST MUSCULOSKELETAL PROBLEMS IN KEYBOARD INSTRUMENTALISTS: THE UNIVERSITY OF NORTH TEXAS MUSICIAN HEALTH SURVEY

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PREVALENCE OF HAND, FINGER, AND WRIST MUSCULOSKELETAL PROBLEMS IN KEYBOARD INSTRUMENTALISTS: THE UNIVERSITY OF NORTH TEXAS MUSICIAN HEALTH SURVEY

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CHAPTER I

INTRODUCTION

Although occupational diseases and injuries have received a great deal of interest for many years, medical concerns for musicians, especially instrumentalists, have been neglected until recently (Brandfonbrener, 1990; Gorman & Warfield, 1987). Until the last two decades, with the development of specialists, many musicians were conjectured to rely on osteopathy, chiropractic, and acupuncture for treatment (Lambert, 1992). It has been estimated that nearly 200,000 people earn their living as performance artists in the United States. Of these artists, approximately 130,000 are instrumentalists and 20,000 are singers (Department of Labor, 1986; Lockwood, 1989).

Musculoskeletal problems in musicians, commonly referred to as 'overuse syndromes', have been mentioned in the literature as early as 1717 by Ramazinni (Pitner, 1990). In 1887, Poore introduced the term 'pianist's cramp', which was analogous to 'writer's cramp' by attributing the symptoms to muscle strain (Anonymous, 1985). More recently, Gary Graffman, a pianist, described his personal problem with his right hand that shortened his music career (Lederman, 1989). After seeing 18 physicians and encountering difficulties in finding knowledgeable medical

care for musicians, Graffman freely discussed his medical problems in public, helping to catalyze the development of performing arts medicine. After the appearance of featured articles that focused on performing arts medicine in the *New York Times* and other media in 1981, the first and only regularly published journal concentrated on performing artists, Medical Problems of Performing Artists, made its debut in March 1986. Since then, a number of multispecialty clinics and groups were formed and were dedicated to the investigation and treatment of the ailments afflicting performers (Lederman, 1989).

Today, overuse syndrome typically affects musicians, keyboard operators, and process workers, as well as doctors, lawyers, journalists, and other occupations that require repetitive motions, especially of the hand (Fry, 1986b).

Two clinical tests usually used for the overuse syndrome are muscle biopsy and intracompartment pressure monitoring, both of which are invasive and may be painful (Bengtson & Schutt & Swee & Berquist, 1993). Since the primary measurements of the overuse syndrome are pain and tenderness, generating accurate measurements are often difficult due to their subjective nature.

Most injuries suffered by performing artists demand long-term treatments and rest due to the strenuous and punishing activities of musicians, which are comparable to the activities of athletes (Palmer, 1997). Additionally, relief brought on by 48 hours of rest could be ruined by half an hour's strenuous practice unless the musician, with the guidance of a physician, identifies the particular movement or position that caused the symptoms (Anonymous, 1985).

The problems of occupational injury of musicians are complex. The majority of musicians were fairly reluctant to seek medical advice in the past, believing that physicians lack the knowledge and experience to treat them correctly. In addition, musicians often face fierce competition within their field, and the professional risk of publicly complaining of an injury drives them away from medical advice (Amadio & Rusotti, 1990; Palmer, 1997; Ziporyn, 1984). Because many musicians earn, on average, less than $20,000 annually from musical work alone, they are often without adequate health insurance and medical care (Brandfonbrener, 1990; Chmelar, 1990; Zaza, 1998). Although the number of musicians seeking medical help seems to be increasing, more research is needed to facilitate their rehabilitation process and identify possible risk factors for occupational injuries (Amadio & Russotti, 1990).

For the purpose of generating national health data for musicians of all ages and groups, Dr. Kris S. Chesky of the University of North Texas Music Department initiated an anonymous Internet survey in 1996. The survey inquired about musculoskeletal problems as well as non-musculoskeletal health problems among instrumentalists. The musculoskeletal portion of the survey utilized pain as the deciding symptom of the presence of musculoskeletal problems. The questionnaire examined the location, severity, and duration of reported pain. This Musician Health Survey is an ongoing study, in which over 4,000 musicians participated thus far.

Research questions were generated as follows:

1. What is the prevalence of finger, hand, and wrist musculoskeletal problems in keyboard instrumentalists among survey participants?

2. Does an association exist between musician type and the frequency of finger, hand, and wrist musculoskeletal hand pain among keyboard instrumentalists?

3. Are the daily instrument playing time, age, and gender related to finger, hand, and wrist musculoskeletal hand pain among keyboard instrumentalists?

CHAPTER II

LITERATURE REVIEW

Musculoskeletal problems in musicians were studied in various ways in the past. The most common categories of previously published studies were case reports, surveys and questionnaires, and clinical findings. In this literature review, several characteristics and risk factors associated with musculoskeletal problems in musicians were explored. First, the characteristics of keyboard instrumentalists were studied, along with differences between keyboard instrumentalists and other musicians. Next, the prevalence of finger, hand, and wrist musculoskeletal injury in keyboard musicians were discussed. The relationship between musician types and musculoskeletal injury prevalence was then explored, followed by the effects of age and gender. Furthermore, the link between duration of playing time and illness was identified. Lastly, the effect of pain severity in illness was examined.

Keyboard:

Musculoskeletal problems in musicians were variously referred to as cumulative trauma disorders, repetitive motion disease, repetition strain injuries, upper limb syndrome, and shoulder-arm syndrome (Blari & Bear-Lehman, 1987). However,

the most frequently used term was 'overuse syndrome'. Fry (1986c) defined the condition as " a painful condition of the hand and arm produced by hand-use-intense activity over long periods and use which is excessive for the individuals afflicted." Markison (1990) noted eleven medical conditions conducive to keyboard players that have produced pain: 1. Neck and shoulder problems; 2. Epicondylitis; 3. Proximal forearm flexor and extensor strain; 4. Posterior interosseous nerve compression; 5. Muscle-tendon junction pain in the mid-to-distal forearm; 6. Single or double crush of the ulnar nerves at the cubital tunnel and flexor carpi ulnaris origins as well as Guyon's canal; 7. Flexor tendinitis and tenosynovitis particularly of the flexor digitorum superficialis tendons in the forearm and wrist; 8. Carpal tunnel syndrome; 9. Basal joint thumb arthritis; 10. Flexor tenosynovitis with or without triggering at the A-1 pulleys; 11. Tenosynovitis in the extensor compartments, tendinitis on the hand dorsum, and connexus inflammation. Others defined the problem more broadly, categorizing it into the disorders of the musculoskeletal apparatus, nerve entrapment syndromes, and disorders of motor functions (Brandfonbrener, 1990; Smith, 1992).

In discussions involving hand and wrist injuries related to musicians, the risk factors were often divided into two types of factors: intrinsic and extrinsic. Intrinsic factors included size, strength, and tone of the muscles in the hand and wrist, flexibility of the joints and fingers, and presence of any underlying musculoskeletal disease. Extrinsic factors included instrument type, technique, and the musician's environment, usually affected by educational and economical background (Brandfonbrener, 1990; Fry, 1986d; Lederman & Calabrese, 1986; Pitner, 1990).

Specifically in keyboard players, in addition to the factors mentioned above, instrument playing posture, support of the instrument, and the resistance against which force must be applied in playing are also considered by many as extrinsic factors (Brandfonbrener, 1990; Ostwald, 1992; Tubiana & Chamagne & Borckman, 1989).

Although postural problems were not uncommon (Fry, 1984; Gorman & Warfield, 1987), one of the most frequently reported musculoskeletal complaint among keyboard players was pain and incoordination of the right hand, even though in some instances pain can be entirely absent in muscle failure (Amadio & Russotti, 1990; Fry, 1986d; Goodman & Staz, 1989; Knishkowy & Lederman, 1986; Larsson & Baum & Mudholkar & Kollia, 1993; Manchester, 1988; Shoup, 1995). In keyboard players, right hand complaints outnumbered those of the left hand in previous studies, generating theories that the right hand is more active and played under a greater demand than the left hand (Fry, 1988; Gorman & Warfield, 1987; Knishkowy & Lederman, 1986; Newmark & Hochberg, 1987). The fourth and fifth fingers of the right hand of keyboard instrumentalists, due to differential demands placed on the hands in most types of keyboard music, were found to be more susceptible to injury than other fingers (Gorman & Warfield, 1987; Lockwood, 1989; Lippmann, 1991). Wolf, Keane, Brandt, and Hillberry (1993) conducted biomechanical tests and concluded that finger positions and force exerted on the finger are directly correlated with musculoskeletal injury.

A major consequence of musculoskeletal injury is degraded motor function. Fry, Ross, and Rutherford (1998) found that pianists with overuse syndrome made more skill-based errors than pianists with no history of overuse. Other conditions that could result from musculoskeletal injuries are loss of control, diminished facility, endurance, and speed (Hochberg & Leffert & Heller & Merriman, 1983).

Prevalence:

In previous survey-based epidemiologic studies, prevalence rates among keyboard instrumentalists were not reported sufficiently. First, the majority of survey-based studies involved orchestra and symphonies in classical settings that rarely included keyboard players. The convenience of obtaining large samples in classical settings was evident, and as a result, the number of keyboard instrumentalists included was relatively small. This can be seen in one of the largest survey studies of musicians, conducted by Fishbein, Middlestadt, Ottati, Straus, and Ellis (1988). While Fishbein et al. recruited 2,212 musicians from 48 symphony orchestras, only 13 keyboard players were included in the study. According to the results of this literature search, the largest survey-based study found on keyboard instrumentalists recruited 89 pianists from Australia, North America, and the United Kingdom, using music schools and symphony orchestras as pool sources (Fry, 1988).

Therefore, better representations of keyboard players were generally seen in survey studies in clinical settings (Brandfonbrener, 1990). However, studies conducted in clinical settings were subject to selection bias, due primarily to an

unsystematic data collection which leads to a misrepresentation of the keyboard population. Furthermore, the investigators were not usually blinded because the primary investigators of the studies often were physicians who have treated the subjects previously (Bejjani & Kaye & Benham, 1996; Fry, 1986a; Fry, 1987; Zaza, 1998). Until the recent development of performing arts medicine, the majority of studies, especially clinical-based survey studies, were usually based on the authors' own experiences and often did not truly represent a random sampling approach (Baird, 1986; Bejjani & Kaye & Benham, 1996; Bengtson & Schutt, 1992; Dawson, 1992).

Second, a number of other studies that focused on the school aged musician population often failed to provide valid prevalence rates. A critical factor in survey studies of school-aged musicians is the time at which the survey is conducted. Prevalence of musculoskeletal problems could substantially differ among the beginning, middle, and the end of the semester. Studies conducted in the beginning of the semester are likely to show musical students who are well rested, projecting a low prevalence. However, towards the end of the semester, their prevalence is likely to increase, attributable to rigorous lessons and practice habits acquired during the semester (Roach & Martinez & Anderson, 1994).

Third, the exact number of keyboard players' participation in some studies was unknown (Caldron & Calabrese & Clough & Lederman & Williams & Leatherman, 1986; Fry, et al., 1988; Larsson et al., 1993; Newmark & Hochberg, 1987; Roach et al., 1994; Zaza, 1992). These studies often indicated the percentage of keyboard players illustrating musculoskeletal symptoms, yet the total number of survey participants was clearly absent, producing results that were not interpretable (Zaza, 1998).

Fourth, in studies where response rates were reported, they ranged from 29% to 100%, with the majority under 60% (Caldron, et al., 1986; Eller & Ostri & Dahlin & Suadicani & Gyntelberg, 1992; Fishbein et al., 1988; Hoppmann & Patrone, 1989; Manchester & Lustik, 1989; Newmark & Lederman, 1987; Newmark & Salmon, 1990; Quarrier, 1995; Salmon & Shook & Lombart & Berenson, 1995; Zaza, 1992). Low response rates are prone to biased results, often producing a sample that is not representative of the target population. Moreover, in other studies, prevalence was erroneously presented as incidence (Fry, 1986a; Newmark & Lederman, 1987; Zaza, 1998).

Fifth, some studies included trauma-induced injuries as well as recurring injuries and music-related injuries, which clouded the purpose of seeking performance-associated prevalence rates and could have introduced selection bias (Dawson, 1988a; Dawson, 1988b; Dawson, 1990; Zaza, 1998). In other studies, it was unclear if non-performance injuries were excluded (Zaza, 1998).

As a result, excluding such potentially biased studies left only a few valid studies that merit special discussion. According to Zaza (1998), who has conducted a literature review of prevalence studies with response rates over 60% and excluded non-performance related injuries, prevalence rates of playing-related musculoskeletal disorders (PRMD) ranged from 39% to 87% in adult instrumentalists including keyboard players and from 34% to 62% in secondary school music student instrumentalists (Fry, et al., 1988; Grieco & Occhipinti & Colombini & Menoni & Bulgheroni & Frigo, 1989; Larsson, et al., 1993; Lockwood, 1988; Pratt & Jessop & Niemann, 1992; Roach, et al., 1994; Zaza, 1998; Zaza & Farewell, 1997).

Playing Technique & Musician Type:

Although a convincing evidence linking musician type with prevalence of musculoskeletal problems is lacking, there are some studies that considered playing techniques as a risk factor. In an attempt to determine the effects of different piano playing styles, Chung, Ryu, Ohnishi, Rowen, and Headrich (1992) used biaxial electrogoniometry to assess the differences in wrist movements in standard exercises and classical examples of trills, arpeggios, octaves, and broken octaves, using nine pianists. The results showed that the wrist motions of weight playing were smaller than that used by the traditional method. Chung et al. also concluded that piano playing, when compared to daily activities, required a wider range of wrist movements, implying a higher risk for injuries. In a subjective study examining 40 Japanese pianists with hand and forearm pain, researchers attributed the source of pain

to specific techniques, including octaves, chords, fortissimo, arpeggios, and wide extended passage (Sakai, 1992). Newmark and Hochberg (1987) also found that rapid passages requiring arpeggios, octaves, or trills were associated with playing-induced pain. While musician types may not have the same effect as playing techniques, they are believed to be similar in respect that both variables examine the subtle variation in ways the instrument is played.

Using MEDLINE and articles from Medical Problems of Performing Artists, only one study was found that discussed the differences among musician types (Newmark & Salmon, 1990). While the study did acknowledge the diversity of participants' musical types, the authors neglected to project an interpretation regarding the effects of musician types on musculoskeletal injuries.

Age:

Based on a number of studies, age has not been sufficiently proven as a risk factor associated with frequency of injuries thus far (Brandfonbrener, 1990; Fry, 1986a; Hiner & Brandt & Katz & French & Beczkiewicz, 1987; Lockwood, 1988; Manchester, 1988). Moreover, Fishbein et al. (1988), concluded that among symphony orchestras, the prevalence rate actually showed a slight decline with age.

In a clinical study conducted by Bejjani, Gross, and Brown (1984), the development of hand disorders was determined to be associated with the age at which the musician first started to play. Fry (1986e) also showed a direct relationship between age and musculoskeletal problems among musicians, that did not include

keyboard instrumentalists. According to this study, a sharp increase of musculoskeletal problems was seen in ages 25 to 35. Cunningham and Kelsey (1984) examined data from the US Health and Nutrition Examination Survey (HANES I), and reported that among all factors analyzed, 10 year increase in age showed the most significant association with musculoskeletal problems in the general US population.

In most studies reviewed, however, the age variable has not been extensively studied as a risk factor. Due to the chronic nature of musculoskeletal problems, and the longevity of musician's careers, conditions such as osteoarthritis should be considered, which to some degree is inevitable with aging (Lederman & Calabrese, 1986). Analysis on the effects of aging has been underreported in some cases due to an inappropriateness in school-based and orchestra-based studies where the sample was generally not stratified by age (Fry et al., 1988; Lockwood, 1988; Roach et al., 1994; Zaza, 1992).

Gender:

Gender has also been identified in numerous studies as a possible risk factor for musculoskeletal conditions. In these previous studies, female musicians showed a higher frequency of performance-related musculoskeletal problems than males, especially of the hands (Brandfonbrener, 1990; Fishbein, et al., 1988; Fry et al., 1988; Goodman & Staz, 1989; Larsson et al., 1993; Lockwood, 1988; Manchester & Flieder, 1991; Roach et al., 1994; Zaza, 1992). Some of the proposed theories concerning the difference are hand size, hand and arm strength flexibility, and joint laxity of the hand

(Brandfonbrener, 1990). There was also evidence that small hand size is disadvantageous for the type of music that requires rapid movements of the extensors (Anonymous, 1985). However, these theories have not been investigated sufficiently to derive concrete conclusions. Furthermore, Lockwood (1988) demonstrated that no correlation was seen between hand size and the likelihood of developing a problem. Although a higher risk was associated with larger string instruments in females in the International Conference of Symphony and Opera Musicians (ICSOM) study, it was unclear whether this difference was due to smaller hand or finger size, arm segment size, strength, or a combination of these and other factors (Fishbein et al., 1988).

Playing Time:

Musical performance can be viewed as a highly skilled neuromuscular activity requiring both speed and endurance. The force applied to create the music itself is relatively low, so that strength is considered a secondary requirement. Nevertheless, as for any endeavor, the combination of skill, speed, and endurance is understood to be best developed by steadily increasing the amount of repetition and the speed of performance until the desired levels are met (Amadio & Russotti, 1990).

In a study of serious amateurs mixed with professional instrumentalists, Newmark and Lederman (1987) showed that the symptoms of overuse syndrome were associated with rapid changes in the quantity and quality of playing. The authors cited a 72% occurrence rate of overuse syndrome symptoms in the subjects when there was a dramatic and sudden increase in time spent playing the instrument. Brandfonbrener

(1990), Manchester and Flieder (1991), and Hiner et al. (1987) also noted a strong linear relationship between the hours spent playing an instrument and the frequency of musculoskeletal injuries. In a case-control study of musicians, athletes, and other occupations, Byl, Wilson, Merzenich, Melnick, Scott, Oakes, and McKenzie (1996) concluded that subjects with degraded sensory motor function in their hands were more likely to be involved in repetitive task occupations. In another case-control study, Manchester and Park (1996) found that university students with performance-related problems practiced more hours as freshmen than controls, although no further differences in practice hours were seen in later years in college. Newmark and Lederman (1987) studied instrumentalists through a survey and found a direct relationship between rapid increase in playing time and frequency of new overuse cases.

Other studies did not find a significant association between practice/playing time and injury (Lockwood, 1988; Roach et al, 1994). Lockwood (1988) surveyed secondary school-aged musicians and found no significant differences in practice habits between musicians with medical problems and those without.

Pain Severity:

The most commonly used scale in previous studies was Fry's severity scale or its modified version (Fry, 1986a):

> *Grade 1: Pain while playing; should be consistent rather than occasional; pain ceased when not playing*

Grade 2: Pain while playing; slight physical signs of tenderness; may have transient weakness or loss of control; no interference with other uses of this location
Grade 3: Pain while playing; pain persists away from instrument; some other uses of this location cause pain; may have weakness, loss of control; loss of muscular response or dexterity
Grade 4: As for Grade 3; all common uses of the location cause pain – housework, driving, writing, turning knobs, dressing, washing, etc. – but these are possible as long as pain is tolerated
Grade 5: As for Grade 4; including loss of use of location due to disabling pain

Most studies reviewed that utilized a severity scale used Fry's scale of grades one through five (Fry, 1986b; Fry, 1986c; Fry, 1988, Lockwood, 1988; Manchester & Lustik, 1989; Shoup, 1995). Hiner et al. (1987) used a 5 point Likert scale while Zaza (1992) has cited her own version, and Fishbein et al. (1988) simply separated mild problems from severe ones based on his own classification.

In clinical studies, pain severity scales were mainly utilized to compare pre and post-treatment comparisons and follow-up studies (Manchester & Lustik, 1989; Goodman & Staz, 1989). Others employed the severity scale to compare the median score between variables (Hiner et al., 1987); to differentiate between mild and severe problems (Fishbein et al., 1988; Lockwood, 1988; Shoup, 1995; Zaza, 1992); to determine the advancement stage of the injuries (Fry, 1986b; Fry, 1988); or to determine appropriate treatments according to the score (Fry, 1986d).

Although the interpretations and uses of severity scale are limited, it can be a valuable tool in differentiating mild cases from severe cases. This can facilitate the identification of more critical cases and perhaps help define a population that is more in need of a rehabilitation than others.

CHAPTER III

METHODS

The University of North Texas Musician Health Survey:

Conducted by Dr. Kris S. Chesky and three graduate students of University of North Texas (UNT), the UNT Musician Health Survey was initially created in 1996 to examine the non-classical musician population often neglected in previous studies. Using the Internet as the medium, Dr. Chesky and his students developed a questionnaire targeting musicians of various backgrounds in various geographic locations throughout the United States. Subjects were recruited through World Wide Web (WWW) links, on-line Internet discussion groups, advertisements in professional publications, and notices by professional societies and organizations.

Located at the address http://www.scs.unt.edu/surveys/msurvey/index.html, The UNT Musicians Health Survey is an anonymous survey consisting of five major sections: demographics, musculoskeletal problems, non-musculoskeletal medical problems, lifestyle/environment, and feedback/form submission.

Questions in the demographics section address the musician's ethnicity, gender, permanent residence, height, weight, formal college music education, musician type, performance area, instrument played, years as a professional musician, percentage of income from performing music, other sources of income, average annual income, and possession of health insurance.

In the musculoskeletal problems section, the survey questions concerning 16 bilateral body locations including fingers, hands, wrists, forearms, elbows, shoulders, neck, upper back, middle back, lower back, hips, knees, calves, ankles, feet, and toes. The survey also inquires about pain severity and duration of pain as well as physician intervention and prior treatment information.

In the next section, medical problems unrelated to musculoskeletal origin are explored. Similar to the ICSOM study, this section contains questions regarding a number of variables. The medical conditions included are: acquired dental malocclusion, acute anxiety, asthma, blackouts and dizziness, chest discomfort, chin rest soreness, depression, earaches, eye strain, fatigue, headaches, hearing loss, heart condition, hemorrhoids, high blood pressure, inguinal hernia, loss of lip, loss of seal, mouth lesions, respiratory allergies, sleep disturbances, stage fright, TMJ syndrome, ulcers, varicose veins, and weight problems.

The lifestyle and environment section recognizes additional possible risk factors to musicians' health, and includes daily playing time, daily sleep habit, weekly exercise routine, diet, marital status, number of children, stress level, weekly alcohol consumption, daily cigarette consumption, beta blocker usage, and opinion of drug use among musicians.

Following the lifestyle and environment section, the feedback section inquires a few questions regarding the survey itself and the length of time required to complete the survey. At the end is an open text section that allows the user to provide comments in response to the survey.

Statistical Analyses:

Data were obtained in the SPSS coded form from Dr. Kris S. Chesky of the University of North Texas Health Science Center, School of Public Health. The age variable was converted from continuous to categorical data, consisting of six age groups. The total number of subjects was 455. All subjects reported their age. Gender was defined as either male or female. Seven subjects were excluded in analyses involving gender due to missing data. Eighteen musician types were initially considered, but due to an uneven distribution, they were reduced to these six major types: church/traditional, classical, educator, jazz, composer/arranger, and casual. Combining the excluded musician types to closely related types was considered. However, because of the distinctive style utilized in each music type, the link between selected and unselected music type was considered weak. Therefore, the twelve

unselected musician types were eliminated rather than combined with selected types. The six types were then recoded and their prevalence tabulated. Three keyboard instrumentalists did not report their music type, and thus were excluded in analyses involving musician type variable. The daily instrument playing time variable was recoded into three categories: less than two hours per day, between three and five hours per day, and over five hours per day. Eighteen subjects did not report their daily instrument playing pattern, and were excluded in the data analyses involving playing time. Reported pain severity at left and right fingers, left and right hands, and left and right wrists were recoded dichotomously into pain and no-pain groups. No data were missing in the reported pain variable. All data were categorical.

Data were analyzed using the SPSS statistical software program (SPSS Incorporated, Chicago, Illinois). Frequency tabulations in each category were conducted in order to define the population by age, gender, musician types, and daily instrument playing time. These four variables were then cross-tabulated with the dependent variable, which was whether or not the individual reported pain at the six body locations described above. The percentages of the individuals who reported pain at those locations were calculated as the prevalence within that group. Due to the low frequency, pain severity was dichotomized into mild and severe pain levels, as opposed to diluting the sample. Mild pain was equal to the grades 1 and 2 used in the survey, whereas severe pain was defined as grades 3, 4, and 5.

Chi-square tests were employed to test for significant differences between instrumentalists with musculoskeletal pain and those without pain on the four variables described above. Pearson chi-square values and their p-values were obtained to determine whether or not the paired variables were statistically independent. In prevalence analysis among age groups, linear-by-linear association chi-square value was also employed to find the significance of the declining trend among older age groups. All hypotheses were tested at the 0.05 level of significance.

CHAPTER IV

RESULTS

Overall distribution of the keyboard instrumentalists who participated in the survey is found in Table 1. The survey participants ranged in ages from 14 to 69 years. Over 70% of the participants were in the 21 to 50 age range. The survey identified 45.8% males and 54.2% females. Eighteen different musician types were chosen by keyboard instrumentalists in the survey. Classical keyboard players far outnumbered other categories, registering 40.7% of total participants. Excluding the 'other' category, classical musician type was followed by educator (22.1%), composer/arranger (8.8%), church/traditional (7.7%), jazz (6.0%), and casual (2.7%). Over 54% of the keyboard instrumentalists in the survey reported daily instrument playing time of less than two hours, while 36.2% reported between three and five hours, and 9.6% reported over five hours of daily playing time.

Table 1. Distribution of Keyboard Instrumentalists by Age, Gender, Musician Type, and Daily Playing Time

Variable	Frequency	Percent (%)
Age		
10-20	66	14.5
21-30	114	25.1
31-40	102	22.4
41-50	115	25.3
51-60	44	9.7
>60	14	3.0
Total	455	100
Sex		
Male	205	45.8
Female	243	54.2
Total♦	448	100
Musician Type		
Alternative	2	0.4
Bluegrass	1	0.2
Blues	4	0.9
Casual/General Business	12	2.7
Church/Traditional	35	7.7
Classical	184	40.7
Composer/Arranger	40	8.8
Contemporary Christian	3	0.7
Country	1	0.2
Educator	100	22.1
Gospel	6	1.3
Jazz	27	6.0
Latin	2	0.4
R & B	1	0.2
Rock	4	0.9
Studio	7	1.5
Theater/Musicals	7	1.5
Other	16	3.5
Total♠	452	99.7§
Playing Time		
0-2 Hours	237	54.2
3-5 Hours	158	36.2
>5 Hours	42	9.6
Total¶	437	100

♦ 7 subjects did not report gender

♠ 3 subjects did not report musician type

¶ 18 subjects did not report playing time

§ Percentage total does not equal 100 due to rounding

Table 2 shows the distribution of reported musculoskeletal pain by location. Among keyboard instrumentalists, grade 1 was the most frequently reported severity of pain when it was present, followed by grade 3, 2, 4, and 5. The percentages of keyboard instrumentalists reporting pain by location is shown in Table 3. Right wrist (34.5%) was the most frequently reported site of the six locations. It was followed by left wrist (29.7%), right fingers (25.1%), right hand (24.4%), left hand (21.8%), and left fingers (21.1%). In terms of location, wrists scored a higher prevalence of pain compared to fingers and hands.

Table 4 shows the prevalence according to four studied variables: age, gender, musician type, and playing time. Stratification of those subjects with the presence of pain revealed an overall inverse pattern with age, with an exception of over 60 group. A Pearson chi-square test did not find statistically significant relationship between age and presence of finger, hand, or wrist musculoskeletal pain ($p = 0.052$). However, when linearity was examined among age groups, the test revealed a significant result. The inverse association of age and prevalence was statistically significant ($p = 0.003$). Female keyboard instrumentalists (66.3%) reported a higher prevalence than male counterparts (50.7%). A chi-square test revealed a significant difference between the two groups, associating the female gender with a higher prevalence ($p = 0.001$). Within the musician type variable, prevalence varied widely among different categories. Jazz musicians reported the highest prevalence of 81.4%, followed by classical keyboard players (63.3%), composers (60%), educators (56%), church musicians (51.4%), and casual keyboard instrumentalists (41.7%). A chi-square test

Table 2. Distribution of Reported Musculoskeletal Pain among Keyboard Instrumentalists by Location

Location	Severity of Reported Pain						
	No Pain	1	2	3	4	5	Total
Right Fingers	341	52	25	20	14	3	455
Left Fingers	359	47	16	20	10	3	455
Right Hand	344	46	18	27	18	2	455
Left Hand	356	41	17	27	14	0	455
Right Wrist	298	55	23	42	32	5	455
Left Wrist	320	52	23	39	18	3	455
Total		293	122	175	106	17	

Table 3. Prevalence of Reported Musculoskeletal Pain among Keyboard Instrumentalists by Location (N = 455)

Location	Frequency	Percent of N
Right Fingers	114	25.1%
Left Fingers	96	21.1%
Right Hand	111	24.4%
Left Hand	99	21.8%
Right Wrist	157	34.5%
Left Wrist	135	29.7%

Table 4. Prevalence of Reported Musculoskeletal Pain in Keyboard Instrumentalists by Age, Gender, Musician Type, and Daily Playing Time

Variable	Frequency	Percent	χ^2	p value
Age			$\chi^2=10.949$	$p=0.052$
10-20	48	48/66=72.7%	$\chi^2=8.878$¶	$p=0.003$¶
21-30	72	72/114=63.2%		
31-40	59	59/102=57.8%		
41-50	58	58/115=50.4%		
51-60	22	22/44=50%		
>60	8	8/14=57.1%		
Total	267	267/455=58.7%		
Gender			$\chi^2=11.090$	$p<0.001$
Male	104	104/205=50.7%		
Female	161	161/243=66.3%		
Total	265	265/448=59.2%		
Musician Type			$\chi^2=8.280$	$p=0.141$
Church/Traditional	18	18/35=51.4%		
Classical	107	107/184=63.3%		
Educator	56	56/100=56%		
Jazz	22	22/27=81.4%		
Composer/Arranger	24	24/40=60.0%		
Casual	5	5/12=41.7%		
Total	232	232/398=58.3%		
Playing Time			$\chi^2=2.361$	$p=0.307$
0-2 Hours	135	135/237=56.9%		
3-5 Hours	100	100/158=63.3%		
>5 Hours	22	22/42=52.4%		
Total	257	257/437=58.8%		

12 other musician types were excluded due to low frequency

¶ Linear-by-linear association chi-square test

did not show a significant relationship between musician type and presence of reported musculoskeletal pain ($p = 0.141$). No distinctive pattern was seen in the instrument playing time variable. Those players who played their instruments two hours or less on a daily basis reported a prevalence of 56.9%, whereas those who played between two and five hours reported 63.3% and the rest who played over five hours showed a prevalence of 52.4%. A chi-square test did not reveal a significant relationship between the daily instrument playing time and reported musculoskeletal pain presence.

When pain severity grades 1 and 2 were excluded, prevalence of reported pain declined substantially (Tables 5 & 6). Table 5 shows relatively similar pattern seen in Table 3, which included mild pain. In Table 5, however, prevalence of right (10.3%) and left (9.0%) hand pain was higher than that of right fingers (8.1%). The reverse is true when mild and severe pain were considered together (Table 3).

Table 6 shows the same variables in relation to the prevalence of reported musculoskeletal pain. When age variable was considered, the pattern differed from overall prevalence (Table 4). Focusing on severe pain only, the 51 to 60 years group reported the highest prevalence (35.7%), followed by 31-40 group (32.4%), 41-50 group (31.8%), 10-20 group (30.3%), 21-30 group (27.2%), and 31-40 group (26.9%). This was different from Table 4, which showed groups below 40 years old with higher prevalence compared to groups over 40 years old. The total prevalence declined from 58.7% overall (Table 4) to 29.5% in severe pain only (Table 6). When gender was considered, female keyboard instrumentalists showed a higher prevalence (34.2%)

Table 5. Prevalence of Severe Pain* among Keyboard Instrumentalists by Location

Variable	Frequency	Percent
Location		
Right Fingers	37	37/455=8.1%
Left Fingers	33	33/455=7.3%
Right Hand	47	47/455=10.3%
Left Hand	41	41/455=9%
Right Wrist	79	79/455=17.4%
Left Wrist	60	60/455=13.2%

* Severe pain = pain severity grades 3, 4, and 5

Table 6. Prevalence of Severe Pain* among Keyboard Instrumentalists by Age, Gender, Musician Type, and Playing Time

Variable	Frequency	Percent With Pain	χ^2	p value
Age Groups			χ^2=1.366	p=0.850
10-20	20	20/66=30.3%		
21-30	31	31/114=27.2%		
31-40	33	33/102=32.4%		
41-50	31	31/115=26.9%		
51-60	14	14/44=31.8%		
>60	5	5/14=35.7%		
Total	134	134/455=29.5%		
Sex			χ^2=5.081	p=0.024
Male	50	50/205=24.4%		
Female	83	83/243=34.2%		
Total	133	133/448=29.7%		
Musician Type			χ^2=1.809	p=0.771
Church/Traditional	13	13/35=37.1%		
Classical	53	53/184=28.8%		
Educator	26	26/100=26%		
Jazz	9	9/27=33.3%		
Composer/Arranger	12	12/40=30%		
Casual	4	4/12=33.3%		
Total	134	134/398=33.7%		
Playing Time			χ^2=0.859	p=0.651
0-2 Hours	68	68/237=28.7%		
3-5 Hours	52	52/158=32.9%		
>5 Hours	12	12/42=28.6%		
Total	132	132/437=30.2%		

* Severe pain = pain severity grades 3, 4, and 5

than male counterparts (24.4%). This is similar to the results seen in Table 4. Within the musician type variable, excluding mild pain, the highest prevalence was seen in the church/traditional keyboard players (37.1%). Casual keyboard players (33.3%) and jazz players (33.3%) were next, followed by composer/arrangers (30.0%), classical musicians (28.8%) and educators (26.0%). This differed from a pattern seen in overall prevalence (Table 4). When daily playing time factor was examined, similar pattern was seen in severe pain prevalence as in overall prevalence (Tables 4 & 6). A statistically significant relationship between gender and severe pain prevalence ($p=0.025$) was found. No other variables was statistically significant.

Table 7 further examines the difference in prevalence between genders. Prevalence ratio (Table 7) of males versus females within each age group was calculated to facilitate the comparison. When males and females were not stratified by age, the prevalence ratio of females to males was 1: 1.31 (Table 4). However, when age stratification was applied, there was a noticeable difference among age groups. Excluding the over 60 group due to small sample size, the largest prevalence ratio was seen in the 21-30 group (1: 1.44), followed by 10-20 group (1: 1.40), 51-60 group (1: 1.26), 41-50 group (1: 1.15), and 31-40 group (1: 1.04) (Table 7).

Table 7. Prevalence of Reported Musculoskeletal Pain among Keyboard Instrumentalists by Age Group and Gender

Age Groups (N)	Pain	No Pain	Prevalence	Prevalence Ratio (F : M)
10-20				
M (21)	12	9	57.1%	
F (45)	36	9	80.0%	1 : 1.40
21-30				
M (42)	21	21	50.0%	
F (71)	51	20	71.8%	1 : 1.44
31-40				
M (45)	26	19	57.8%	
F (53)	32	21	60.4%	1 : 1.04
41-50				
M (68)	32	36	47.1%	
F (46)	25	21	54.3%	1 : 1.15
51-60				
M (24)	11	13	45.8%	
F (19)	11	8	57.9%	1 : 1.26
>60				
M (5)	2	3	40.0%	
F (9)	6	3	66.7%	1 : 1.67

CHAPTER V

DISCUSSION

The present study differs from previous reported studies in three respects. First, data collection was conducted from a self-reported survey posted on the Internet. Second, the demographics of the participants were not limited to occupational or geographical constraints. Third, this study investigated the effects of musician types on the frequency of musculoskeletal injuries among keyboard instrumentalists.

Although the present study examined keyboard players exclusively, the results of this study compared similarly with previous surveys of musculoskeletal problems among musicians. This can be somewhat misleading due to the variation in past studies. Previous studies varied greatly in study populations in terms of age, skill level, instruments played, and gender. Consequently, previously published results revealed a rather broad range of prevalence. The fact that the findings of the present study fit within that wide range of prevalence percentage does not validate this study. The results of this study falling within previously reported prevalence ranges only indicates that the present study did not produce any extreme findings.

Overall Prevalence and Limitations:

The results of this study showed that 58.7% of the survey participants reported at least one musculoskeletal pain in the fingers, hands, or wrists (Table 4). This is well within the range assessed from other valid, survey-based, prevalence studies, which yielded prevalence ranging from 39% to 87% in general musician population, including keyboard instrumentalists (Fry, et al., 1988; Grieco, et al., 1989; Larsson, et al., 1993; Lockwood, 1988; Pratt, et al., 1992; Roach, et al., 1994; Zaza, 1998; Zaza & Farewell, 1997). Based on the results, keyboard instrumentalists exhibited a similar prevalence rate of musculoskeletal problems as other instrumentalists. However, the UNT Musicians Health Survey did not specify the nature of musculoskeletal injuries, which could have included non-performance related injuries. In addition, because some of the study participants hold primary occupations unrelated to music, there is no way of knowing the true cause of the injuries.

Another limitation to this study is the manner in which the data were collected. Only those musicians who were familiar with the use of the Internet were exposed to the survey. This novel data collection method may have discouraged older musicians from completing the survey. This is reflected in the low participation rate among older musicians, which is evident in the age distribution (Table 1). Furthermore, as in any self reported surveys, it may have been possible that musicians with hand pain were more likely to complete the survey, due to increased interest.

In addition, the survey instrument design did not allow for the assessment of response rate among participants. Musicians are typically known for refusing to participate in surveys to reveal any previous or existing injuries, fearing publication of their identity would lead to the loss of their jobs. While the Internet survey requested no name or addresses, there is no way of knowing the number of musicians who refused to participate. Furthermore, multiple entries could have been possible, although the chances of this occurring maybe low. Due to the anonymous design of the instrument, it lacked the mechanism to prevent or eliminate multiple entries by study participants. The inability of the instrument to detect response rate affected the validity of the study.

Finally, although the keyboard instrument population was obtained by using their denoted primary instrument, most of the participants played multiple instruments and some categorized themselves as multiple musician types. For example, even though all participants in the study identified their primary instruments as keyboard, many played other instruments, including string, woodwind, and brass, either recreationally or professionally. Therefore, musculoskeletal injuries reported in the survey could have been the result of playing other instruments. The affect of this factor is beyond the scope of the present study.

Age:

Even though previously published studies have shown contrasting results, age was inversely associated with the frequency of musculoskeletal pain of the fingers, hands, or wrists among keyboard instrumentalists in the present study (Bejjani & Gross & Brown, 1984; Brandfonbrener, 1990; Cunningham & Kelsey, 1984; Lockwood, 1988; Manchester, 1988). When all grades of pain were considered, a steady decline of prevalence was seen in older age groups (Table 4). Using the linear-by-linear chi-square test, this trend was found to be significant ($p = 0.003$), although the Pearson chi-square value was not significant ($p = 0.052$). The linear-by-linear chi-square test typically is used to examine the significance of a linear association between two variables when ascending or descending trend is detected. In this case, the declining trend was statistically significant. This result is similar to the ICSOM study where the highest prevalence was seen in the 35-45 age group and slightly declined with age among symphony and opera musicians (Fishbein, et al., 1988). Fry (1986e) also found the highest prevalence of musculoskeletal problems in the 25-35 age group in his study compared to older groups. Comparably, this study showed the greatest prevalence in the 10-20 group (72.7%) and stedily declined with age, with an exception of over 60 group (57.1%), which showed a higher prevalence compared to the 51-60 group (50.0%) when all grades of pain are considered (Table 4).

The most likely reason for this break in the pattern is the small sample size of over 60 group (n=14), which comprised of only 3.0% of the participants (Table 1). Likewise, because age stratification of the survey participants in the ICSOM study is not clear, the same effect could have been present in that study as well.

When the perceived pain is severe, however, a different pattern is seen. Only observing pain severity grades 3, 4, and 5, the prevalence among age groups differed from when all levels of pain were considered (Table 6). In severe pain prevalence analysis, the 51-60 group (31.8%) and over 60 group (35.7%) showed a higher prevalence than 10-20 group (30.3%) or 21-30 group (27.2%) (Table 6). In contrast, the ICSOM study found a lower prevalence of severe problems in the older group, just as when all pain were considered (Fishbein, et al., 1988).

One possibility of the declining trend with age is that older musicians with more experience might have developed a higher threshold for pain than younger musicians over the years of intense daily practice. It may be possible that older musicians are desensitized by performance-related pain, especially when the pain is mild, and perceive it as routine, wheareas the effects of pain are more profound in younger musicians who have not had as much exposure to pain. That may explain the lower prevalence in older groups when all levels of pain are considered, and the reverse pattern seen when mild pain were excluded.

A better determinant of musculoskeletal pain prevalence may be the age at which the musician first stated to play, such as the study conducted by Bejjani, Gross, and Brown (1984), which found an association between the two variables. This methodology would produce more valid results if in fact the number of years spent as a musician is directly associated with the likelihood of obtaining musculoskeletal problems.

Gender:

One of the most significant risk factor previously found to be associated with musculoskeletal problems in musicians is gender. In previously published studies, female musicians frequently showed a higher prevalence of musculoskeletal problems than male counterparts, eliciting theories concerning the difference of hand size and strength between genders (Brandfonbrener, 1990; Goodman & Staz, 1989; Roach, et al., 1994; Zaza, 1992). This study also revealed a higher prevalence in female keyboard instrumentalists (66.3%) than in male keyboard instrumentalists (50.7%) (Table 4).

In an attempt to further examine the difference between genders, this statistically significant result ($p < 0.001$) was further examined using the age stratification of each gender (Table 7). For comparison reasons, prevalence ratios were calculated and compared among the age groups. When all levels of pain were considered and no age stratification was employed, the prevalence ratio was 1 (males): 1.31 (females). This difference is primarily due to the greater difference seen

between genders in the younger group (Table 7). For example, in the 10-20 and 21-30 group, the prevalence ratios were 1: 1.40 and 1: 1.44, respectively. Because the 10-20 and 21-30 age group comprised almost 40% of the survey participants, the effect of the prevalence differences between genders seen in the under 30 groups were that much greater. Thus, the overall difference seen in the gender variable is confounded by age, with greater differences seen in the under 30 age groups.

When only severe pain were considered, the results were similar. Female keyboard instrumentalists also showed a higher prevalence of severe pain, although statistically, the results were not as significant ($p = 0.024$) as when all grades of pain were considered ($p < 0.001$) (Tables 4 & 6). One explanation may be that female keyboard instrumentalists are more likely to report any musculoskeletal pain, but less likely to report severe pain, due to the possible difference in thereshold for pain between genders. The notably higher prevalence seen in under 30 age groups in females compared to over 30 age groups suggest that female keyboard instrumentalists are experiencing much more difficulty at younger ages than male counterparts. Especially noticeable is the prevalence seen in females in the 10-20 age group, which showed 80.0% having any musculoskeletal pain (Table 7). Whether this difference is due to the gender difference in hand size and strength, genetics, or combination of these and other factors, as suggested in other studies, is unknown. The UNT Musicians Health Survey did not inquire hand size nor hand strength, and other factors can not be explained by the depth of this study.

Musician Type:

While there were no other studies that examined musician types as a risk factor, as discussed in the Literature Review section, there were studies that successfully identified piano playing techniques in association with musculoskeletal problems (Chung, et al., 1992; Newmark & Hochberg, 1987; Sakai, 1992). The present study, however, did not find a statistically significant association between musician types and musculoskeletal problems of the fingers, hands, or wrists among keyboard instrumentalists. Several factors may have led to this lack of significant findings. First, there were 18 different musical types, which likely lowered the statistical power by diluting the study sample size. Second, the decision not to combine the categories inevitably reduced the total number of subjects. Third, the distribution of keyboard instrumentalists among different music types was highly skewed, with over 62% of participants as classical and educator keyboard instrumentalists, while the rest 38% were scattered over 16 other categories (Table 1).

Efforts were made to strengthen the power of analysis by eliminating categories with low number of participants and considering only major musician types, but the results produced no significant finding ($p = 0.141$), possibly due to the small sample size. Jazz keyboard players reported the highest prevalence among six chosen categories, with 81.4% when all levels of pain were considered (Table 4). Since no other studies were found that examined the effect of musician types, comparisons can not be made at this time. While the high prevalence seen in jazz

keyboard players warrant further investigation, whether or not it was related to the technique used in jazz music or other factors can not be determined from the results of this study.

When mild pain was excluded, the results showed that the relationship was less significant ($p = 0.771$) than when all pain were considered ($p = 0.141$) (Tables 4 & 6). This may be contributable to the fact that by eliminating mild cases, the sample size was further reduced and diminished the statistical power even more. One notable finding is the order of prevalence among musician types. Whereas jazz musicians exhibited highest prevalence when all pain were considered, church/traditional keyboard players (37.1%) had the highest prevalence when only severe cases were counted (Table 6).

Playing Time:

Although the results of previously published studies were mixed on the effects of playing time related to the frequency of musculoskeletal injuries, the majority of studies reviewed indicated playing time as a risk factor (Brandfonbrener, 1990; Hiner, et al., 1987; Manchester & Park, 1996; Lockwood, 1988; Roach, et al., 1994). In this study, the difference among keyboard players who played two hours or less per day, between three and five hours per day, and over five hours was not significant ($p = 0.307$) (Table 4).

Overall, keyboard instrumentalists who reported between three and five hours of daily playing time had the highest pravalence of 63.3%, which was higher than those musicians who reported more than five hours of daily playing time (52.4%) (Table 4). One possible explanation would be that those musicians suffering from musculoskeletal pain of the fingers, hands, or wrists most likely were not able to play the instrument for a long period of time. Another possibility based on the result is a potential positive effect of daily playing time on the frequency of musculoskeletal problems among keyboard instrumentalists. However, those instrumentalists who played two hours or less per day exhibited a lower prevalence of musculoskeletal problems (56.9%) than those who played between three and five hours per day (63.3%) (Table 4). In the severe pain analysis, same pattern can be seen, with the group who played between three and five hours per day showing a higher prevalence (32.9%) than those who played two hours or less per day (28.7%) and those who played more than five hours per day (28.6%) (Table 6). One unlikely explanation is that the effect of daily playing time is negative up to five hours per day, and the effect becomes less negative, or even positive, when the playing time exceeds five hours per day. The decriptive nature of the present study does not allow further determination on the effects of daily playing time on the frequency of musucloskeletal problems of the fingers, hands, or wrists among keyboard instrumentalists.

Other Findings:

In addition to the main study questions, differences in prevalence of musculoskeletal problems were examined by location, including left and right fingers, left and right hands, and left and right wrists. Table 3 shows the breakdown of prevalence rates by location. The highest prevalence among the six locations was seen in the right wrist (34.5%). In general, the right anatomical side of the participants were more problematic than those of the left side. This is in accord with previously published findings of other similar studies (Fry, 1988; Gorman & Warfield, 1987; Knishkowy & Lederman, 1986; Newmark & Hochberg, 1987). The same theory used to explain the difference in those studies can also be applied in this study: the right side of keyboard instrumentalists are possible more susceptible to musculoskeletal injuries due to its more active role in keyboard instrument performance. The same pattern is repeated when only severe pain is analyzed (Table 5). Therefore, according to the results of this study, right fingers, hand, and wrist were more prone to musculoskeletal injuries in keyboard instrumentalists than left fingers, hand, and wrist.

Conclusion:

This study is unique in that a large sample of keyboard instrumentalists were exclusively studied. According to the literature review introduced in Chapter II, the present study of 455 keyboard instumentalists far outnumbered the next largest study

found, which included 89 pianists (Fry, 1988). Furthermore, this study included amateur and student musicians as well as profesional musicians, whereas many previously published studies focused solely on one particular population.

In conclusion, the overall prevalence rate of musculoskeletal problems among 455 keyboard instrumentalists was 58.7%. Regarding risk factors, the present study found an inverse relationship between age and frequency of musculoskeletal problems among keyboard instrumentalists. Gender was also a significant determinant factor, with female instrumentalists more likely to report musculoskeletal problems of the fingers, hands, or wrists than male keyboard instrumentalists. However, this gender difference was confounded by age: prevalence ratios of younger groups between males and females were larger than those in the older group. Daily instrument playing time and musician type were not significantly associated with the frequency of musculoskeletal problems among keyboard instrumentalists.

Recommendations

Based on the findings of this study, female keyboard instrumentalists in the early stage of their career should be targeted with appropriate interventions. 80% of female keyboard instrumentalists in the 10-20 age group reported to have musculoskeletal problems of the finger, hand, or wrist, higher than any other groups (Table 7). This indicates that female instrumentalists in high school and college are

more susceptible to musculoskeletal problems of the finger, hand, or wrist. Possible interventions suggested at this time include reducing playing time, increasing rest periods, changing instrument playing techniques, and seeking appropriate treatment at the onset of symptoms.

A few adjustments can be made in the methodology of the Internet survey to strengthen future studies. First, the questions inquiring musculoskeletal injuries can be altered to eliminate previous injuries and non-performance related injuries. This will help validate future significant findings. Second, the target population should be well defined to select those that have the same chance of using the Internet. For example, the Internet survey could be a valuable tool in assessing the risk factors among college level musicians, who are known to have an easy access to the Internet. This would reduce selection bias that would otherwise abate the participation of older age groups who are not familiar with the use of the Internet. Third, a mechanism that allows individuals to submit only one survey entry will help eliminate multiple and duplicate responses from same participants.

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