RISK FACTORS FOR PIANO-RELATED PAIN AMONG COLLEGE STUDENTS AND PIANO TEACHERS: POSSIBLE SOLUTIONS FOR REDUCING PAIN BY USING THE ERGONOMICALLY MODIFIED KEYBOARD

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Playing-related pain is a common and serious problem among pianists. Information on cause and prevention is extremely limited due to a lack of scientific research. The purpose of this study was to (1) review and describe risk factors for piano-related pain among college students and piano teachers that were reported in my previous two research studies; (2) justify the use of an ergonomically modified keyboard as a potential solution for reducing playing-related pain; and (3) test and evaluate the effectiveness of an ergonomically modified keyboard for alleviating pianists' pain.

Both study populations reported high prevalence rates for playing-related pain: 86% for college students (n = 35), 91% for piano teachers (n = 47). For both populations, statistical analyses confirmed that pianists with small physical size (hand size) were more prone to pain. This finding helped rationalize the use of an ergonomically modified keyboard (the key width is 1/16 narrower than the standard) for small-handed pianists as an ergonomic intervention.

To test the effectiveness of an ergonomically modified keyboard, 35 college students played identical music on both the reduced-sized keyboard and the standard keyboard. Observations of video-recorded performances revealed that small-handed pianists can avoid extreme stretching of their hands when playing on the modified keyboard. Statistical analysis of questionnaire data confirmed that the modified keyboard helped small-handed pianists to play with less pain and tension. These results warrant the serious consideration of adopting ergonomic principals into the world of piano.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Musicians are athletes. Both groups have the potential to overuse their bodies and suffer from performance-related problems due to strenuous practices. The critical difference is that athletes know how to take care of their bodies better than musicians do, thanks to the field of sports medicine and countless scientific research studies. Moreover, college and professional athletes have available to them a wide array of personal trainers, therapists, and physicians provided by the college or by the team. Historically, musicians' playing-related problems can be traced back to around 1830, about a century after the piano was invented. So-called "pianist's cramp" was a major struggle for Robert Schumann[1] and had already been recognized in a medical journal of the late nineteenth century.[2] Year after year, a high prevalence rate of pianists' pain has been reported. Despite years of pianists reporting significant playing-related pain, information about musicians' health has been extremely limited. Part of the reason why this issue has been ignored in the piano world could be that pain is considered unavoidable.[3] Historically and pedagogically this extreme philosophy has held us back from helping injured pianists and contributed to a lack of scientific research to recognize risk factors and to find solutions for prevention. While music is both beneficial and beautiful, it is important to recognize that for some musicians, playing carries with it some risks of injury.

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[1] Eckart Altenmüller, "Robert Schumann's Focal Dystonia," *Neurological Disorders in Famous Artists* 19 (2005): 179-188.

[2] G. Vivian Poore, "Clinical Lecture on Certain Conditions of the Hand and Arm which Interfere with the Performance of Professional Acts, Especially Piano-playing," *The British Medical Journal* 1 (1887): 441-444.

[3] Robert Alford and Andras Szanto, "Orpheus Wounded: The Experience of Pain in the Professional Worlds of the Piano," *Theory and Society* 25, no. 1 (1996): 5.

Background

Historically piano teaching and learning have been heavily based on traditions. Articles and books have been written about the traditional pedagogical schools and techniques and more widely accepted among pianists than the science-based research. The lack of proper scientific research is clear when, as of 2006, only 12 papers were considered fairly reliable and valid out of 482 publications dealing with the prevalence and risk factors for playing-related musculoskeletal disorders of pianists.[4] Presented below are the studies selected from the twelve papers and more current publications. They are grouped based on the research types.

Epidemiological studies report the prevalence rate and the risk factors for piano-related problems. A survey conducted over the Internet for 455 keyboard players revealed that age and gender were found to be risk factors.[5] Dr. Naotaka Sakai in Japan[6] and Dr. Luc De Smet in France[7] argued that small hands are more prone to these problems. A study published in Italy indicated that age, lack of athletic exercise and acceptance of a "no pain, no gain" attitude are strongly correlated with pianists' musculoskeletal disorder.[8]

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[4] Peter Bragge, Andrea Bialocerkowski and Joan McMeeken, "A Systematic Review of Prevalence and Risk Factors Associated with Playing-related Musculoskeletal Disorders in Pianists," *Occupational Medicine* 56, no. 1 (2006): 28-38.

[5] Chong Pak and Kris Chesky, "Prevalence of Hand, Finger, and Wrist Musculoskeletal Problems in Keyboard Instrumentalists," *Medical Problems of Performing Artists* 15 (2000): 17-23.

[6] Naotaka Sakai, "Hand Pain Related to Keyboard Techniques in Pianists," *Medical Problems of Performing Artists* 7 (1992): 63-65.

[7] Luc De Smet, Helena Ghyselen, and Roeland Lysens, "Incidence of Overuse Syndromes of the Upper Limb in Young Pianists and its Correlation with Hand Size, Hypermobility and Playing Habits," *Annales de Chirurgie de la Main* 17, no. 4 (1998): 309-313.

[8] Stefano Bruno, Antonio Lorusso, and Nicola L'Abbate, "Playing-related Disabling Musculoskeletal Disorders in Young and Adult Classical Piano Students," *International Archives of Occupational and Environmental Health* (2008).

Some survey studies targeted educators or piano teachers. Ms. Margaret Redmond surveyed knowledge and awareness of prevention oriented approaches to playing piano among 42 piano teachers who were members of the Washington State Music Teachers Association.[9] Over 75 % of participants reported a desire to obtain more information on injury prevention. Dr. Charles Turon questioned performing arts medicine clinicians (N=36) about the teachers' roles in the prevention of health-related problems among their students.[10] Clinicians recommended improvements in health science or music education courses or seminar/workshops.

There were studies dedicated only to the analysis of pianists' hands. The most pioneering analytical study is the intense and detailed examination of size variation and joint mobility of 238 pianists' hands by Dr. Christoph Wagner in Germany.[11] He stated that the male hand is significantly bigger than the female hand and pointed out that some joint mobility was greater in the female population. A similar study was conducted by researchers in Spain regarding a repetitive strain injury (RSI).[12] Sixty-five percent of the total study population (341 pianists) was affected by RSI. A tendency for small hands (less than 22 cm in hand span) and a distinct Morphotype B hand (the width of palm is greater than the length of palm) was found in the affected population. They also observed that the pianists with maximal flexion and

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[9] Margaret Redmond and Anne Tiernan, "Knowledge and Practices of Piano Teachers in Preventing Playing-related Injuries in High School Students," *Medical Problems of Performing Artists* 16 (2001): 32-42.

[10] Charles Turon, "Educational Prerequisites for Piano Teachers Assisting in the Prevention, Detention, and Management of Performance-related Health Disorders" (Ph.D. diss., University of Oklahoma, 2000).

[11] Christoph Wagner, "The Pianist's Hand: Anthropometry and Biomechanics," *Ergonomics* 31 (1988): 97-131.

[12] J Farias, FJ Ordonez, M Rosety-Rodriguez, C Carrasco, A Ribelles, M Rosety, JM Rosety, and M Gomez del Valle, "Anthropometrical Analysis of the Hand as a Repetitive Strain Injury (RSI) Predictive Method in Pianists," *Italian Journal of Anatomy and Embryology* 107, no. 4 (2002): 225–231.

extension in the wrist joint were rarely affected by RSI.[13] Analyzing the finger posture/position on the keyboard, Mr. David Harding pointed out that the use of a more curved finger position reduces flexor tendon tensions.[14]

Some studies focused on measuring force or muscle activities generated by piano playing. A study that evaluated 8 injury-free pianists' performance techniques and their joint and tendon forces in the hand showed that playing loudly with excessive force and finger postures/positions with unnecessary tendon and joint forces may affect the incidence of musculoskeletal injuries.[15] A medical team measured the force generated by 10 expert pianists and 10 musical amateurs by installing an f-scan sensor-matrix-foil under five keys of the piano.[16] Significant difference in force between the two groups was observed; however, the force was increased in both groups when the subjects were required to play more complex pieces. Amateurs tended to use unnecessary force on the keys. Researchers in Osaka, Japan devoted themselves to this area of study. They published articles regarding (1) keystroke force in pianists with two types of touch –"struck" or "pressed" – utilizing a force-sensor and (2) the differences between expert and novice pianists in the upper limb movements when pressing the keys.[17, 18]

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[13] M Rosety-Rodriguez, FJ Ordóñez, J Farias, M Rosety, C Carrasco, A Ribelles, JM Rosety, and M Gómez del Valle, "The Influence of the Active Range of Movement of Pianists' Wrists on Repetitive Strain Injury," *European Journal of Anatomy* 7, no. 2 (2003): 75-77.

[14] David Harding, Kenneth Brandt, and Ben Hillberry, "Minimization of Finger Joint Forces and Tendon Tensions in Pianists," *Medical Problems of Performing Artists* 4 (1989): 103-108.

[15] Gregory Wolf, Martha Keane, Kenneth Brandt, and Ben Hillberry, "An Investigation of Finger Joint and Tendon Forces in Experienced Pianists," *Medical Problems of Performing Artists* 8 (1993): 84-95.

[16] Dietrich Parlitz, Thomas Peschel, and Eckart Altenmuller, "Assessment of Dynamic Finger Forces in Pianists: Effects of Training and Expertise," *Journal of Biomechanics* 31 (1998): 1063–1067.

[17] Hiroshi Kinoshita, Shinichi Furuya, Tomoko Aoki, and Eckart Altenmüller, "Loudness Control in Pianists as Exemplified in Keystroke Force Measurements on Different Touches," *Journal of Acoustical Society of America* 121, no. 5(2007): 2959-2969.

Another study in 2008 by a Japanese researcher reported that psychological stress (music performance anxiety) significantly increased muscle activity and could lead to playing-related musculoskeletal problems.[19] Dr. Brenda Wristen studied two small-handed pianists utilizing Surface Electromyography, Electro-goniometers, and the narrower-sized keyboard (the 7/8 keyboard).[20]

Rationale of the Study

To some extent, the literature in the previous section contributes to understanding the nature, magnitude and cause of pianists' playing-related problems; however, numerous questions remain unanswered. Future research should aim towards one ultimate question: *what can help reducing pianists' pain while playing and how?* Identifying the risk factors is one of the steps to solve this question. Understanding individual variants in terms of physical size and performance habits is also important. Overall, additional research is strongly warranted especially (1) to investigate the understudied populations and wider variety of populations (2) to learn the relationship between playing-related problems and individual physical/task variants as highlighted by Dr. Alice Brandfonbrener[21], and (3) to discover a possible solution for reducing pianists' playing-related pain derived from the knowledge about the risk factors and examine its effectiveness.

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[18] Shinichi Furuya and Hiroshi Kinoshita, "Organization of the Upper Limb Movement for Piano Key-depression Differs between Expert Pianists and Novice Players," *Experimental Brain Research* (2007).

[19] Michiko Yoshie, Kazutoshi Kudo, and Tatsuyuki Ohtsuki, "Effects of Psychological Stress on State Anxiety, Electromyographic Activity, and Arpeggio Performance in Pianists," *Medical Problems of Performing Artists* 23, no. 3 (2008): 120-132.

[20] Brenda Wristen, Myung-Chul Jung, Alexis Wismer, and Susan Hallbeck, "Assessment of Muscle Activity and Joint Angles in Small-Handed Pianists: A Pilot Study on the 7/8-Sized Keyboard versus the Full-Sized Keyboard," *Medical Problems of Performing Artists* 21, no. 1 (2006): 3-9.

[21] Alice Brandfonbrener, "Epidemiology and Risk Factors," in *Medical Problems of the Instrumentalist Musician*, ed. Raoul Tubiana and Peter C. Amadio (London: Martin Dunitz, 2000), 171-194.

Purpose of the Study

The current study will (1) review and discuss the risk factors for piano-related pain among college students and piano teachers that were reported in the author's previous two research studies, (2) justify the use of the ergonomically modified keyboard as a possible solution for reducing playing-related pain as a result of the two studies, and (3) test and evaluate the effectiveness of the keyboard for alleviating pianists' pain. This research will be conducted in a reliable and valid approach through scientific research protocol and the appropriate statistical analysis to evaluate the usefulness of possible solutions. The data provided in this paper will be simple and objective facts, instead of subjective opinions. It is hoped that pianists will make use of these resources to improve their practice and performance habits and to optimize their health.

REVIEW OF TWO STUDIES CONDUCTED BY THE AUTHOR

I conducted two piano-related research studies, one in 2005 and one in 2006. Both studies were published in the journal, *Medical Problems of Performing Artists* in 2006 and 2008: *Risk Factors for Piano-related Pain among College Students*[22] and *Risk Factors for Playing-related Pain among Piano Teachers.*[23] This section presents the research procedures and the findings of the two studies.

Methods of the Two Studies

Subjects

The following populations consented to participate. The Institutional Review Board (IRB) of the University of North Texas approved both studies prior to the execution.

- Study 1: Thirty-five piano major students at University of North Texas were recruited and compensated their time.
- Study 2: Forty-seven piano teachers who attended the 2006 annual conference of the Music Teachers National Association (MTNA) in Austin, Texas, volunteered. The study sample was selected from the total participants based on their teaching hour (> 0 hour/week). Nine subjects were excluded.

Questionnaire

The questionnaire (see Appendix A) consisted of sections about demographics, musical background, practice habits, and medical problems (musculoskeletal/non-musculoskeletal).

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[22] Eri Yoshimura, Pamela Mia Paul, Cyriel Aerts, and Kris Chesky, "Risk Factors for Piano-related Pain among College Students," *Medical Problems of Performing Artists* 21, no. 3 (2006): 118-125.

[23] Eri Yoshimura, Anncristine Fjellman-Wiklund, Pamela Mia Paul, Cyriel Aerts, and Kris Chesky, "Risk Factors for Playing-related Pain among Piano Teachers," *Medical Problems of Performing Artists* 23, no. 3 (2008): 107-113.

Many questions in this questionnaire were presented with a visual analogue scale (VAS), which is the 10-cm line with adjective descriptors representing the full range of possible responses as shown below. The VAS is a reliable and valid approach for assessment.

Never |————————————————————————| Always

Figure 1: Visual Analogue Scale

Playing-related pain was assessed using the VAS in response to the following four 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?

Anthropometric Measurement

Upper arm length, lower arm length, wrist circumference, hand length and hand span were measured by a cloth measure tape. The index finger diameter was measured by a jeweler's ring size tool. Subjects were asked to submerge their hand in a bucket of water to assess the hand volume. Digital pictures of each digit-to-digit span (Fingers 1-2, 2-3, 3-4, 4-5) are taken to measure each span angle on the printed photograph.

Elements of Performance

The HPM Basic Elements of Performance XII System was utilized to quantify wrist range of motion, rotation speed, isometric strength, and pinch strength. Subjects were instructed to follow the standardized procedure (Human Performance Measurement, Inc., Arlington, TX).

Statistical Analysis Methods

Statistical Package for the Social Sciences (SPSS) was used for all statistical analysis. The following analysis were run in order:

1. Descriptive statistics – the collected data was statistically analyzed based on data types; (1) scale (interval) data (including the VAS) was described as its minimum, maximum, mean, and standard deviation and (2) frequencies (numbers and percentage) of nominal and ordinal data were presented.
2. Cross-correlations – Pearson correlation coefficient was computed to determine the relationship between dependent (predicted) and independent (predictor) variables. The four questions regarding playing-related pain were treated as dependent variables, the rest of the scale data were independent variables.
3. Inter-correlations – The independent variables that are significantly correlated with dependent variables were grouped into categories (factors) based on the inter-correlations outcome (e.g., size and strength are considered the same factor because they are positively correlated to each other).
4. Factor development – The highest correlated independent variable from each factor was selected to develop the regression model for each dependent variable. The chosen variables for each model remained unrelated to each other for the best result.
5. Multiple linear regression analysis (Enter method) – The four models were tested using linear regression to predict a dependent variable score from several independent variable scores.

Results of the Two Studies

In this section, the results of two studies (Study 1 = UNT, Study 2 = MTNA) are discussed and compared.

Descriptive Statistics

As shown in Table 1, about 80 % of participants are female for both studies. Possibly due to the nature of study population (college students and piano teachers), the mean difference of age is statistically significant (UNT 27.17 years, MTNA 42.91 years); so are "Number of children," "Average amount of exercise," and "Number of years of private lessons." More than 80 % of the UNT participants are single. On the other hand, almost half the MTNA study participants are married. Over 95 % of the MTNA subjects reported to be Caucasian.

Table 1: Demographic Characteristics and Music Background Data

		UNT		MTNA	
		No.	%	No.	%
Gender	Male	8	22.9	8	17.0
	Female	27	77.1	39	83.0
Marital Status	Single	29	82.9	22	46.8
	Married	6	17.1	23	48.9
	Widowed	0	0	2	4.3
Race	Asian	20	57.1	1	2.1
	Caucasian	14	40.0	45	95.7
	Hispanic	1	2.9	1	2.1
		Minimum	Maximum	Mean	Std. Deviation
UNT	Age	21	41	27.17	4.99
	Number 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/month)	0	25	2.91	4.59
	Age started piano	3	13	6.04	2.30
	Number of years of private lessons	7.5	30	19.37	5.21
	Years of college instruction in piano	2	20	7.33	4.27
	Size of hands (subjective)*	0.10	10	4.78	2.51
MTNA	Age	15	75	42.91	16.43
	Number of Children	0	4	0.89	1.36
	Average amount of sleep (hrs/day)	5	9	7.23	0.87
	Average amount of exercise (hrs/week)	0	15	4.59	3.41
	Average travel (days/month)	0	10	2.55	2.03
	Age started piano	3	13	6.17	2.00
	Number of years of private lessons	3	30	14.53	5.93
	Years of college instruction in piano	0	15	5.81	3.38
	Size of hands (subjective)*	0.60	10	4.95	2.56

*Subjects answered on VAS (0-10 am)

Table 2 reports the practice habits of the subjects. In general, college students (UNT) spend more time playing the piano than piano teachers who spend more time teaching than college students. The average hours are significantly different. Teachers also tend to use more time for other hand activities (e.g., computer, exercise, housework, etc).

Table 2: Practice Habits

		Minimum	Maximum	Mean	Std. Deviation
UNT	Practice hours per week	3.0	42.0	24.83	8.46
	Lesson hours per week	0	6.0	1.20	0.96
	Accompanying hours per week	0	20.0	5.66	5.00
	Chamber music/Ensemble hours per week	0	6.0	1.11	1.62
	Teaching hours per week	0	25	5.49	7.45
	Keyboard related activities hours per week	0	13.0	2.03	2.96
	Number of performance in school per semester	0	40.0	5.28	7.29
	Number of performance outside school per semester	0	20.0	3.13	4.289
	Practice hours on upright piano per week	0	42.0	4.79	9.19
	Practice hours on grand piano per week	0	42.0	22.80	11.86
	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
	Breaks - How long (min)	2.0	30.0	11.72	7.27
	Breaks - How often (hour)	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 activities time spent (hours/week)	0	19.0	3.67	3.99
		Minimum	Maximum	Mean	Std. Deviation
MTNA	Practice hours per week	0	28.0	9.08	7.95
	Lesson hours per week	0	2.5	.38	.64
	Accompanying hours per week	0	20.0	2.20	3.56
	Chamber music/Ensemble hours per week	0	10.0	.83	1.68
	Teaching hours per week	1	40.0	16.63	9.63
	Keyboard related activities hours per week	0	10.0	1.49	2.34
	Number of performance in school per semester	0	16.0	1.66	3.28
	Number of performance outside school per semester	0	50.0	3.36	7.90
	Practice hours on upright piano per week	0	40.0	2.51	6.74
	Practice hours on grand piano per week	0	54.0	11.656	12.32
	Do you warm-up before practice?*	0	10.0	5.30	3.46
	Physical warm-up time spent (min)	0	15.0	2.18	3.06
	Psychological warm-up time spent (min)	0	20.0	1.42	3.57
	Musical warm-up time spent (min)	0	35.0	9.40	8.20
	Do you take breaks during practice?*	0	10.0	6.45	3.21
	Breaks - How long (min)	0	45.0	8.86	7.85
	Breaks - How often (hour)	0	5.0	1.27	.88
	Do you stop practice because of physical fatigue?*	0	10.0	4.56	3.34
	Do you stop practice because of mental fatigue?*	0	10.0	4.91	2.94
	Primary hand activities time spent (hours/week)	0	35.0	9.53	9.16

*Subjects answered on VAS (0-10 am)

Both studies show a high percentage of subjects who experience pain while playing: UNT 86 % and MTNA 91 %. Almost half the population of the MTNA study indicates that they experience stage fright; the UNT study reports over 40 % with the same problem (Table 3). Forty percent of both studies suffer from headaches. The larger percentage differences are seen in hearing loss and weight problems, and high blood pressure.

Table 3: Responses to Pain Questions and Non-musculoskeletal Problems

		Minimum	Maximum	Mean	Std. Deviation
UNT	Do you experience pain when playing?*	.00	9.20	2.83	2.60
	Do you experience pain after playing?*	.00	9.00	2.91	2.79
	Does pain stop you from playing?*	.00	9.80	2.49	3.16
	How much of your playing is affected by pain?*	.00	10.00	2.99	2.58
MTNA	Do you experience pain when playing?*	.00	10.00	3.11	2.76
	Do you experience pain after playing?*	.00	10.00	2.73	2.70
	Does pain stop you from playing?*	.00	10.00	2.70	2.99
	How much of your playing is affected by pain?*	.00	10.00	3.11	3.22

Non-Musculoskeletal Problems		None (Count)	%	Mild (Count)	%	Severe (Count)	%
Acquired Dental Malocclusion	UNT	30	85.7	3	8.6	2	5.7
	MTNA	40	90.9	3	6.8	1	2.3
Acute Anxiety	UNT	27	77.1	8	22.9	0	0
	MTNA	35	81.4	4	9.3	4	9.3
Asthma	UNT	32	91.4	2	5.7	1	2.9
	MTNA	41	93.2	3	6.8	0	0
Blackouts/Dizziness	UNT	32	91.4	3	8.6	0	0
	MTNA	40	90.9	3	6.8	1	2.3
Chest Discomfort	UNT	31	88.6	4	11.4	0	0
	MTNA	40	90.9	4	9.1	0	0
Chin Rest Sore	UNT	34	97.1	1	2.9	0	0
	MTNA	43	97.7	0	0	1	2.3
Depression	UNT	23	65.7	12	34.3	0	0
	MTNA	34	77.3	9	20.5	1	2.3
Earaches	UNT	35	100	0	0	0	0
	MTNA	39	88.6	5	11.4	0	0
Eye Strain	UNT	25	71.4	8	22.9	2	5.7
	MTNA	27	61.4	17	38.6	0	0
Fatigue	UNT	18	51.4	14	40.0	3	8.6
	MTNA	27	61.4	13	29.5	4	9.1
Headache	UNT	21	60.0	13	37.1	1	2.9
	MTNA	26	59.1	18	40.9	0	0
Hearing Loss	UNT	34	97.1	1	2.9	0	0
	MTNA	35	79.5	8	18.2	1	2.3
Heart Condition	UNT	34	97.1	1	2.9	0	0
	MTNA	42	95.5	1	2.3	1	2.3
Hemorrhoids	UNT	35	100	0	0	0	0
	MTNA	40	93.0	3	7.0	0	0
High Blood Pressure	UNT	35	100	0	0	0	0
	MTNA	35	79.5	9	20.5	0	0

Table 3 – *Continued*

Inguinal Hernia	UNT	35	100	0	0	0	0
	MTNA	44	100	0	0	0	0
Loss of Lip	UNT	35	100	0	0	0	0
	MTNA	44	100	0	0	0	0
Loss of Seal	UNT	35	100	0	0	0	0
	MTNA	44	100	0	0	0	0
Mouth Lesions	UNT	34	97.1	1	2.9	0	0
	MTNA	44	100	0	0	0	0
Respiratory Allergies	UNT	28	80.0	7	20.0	0	0
	MTNA	31	70.5	11	25.0	2	4.5
Sleep Disturbances	UNT	27	77.1	8	22.9	0	0
	MTNA	32	72.7	12	27.3	0	0
Stage Fright	UNT	20	57.1	14	40.0	1	2.9
	MTNA	21	47.7	16	36.4	7	15.9
TMJ Syndrome	UNT	31	88.6	4	11.4	0	0
	MTNA	34	77.3	8	18.2	2	4.5
Ulcer	UNT	33	94.3	2	5.7	0	0
	MTNA	44	100	0	0	0	0
Varicose Veins	UNT	35	100	0	0	0	0
	MTNA	39	88.6	5	11.4	0	0
Weight Problems	UNT	30	85.7	4	11.4	1	2.9
	MTNA	32	72.7	11	25.0	1	2.3

*Subjects answered on VAS (0-10 am)

Number of musculoskeletal and non-musculoskeletal problems are shown in Table 4. These variables are considered an indication of "overall health." About a half of the UNT population reports musculoskeletal pain in more than four locations, in contrast to only a quarter of the MTNA population with more than four pain locations.

Table 4: Number of Musculoskeletal Pain Sites

	UNT		MTNA	
	No.	%	No.	%
0	3	8.6	4	9.1
1	7	20.0	11	25.0
2	4	11.4	10	22.7
3	4	11.4	7	15.9
4	9	25.7	7	15.9
5	1	2.9	2	4.5
6	1	2.9	1	2.3
7	2	5.7	1	2.3
8	2	5.7	0	0
9	0	0	1	2.3
10	1	2.9	0	0
14	1	2.9	0	0
Total	35	100.0	44	100.0

Table 4 – *Continued*
Number of Non-musculoskeletal Problems

	UNT		MTNA	
	No.	%	No.	%
0	5	14.3	4	9.1
1	7	20.0	2	4.5
2	5	14.3	9	20.5
3	2	5.7	6	13.6
4	4	11.4	4	9.1
5	3	8.6	4	9.1
6	3	8.6	4	9.1
7	2	5.7	2	4.5
8	3	8.6	6	13.6
9	0	0	1	2.3
10	0	0	2	4.5
11	1	2.9	0	0
Total	35	100.0	44	100.0

The overall tendency is that the MTNA population is physically larger than UNT's (possibly due to the ethnicity of the study population: Asian and Caucasian), and flexibility (digit-to-digit span) is greater in the UNT population than the MTNA as shown in Table 5. The mean differences are statistically significant in weight, left upper arm length, index finger diameter, thumb-index span, 2-3 span, left 3-4 span, and 4-5 span. The average left-side digit-to-digit spans are wider than the right side for both studies.

Table 5: Anthropometric Measures of Upper Extremity

		Minimum	Maximum	Mean	Std. Deviation
UNT	Height (cm)	147.00	188.00	164.09	9.81
	Weight (kg)	40.0	83.0	58.27	11.77
	Left Upper Arm Length (mm)	260.0	350.0	298.74	22.18
	Right Upper Arm Length (mm)	260.0	355.0	299.69	23.81
	Left Forearm Length (mm)	215.0	288.0	245.97	22.00
	Right Forearm Length (mm)	215.0	287.0	244.20	19.17
	Left Hand Length (mm)	148.0	202.0	174.40	13.03
	Right Hand Length (mm)	153.0	203.0	174.86	12.51
	Left Wrist Circumference (mm)	135.0	181.0	153.77	12.40
	Right Wrist Circumference (mm)	140.0	184.0	154.23	12.95
	Left Index Finger Diameter (mm)	15.3	21.0	17.70	1.47
	Right Index Finger Diameter (mm)	15.9	21.3	17.98	1.46
	Left Hand Volume (mL)	187.5	500.0	335.71	98.34
	Right Hand Volume (mL)	187.5	562.5	352.13	97.04
	Left Hand Span (mm)	181.00	250.00	212.43	17.73

Table 5 – *Continued*

	Right Hand Span (mm)	183.00	250.00	209.74	17.18
	Left Interval on Keyboard	8	11	9.49	0.78
	Right 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
MTNA	Height (cm)	154.90	182.90	167.69	7.47
	Weight (kg)	46.8	113.6	69.68	14.39
	Left Upper Arm Length (mm)	280.0	362.0	309.36	18.93
	Right Upper Arm Length (mm)	226.0	362.0	308.27	22.36
	Left Forearm Length (mm)	204.5	303.0	250.60	20.60
	Right Forearm Length (mm)	203.0	354.0	253.53	28.44
	Left Hand Length (mm)	156.0	213.0	176.55	12.67
	Right Hand Length (mm)	156.0	222.0	177.32	12.79
	Left Wrist Circumference (mm)	140.0	181.0	157.28	10.90
	Right Wrist Circumference (mm)	140.0	182.0	158.46	11.39
	Left Index Finger Diameter (mm)	16.5	21.6	18.43	1.28
	Right Index Finger Diameter (mm)	16.8	22.9	18.87	1.36
	Left Hand Volume (mL)	125.0	700.0	322.19	135.56
	Right Hand Volume (mL)	187.5	700.0	333.13	136.18
	Left Hand Span (mm)	190.00	250.00	213.36	13.76
	Right Hand Span (mm)	183.00	256.00	212.02	16.16
	Left Interval on Keyboard	8	11	9.40	0.78
	Right Interval on Keyboard	8	10	9.24	0.73
	Left Thumb-Index Span (deg)	37	103	80.40	14.10
	Right Thumb-Index Span (deg)	38	96	74.14	13.68
	Left 2-3 Span (deg)	10	53	36.21	8.37
	Right 2-3 Span (deg)	18	53	34.92	8.04
	Left 3-4 Span (deg)	5	45	28.21	7.35
	Right 3-4 Span (deg)	11	44	26.29	8.03
	Left 4-5 Span (deg)	24	58	42.67	7.53
	Right 4-5 Span (deg)	20	55	39.83	8.36

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

Table 6 shows that the averages of range of motion and rotation speed are greater for supination than for pronation in both studies. Isometric strength is generally stronger for clockwise motion than for counter-clockwise. More than 90 % of subjects are right-handed.

Table 6: Basic Elements of Performance

		Minimum	Maximum	Mean	Std. Deviation
UNT	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
MTNA	Range of Motion Left Pronation (deg)	62.4	155.7	104.82	21.01
	Range of Motion Left Supination (deg)	85.9	150.7	124.15	17.11
	Range of Motion Right Pronation (deg)	58.3	150.0	104.76	18.56
	Range of Motion Right Supination (deg)	18.0	167.1	123.52	22.92
	Rotation Speed Left Pronation (deg/sec)	175.0	996.0	517.26	206.30
	Rotation Speed Left Supination (deg/sec)	135.0	1307.0	604.23	360.01
	Rotation Speed Right Pronation (deg/sec)	115.0	1210.0	534.53	265.11
	Rotation Speed Right Supination (deg/sec)	164.0	1541.0	692.63	363.80
	Isometric Strength Left Pronation (N-m)	2.6	16.7	6.97	2.75
	Isometric Strength Left Supination (N-m)	1.8	10.1	4.40	1.87
	Isometric Strength Right Pronation (N-m)	1.8	10.7	5.32	2.53
	Isometric Strength Right Supination (N-m)	3.1	14.0	7.02	2.23
	Pinch Strength Left (N)	0.6	2.7	1.84	0.56
	Pinch Strength Right (N)	1.0	4.8	2.19	0.77
		No.		%	
UNT	Right	33		97.1	
	Left	1		2.9	
MTNA	Right	42		93.3	
	Left	3		6.7	

Cross- and Inter- Correlations

It is obvious that the UNT study shows more independent variables significantly correlated with dependent variables than the MTNA study (Table 7). Negative numbers mean that pain and the items on the left column are inversely related. Overall, the anthropometric measurements are negatively correlated to pain – e.g., the larger in size, the less frequently pain is experienced. In contrast, positive outputs at the two bottom rows represent that the occurrence of pain and numbers of musculoskeletal and non-musculoskeletal problems are corresponding with one another. For the UNT study, powerful negative correlation between

pain and flexibility (Right 3-4 span and range of motion) are observed. The MTNA study reports that the variables associated with warm-up habits are positively and strongly correlated with dependent variables.

Table 7: Independent Variables Correlated with One or More Dependent Variables

UNT Study

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

MTNA Study

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?
Average amount of sleep	0.178	0.277	0.224	0.374*
Years of college instruction in piano	-0.361*	-0.208	-0.108	-0.086
Practice hours per week	-0.223	-0.205	-0.344*	-0.172
Accompanying hour per week	-0.287	-0.296*	-0.069	0.085
Practice hour on grand piano per week	-0.328*	-0.220	-0.178	-0.148
Warm-up before practice	0.227	0.323*	0.139	0.098
Physical warm-up time spent	0.364*	0.464**	0.079	0.192
Stop practice because of physical fatigue	0.347*	0.361*	0.327*	0.288
Right wrist circumference	-0.317*	-0.085	-0.175	-0.274
Left interval on keyboard	-0.318*	-0.181	-0.159	-0.281
Right 2-3 Span	0.142	0.096	0.229	0.338*
Pinch strength left	-0.034	0.094	-0.146	-0.339*
Number of non-MS problems	0.320*	0.359*	0.096	-0.005
Number of MS pain sites	0.390*	0.403**	0.191	0.354*

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

The notable difference between the UNT study and the MTNA study is the number of factors developed for the regression model as shown in Table 8. The two variables regarding number of musculoskeletal and non-musculoskeletal problems are treated as one factor for the MTNA study because they are significantly correlated. As stated in the Methods section, independent variables should be uncorrelated with one another for the best result of regression analysis. The two studies differ in one factor (Flexibility and Warm-up habits), but the rest of the factors remained unchanged.

Table 8: Factors with Related Variables

UNT Study

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 ®, 3-4 span ®
Factor 4	Number of Non-MS problem	
Factor 5	Number of MS Problem	

MTNA Study

Factor 1	Exposure	Years of college instruction in piano, Practice hours per week, Accompanying hour per week, Practice hour on grand piano per week
Factor 2	Warm-up habits	Warm-up before practice, Physical warm-up time spent
Factor 3	Size/Strength	Right wrist circumference, Left interval on keyboard, Pinch strength left
Factor 4	Number of MS problems and non-MS problems	

Pearson Correlation of Numbers of MS and non-MS Problems

			Number of Non-MS Locations
UNT	Number of MS Pain Locations	Pearson Correlation	0.258
		Sig. (2-tailed)	0.135
MTNA	Number of MS Pain Locations	Pearson Correlation	0.459**
		Sig. (2-tailed)	0.003

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

Factor Identification

Table 9 illustrates the variables selected from each factor group. Each model consists of 4 or 5 factors that are most significantly correlated with dependent variables but unrelated to each other. If the variables are related, the second highest correlated ones are chosen.

Table 9: Regression Model

UNT Study

	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.

MTNA Study

	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 (Exposure)	Years of college instruction in piano	Accompanying hour per week	Practice hours per week	Teaching hours per week*
Factor 2 (Warm-up habits)	Physical warm-up time spent	Physical warm-up time spent	Warm-up before practice	Physical warm-up time spent
Factor 3 (Size/Strength)	Left interval on keyboard	Left interval on keyboard	Right wrist circumference	Left interval on keyboard*
Factor 4 (Number of MS problems)	Number of MS problems	Number of MS problems	Number of MS problems	Number of MS problems

*Second highest correlated variable.

Regression Analysis

As reported in Table 10, results from the multiple regression analysis confirm that all the models in the UNT study are statistically significant. The adjusted R^2 values indicate that all

models in the UNT study accounted for at least 40 % of the variance in the criterion variables (the four pain questions). Model 2, with the most powerful predictions, reveals that the selected five factors contribute to understanding 60 % of the dependent variable ("Do you experience pain after playing?"). In comparison, the MTNA study reports the less strong adjusted R^2 values with the highest of almost 30 % in Model 1.

Table 10: Multiple Regression Data

UNT Study

	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			

MTNA Study

	Predictors	Beta	Adjusted R^2	F	*p*-Value
Model 1			0.296	4.472	0.006
Factor 1	Years of college instruction in piano	-0.232			
Factor 2	Physical warm-up time spent	0.290			
Factor 3	Left interval on keyboard	-0.200			
Factor 4	Number of MS problems	0.304			
Model 2			0.263	3.937	0.011
Factor 1	Accompanying hour per week	-0.306			
Factor 2	Physical warm-up time spent	0.233			
Factor 3	Left interval on keyboard	-0.048			
Factor 4	Number of MS problems	0.359			
Model 3			0.069	1.667	0.182
Factor 1	Practice hours per week	-0.331			
Factor 2	Warm-up before practice	0.052			
Factor 3	Right wrist circumference	-0.071			
Factor 4	Number of MS problems	0.241			
Model 4			0.113	2.052	0.113
Factor 1	Teaching hours per week	-0.236			
Factor 2	Physical warm-up time spent	-0.005			
Factor 3	Left interval on keyboard	-0.162			
Factor 4	Number of MS problems	0.310			

Risk Factors for Piano-related Pain

Results from both studies revealed the high prevalence rates for playing-related pain among college piano students and piano teachers and found the factors that are consistently important for comprehending the pain. There also exist factors that made unique contributions to understanding this occupational health concern.

(1) Flexibility – uniquely found in the UNT study, the right 3-4 span was one of the strongest variables negatively-correlated with the pain questions. This result suggests that college piano students who have a wider 3-4 span on the right hand tend to experience less

pain. This digit-to-digit span is unrelated to hand size. The follow-up analysis reported that this variable (right 3–4 span) greatly contributed to explaining the playing-related pain. This finding was never been noted in previous studies.

(2) Warm-up habits – exclusively observed in the MTNA study, "physical warm-up time spent" was significantly correlated with the pain while and after playing. The positive Pearson correlation values imply that piano teachers who spend more time on physical warm-up have a tendency to experience pain more frequently. This finding could be a reversed hypothesis that piano teachers spend more time on physical warm-up because they feel pain more often. More detailed information from the questionnaire reveals that the physical warm-up was described as "stretching" by nearly all subjects (95%) who answered that they do physical warm-ups. As discussed in the author's article "Risk Factors for Playing-related Pain among Piano Teachers,"[24] use and effect of stretching before activities is still controversial and unidentified, especially in sports. The discovery in the MTNA study that stretching might contribute to piano-related pain could contradict the universal teaching principle. Therefore, additional research is warranted in order to better understand the role of stretching before piano playing and to avoid misguidance for pianists.

(3) Exposure – even though this factor was observed in both studies, the result was somewhat opposite (the positive and negative correlation). One possible interpretation of this contradiction is that college students are affected by pain more because they

[24] Eri Yoshimura, Anncristine Fjellman-Wiklund, Pamela Mia Paul, Cyriel Aerts, and Kris Chesky, "Risk Factors for Playing-related Pain among Piano Teachers," *Medical Problems of Performing Artists* 23, no. 3 (2008): 107-113.

play more or longer; on the contrary, piano teachers play less frequently because they experience more pain. These findings suggest a potential threshold level of overuse and underuse.

(4) Overall health (number of musculoskeletal and non-musculoskeletal problems) – this factor is one of the strongest predictors for playing-related pain that consistently reported a straightforward explanation: the more problems with overall health, the more pain.

(5) Size/strength – this factor is one of the most important variables because it repeatedly appeared in both studies. The negative correlation values support the hypothesis that people who have smaller hands and less strength tend to suffer from pain more than people who are bigger and stronger.

THE ERGONOMICALLY MODIFIED KEYBOARD

Ergonomics

The two studies conducted by the author consistently reported that physical size is inversely correlated with pain. This finding (small-handed pianists are more prone to pain than large-handed pianists) has been confirmed by other research studies as indicated in the introduction.[25, 26] Since it is recognized that the female hand is smaller than the male's, gender is also related to this finding as shown in Pak's study.[27] When physical size is confirmed as a risk factor in occupational tasks (typing, sitting, driving etc), tools are designed or altered to fit people because it is impossible to change body size intentionally – this is called ergonomics. Adjusting the size of tools to fit an individual's body size is widely acknowledged and sometimes required in order to prevent injuries or to reduce discomfort – this is a principal role of ergonomics.[28] In other words, people are encouraged to use ergonomically modified/designed instruments or tools when a mismatch of size occurs. The effectiveness of ergonomic interventions for musculoskeletal disorders has been confirmed by numerous studies.[29, 30] Based on this practice, it is recommended that small-handed pianists play on the narrower-

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[25] Naotaka Sakai, "Hand Pain Related to Keyboard Techniques in Pianists," *Medical Problems of Performing Artists* 7 (1992): 63-65.

[26] Luc De Smet, Helena Ghyselen, and Roeland Lysens, "Incidence of Overuse Syndromes of the Upper Limb in Young Pianists and its Correlation with Hand Size, Hypermobility and Playing Habits," *Annales de Chirurgie de la Main* 17, no. 4 (1998): 309-313.

[27] Chong Pak and Kris Chesky, "Prevalence of Hand, Finger, and Wrist Musculoskeletal Problems in Keyboard Instrumentalists," *Medical Problems of Performing Artists* 15 (2000): 17-23.

[28] Division of Occupational Health and Safety,"Ergonomics At Work"; available from http://dohs.ors.od.nih.gov/ergonomics_home.htm; Internet; accessed 29 April 2009.

[29] Ritva Ketola, Risto Toivonen, Marketta Häkkänen, Ritva Luukkonen, Esa-Pekka Takala, and Eira Viikari-Juntura, "Effects of Ergonomic Intervention in Work with Video Display Units," *Scandinavian Journal of Work, Environment & Health* 28, no. 1 (2002): 18-24.

[30] Katharyn Grant, and Daniel Habes, "Summary of Studies on the Effectiveness of Ergonomic Interventions," *Applied Occupational and Environmental Hygiene* 10 (1995): 523-530.

keyed instrument to fit their hand size, just like a smaller-handed violin player would choose the shorter violin to play. Unfortunately, modifying the keyboard span is not an available option for the majority of pianists today as explained in the next section.

Keyboard Span

Ever since the piano (pianoforte) was invented by Bartolomeo Cristofori at the beginning of the eighteenth century, the width of piano keys has not changed significantly. In 2008, Sakai reported that the octave span of Cristofori's piano from 1720 (the oldest existing piano) was exactly same as the modern piano.[31] It is also important to emphasize that the keyboard span remained the same even as the size of the keys was gradually reduced from the late eighteenth to the mid nineteenth century. Sakai concluded that many technically demanding piano pieces were composed using the narrower-spanned keyboard, and "this fact is compatible with the paradoxical situation that many modern pianists struggle with difficult piano techniques on a modern keyboard."

Considering Sakai's argument, it makes more sense to adopt the ergonomically modified keyboard not only to help small-handed pianists but also to practice a more historically informed performance. It would have been a normal performance practice for pianists from the late eighteenth to the mid nineteenth century to use different sizes of keyboards. Disappointingly, however, the idea of using modified instruments is not accepted by the current piano establishment because of the "standardized" key width since the late nineteenth century. The possible reasons for this modern custom are the portability of the instrument and pianists' fear of the unfamiliar key size. Financial reasons are certainly also involved.

[31] Naotaka Sakai, "Keyboard Span in Old Musical Instruments: Concerning Hand Span and Overuse Problems in Pianists," *Medical Problems of Performing Artists* 23, no. 4 (2008): 169-171.

In 2005, UNT acquired its first ergonomically modified keyboard. It is called "15/16 keyboard" with keys that are 1/16 narrower than the standard size (see Figure 2).

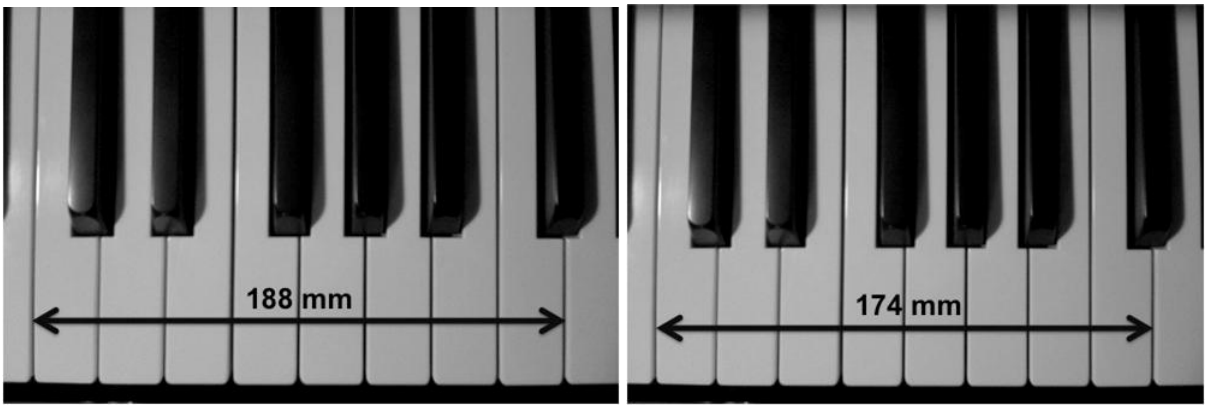

Figure 2: Octave Span of Standard-sized Keyboard (Left) and 15/16 Keyboard (Right)

As seen in Figure 2, the difference (14 mm) is about half an inch per octave. This keyboard is designed to be portable and can be fitted into a Steinway piano frame by an experienced piano technician in a matter of minutes. As of 2009, UNT owns three such keyboards and offers opportunities for piano students to practice and perform with those keyboards. In the past, several piano students used this keyboard for their recitals, including myself.

Ergonomic Intervention

Ergonomic intervention using the reduced-sized keyboard for pain prevention is justified as discussed above. Thus, the hypothesis is raised here – *The ergonomically modified keyboard (the 15/16 keyboard) helps small-handed pianists to play with less pain.* Up till now, the effectiveness of the keyboard has not been confirmed by any scientific research. One study in 2006 utilized a 7/8 keyboard to test physical ease; however, the presented data were not

sufficient to address the hypothesis because of the small sample size (*N*=2) and no data regarding playing-related pain.[32] The following study is the first one to evaluate the effectiveness of the ergonomically modified keyboard with a sufficient sample size and statistical data associated with playing-related pain.

[32] Brenda Wristen, Myung-Chul Jung, Alexis Wismer, and Susan Hallbeck, "Assessment of Muscle Activity and Joint Angles in Small-Handed Pianists: A Pilot Study on the 7/8-Sized Keyboard versus the Full-Sized Keyboard," *Medical Problems of Performing Artists* 21, no. 1 (2006): 3-9.

THE ERGONOMICALLY MODIFIED KEYBOARD STUDY

Methods

Subjects and Music

Thirty-five piano major students at University of North Texas was assigned the repertoire:

(1) Ascending and descending octave scale in C major with 8th note, 16th note, and sextuplets (quarter note = 60), *piano* and *forte*

(2) Ascending and descending chord scale in C major with 8th note, 16th note, and sextuplets (quarter note = 60), *piano* and *forte*

(3) Last section of *L'Isle Joyeuse* by Claude Debussy (one page excerpt)

Piano

Two Steinway pianos with the standard keyboard and the 15/16 keyboard (by Steinbuhler & Company: Titusville, PA)

Procedure

Each subject was given two weeks to practice the assigned repertoire and 45 minutes to practice on the 15/16 keyboard. After two weeks, subjects were asked to perform the music on both the standard and the 15/16 keyboard on two separate days, but the first keyboard was randomly selected. Their performances were recorded by a camcorder (Sony DCR-TRV18) that was located directly above the keyboard. These video images were stored on digital video discs. Subjects were asked to fill out the questionnaire before and after performances to evaluate perceptions of performance ability and comfort (see Appendix B).

Video and Statistical Analysis

The still images of their hands were captured from the video files using the Image Capture software. The selected frame for analysis was the moment when the subjects played a chord (B-C#-G#-B) from Debussy's *L'isle joyeuse*. All statistical analysis was executed using SPSS software.

Results

Performance Data

The images captured from the video file are observed, compared, and analyzed in this section.

Figure 3: Small Hand (span: 183 mm) and
Large Hand (span: 250 mm) on the Standard Keyboard

Figure 3 shows the smallest and largest hand among the study population playing the same chord (B-C#-G#-B) on the standard keyboard. The difference of hand position/posture between the large and small hands is very evident. The fingers of the large hand are naturally

curved and easily pressing all four keys. On the other hand, the fingers of the small hand are stretched out uncomfortably and barely reaching the octave.

Figure 4a: Right Hand (span: 183 mm) Plays on the Standard (Left) and 15/16 Keyboard (Right)

Figure 4b: Right Hand (span: 190 mm) Plays on the Standard (Left) and 15/16 Keyboard (Right)

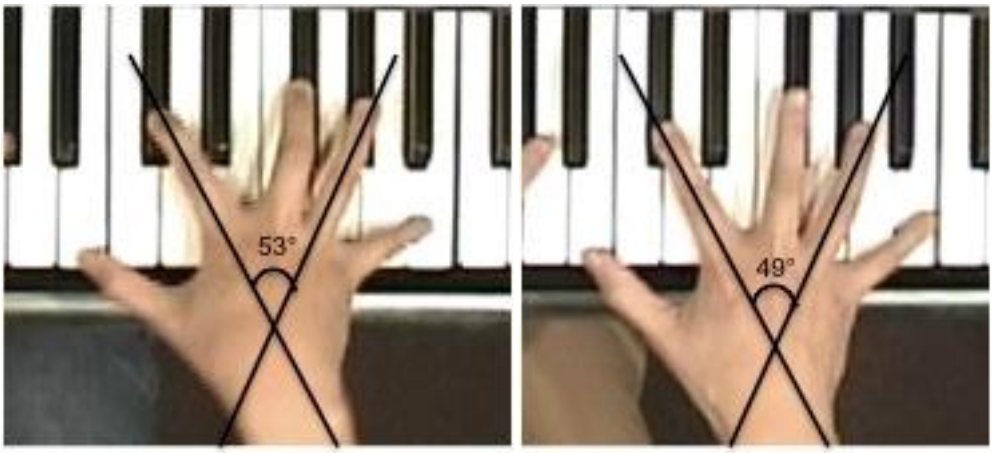

Figure 4c: Right Hand (span: 197 mm) Plays on the Standard (Left) and 15/16 Keyboard (Right)

The images of Figure 4 represent small hands with less than 200 mm hand span. When the same chord was played on both keyboards, the angle between digit 2 and 4 is reduced on the 15/16 keyboard. Moreover, it is clear that all hands above look more comfortable on the 15/16 keyboard compared to one on the standard keyboard; (1) The thumb looks less stretched and more curved (Figure 4a), (2) fingers are centered more on the keys (Figure 4b), and (3) finger 1 and 5 are reaching a wider range of keys (Figure 4c). Through the observations above, it is reasonable to conclude that the 15/16 keyboard helps not only to alleviate possible pain or problems but also to play with more dynamics and accuracy.

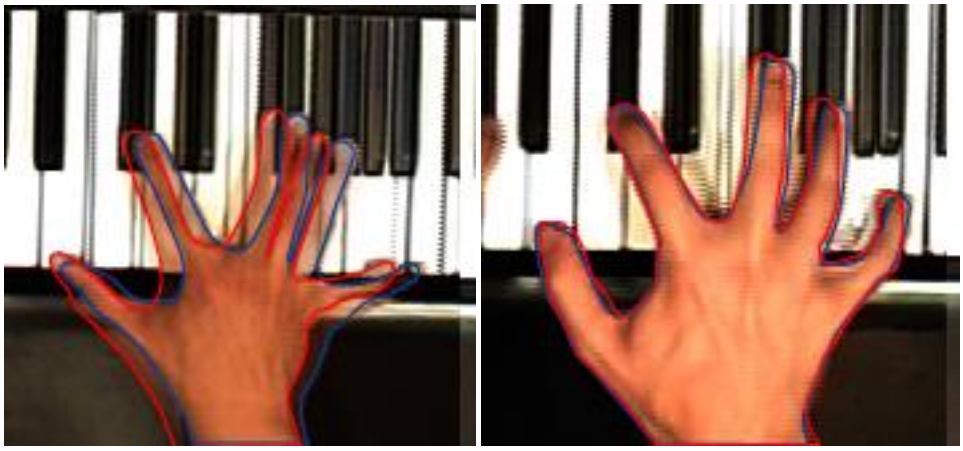

Figure 5: Piled-up Images of the Smallest Hand (Left) and Largest Hand (Right)
Outline for Right Hand on the Standard Keyboard (Blue) and 15/16 Keyboard (Red)

To argue more strongly that the 15/16 keyboard helps the small-handed pianists more than the large-handed pianists, the same hand on the two different keyboards is piled up together to see the differences when playing on both keyboards (Figure 5). For the large hand, postures are almost identical, and both outlines are closely matched. Only the tips of the fingers are displaced slightly, and the span between finger 1 and 5 is not changed. In contrast, postures of the small hand are significantly different as demonstrated by the two outlines in Figure 5. It is clear that the small hand feels the distance of keys more dramatically and that the hand on the 15/16 keyboard is much less stretched (Red line). To summarize, the difference between the two keyboards affects the arch and span of the whole hand for the small hand, but only the placement of the fingertips for the large hand. These results reveal that the 15/16 keyboard helps the small-handed pianists prevent both problems and injuries by improving the posture of hands and reducing unnecessary stretch.

After Performance Data

The data presented in this section were collected by the questionnaire, which subjects filled out after their performance on each keyboard (standard and 15/16). This questionnaire asked how much pain and tension subjects experienced while playing. After playing the same musical examples on *both* standard and 15/16 keyboards, subjects answered the question: *If you were given a choice, which keyboard would you prefer to use? And why?* As in Table 11, about 30 % of piano major students (10 students) responded that they would prefer to use the 15/16 keyboard. Among them, 60 % considered themselves small-handed pianists (Table 12).

Table 11: Keyboard Preference

	No.	%
15/16	10	28.6
Standard	21	60.0
Pending	4	11.4
Total	35	100.0

Table 12: Keyboard Preference vs. Subjective Hand Size

		Final Decision			Total
		15/16	Standard	Pending	
Small - Medium – Large (Subjective)	Small	6	4	2	12
	Medium	2	11	0	13
	Large	2	6	2	10
Total		10	21	4	35

Table 13 reports the actual measurements of hand spans of the study population. The right hand is smaller than the left hand on average, and the difference between minimum and maximum is about 7 cm (2 ¾ inch). The distance is equivalent to the width of 3 piano keys.

Table 13: Hand Span

	Minimum	Maximum	Mean	Std. Deviation
Left Hand Span	181.00	250.00	212.43	17.73
Right Hand Span	183.00	250.00	209.74	17.18

Table 14 shows that the students whose hand span is smaller than the average of the study population are much more likely to favor the 15/16 keyboard than the students who have a larger hand span.

Table 14: Keyboard Preference vs. Actual Hand Size

		Final Decision			Total
		15/16	Standard	Pending	
Left Hand Span	Larger than mean (212.4 mm)	3	13	2	18
	Smaller than mean (212.4 mm)	7	8	2	17
Right Hand Span	Larger than mean (209.7 mm)	2	14	2	18
	Smaller than mean (209.7 mm)	8	7	2	17

The Pearson correlation in Table 15 reports that subjects' hand spans are significantly correlated with pain and tension experienced while playing on both keyboards. The negative numbers indicate the inverse relationships (small hand span = more pain).

Table 15: Pearson Correlation of Hand Span and Pain/Tension

		Did you feel any **pain** while playing the **standard** keyboard?	Did you feel any **tension** while playing the **standard** keyboard?	Did you feel any **pain** while playing the **15/16** keyboard?	Did you feel any **tension** while playing the **15/16** keyboard?
Left Hand Span	Pearson Correlation	-0.631**	-0.556**	-0.521**	-0.416*
	Sig. (2-tailed)	0.000	0.001	0.001	0.013
Right Hand Span	Pearson Correlation	-0.532**	-0.452**	-0.424*	-0.352*
	Sig. (2-tailed)	0.001	0.006	0.011	0.038

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

As indicated in Table 16, students with smaller hands (< 212.4 mm) reported significantly ($p < 0.05$) more pain and tension than students with larger-hands (> 212.4 mm). This difference was observed bilaterally.

Table 16: Mean Comparison of Pain and Tension Between Small and Large Hands

	Left Hand Span (mean = 212.4mm)	N	Mean (SD)	t	Sig. (2-tailed)
Did you feel any **pain** while playing the **standard** keyboard?*	Larger than mean	18	0.45 (0.89)	-4.504	0.000
	Smaller than mean	17	3.78 (3.00)		
Did you feel any **tension** while playing the **standard** keyboard?*	Larger than mean	18	1.79 (1.91)	-3.251	0.003
	Smaller than mean	17	4.63 (3.14)		
Did you feel any **pain** while playing the **15/16** keyboard?*	Larger than mean	18	0.39 (0.70)	-2.479	0.018
	Smaller than mean	17	1.55 (1.85)		
Did you feel any **tension** while playing the **15/16** keyboard?*	Larger than mean	18	1.36 (1.91)	-2.104	0.043
	Smaller than mean	17	3.08 (2.86)		

*Subjects answered on VAS (0-10 cm)
Significance level ($p < 0.05$)

Table 16 – *Continued*

	Right Hand Span (mean = 209.7mm)	N	Mean (SD)	t	Sig. (2-tailed)
Did you feel any **pain** while playing the **standard** keyboard?*	Larger than mean	18	0.61 (1.05)	-3.849	0.001
	Smaller than mean	17	3.61 (3.13)		
Did you feel any **tension** while playing the **standard** keyboard?*	Larger than mean	18	2.07 (2.14)	-2.472	0.019
	Smaller than mean	17	4.34 (3.23)		
Did you feel any **pain** while playing the **15/16** keyboard?*	Larger than mean	18	0.39 (0.70)	-2.479	0.018
	Smaller than mean	17	1.55 (1.85)		
Did you feel any **tension** while playing the **15/16** keyboard?*	Larger than mean	18	1.39 (1.89)	-2.025	0.051
	Smaller than mean	17	3.05 (2.89)		

*Subjects answered on VAS (0-10 cm)
Significance level ($p < 0.05$)

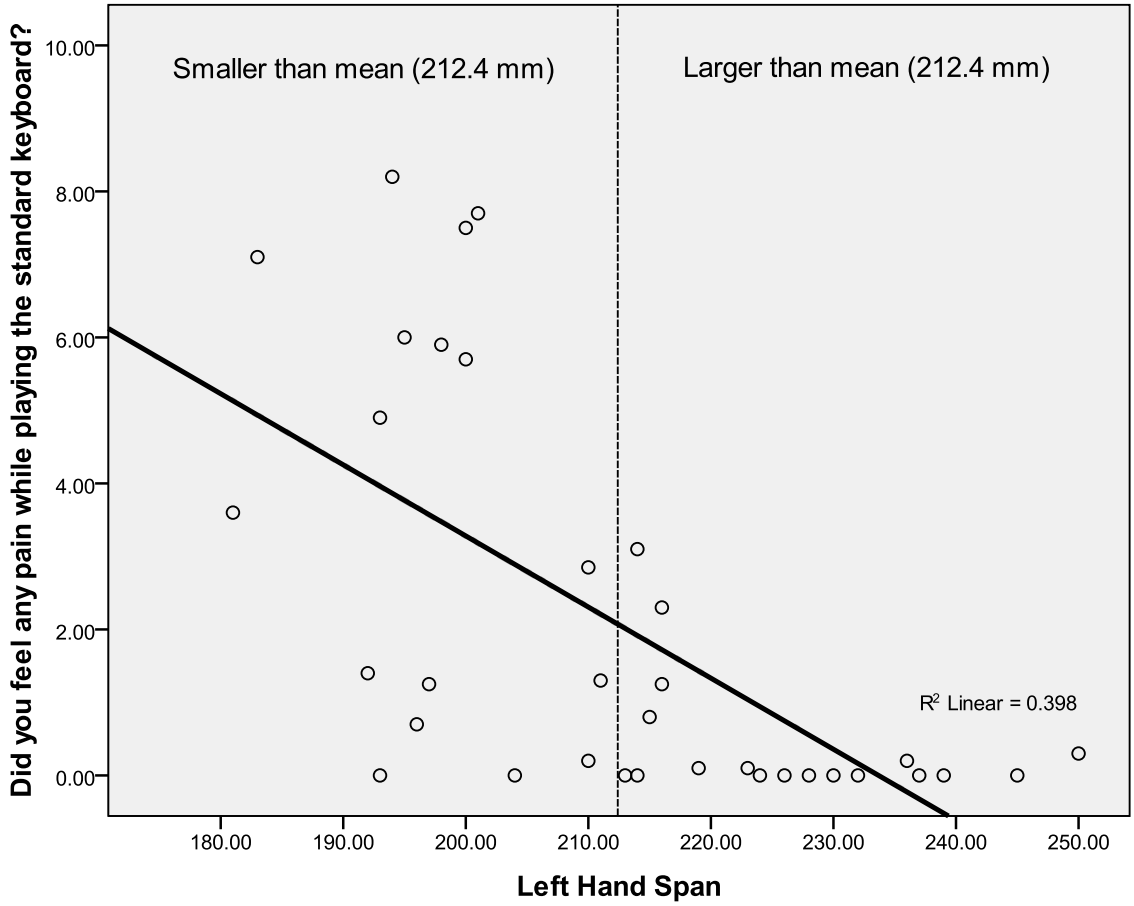

Figure 6a: Scatterplot and Regression Line of Left Hand Span (X) and Pain on the Standard Keyboard (Y)

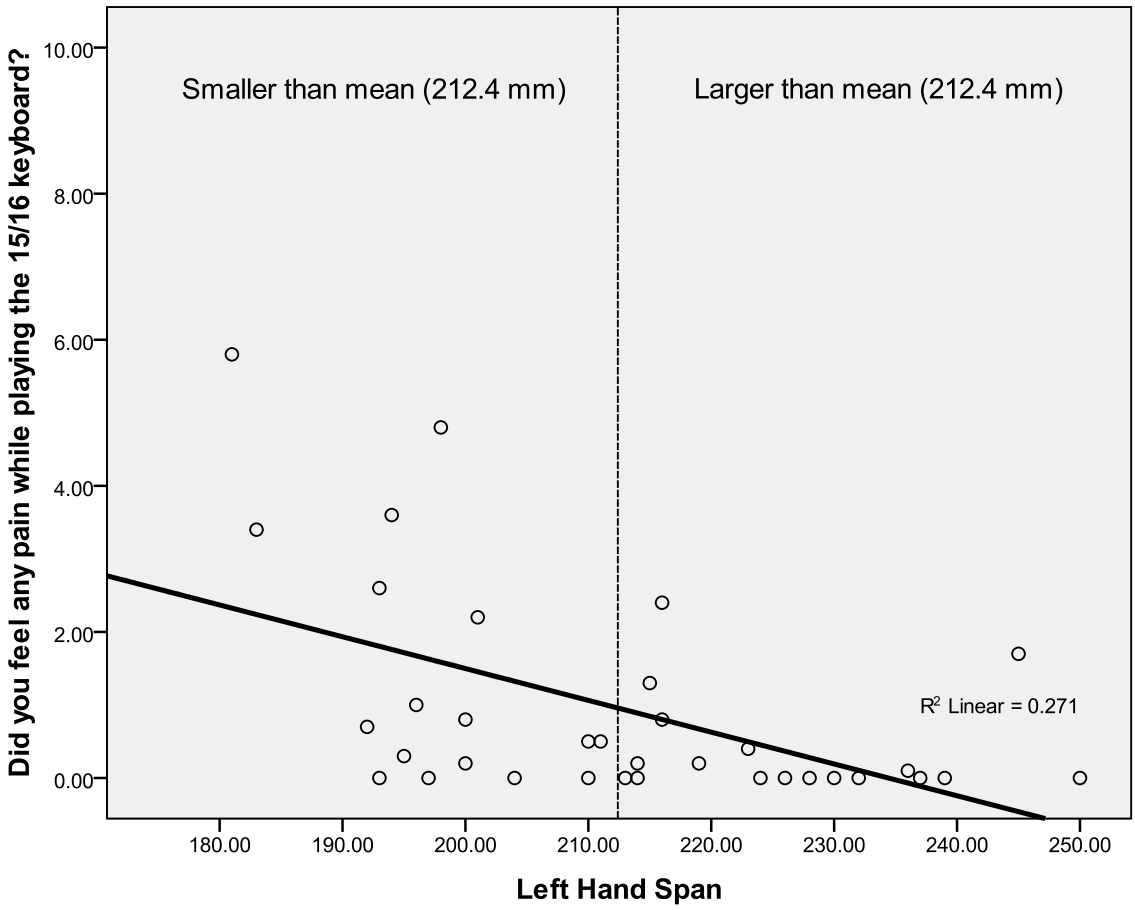

Figure 6b: Scatterplot and Regression Line of Left Hand Span (X) and Pain on the 15/16 Keyboard (Y)

Figures 6a and 6b graphically show individual subject's pain scores associated with the standard keyboard and the 15/16 keyboard respectively. The negative slopes of the regression lines illustrate that hand span and pain scores are inversely correlated for both conditions. However, the slope of the regression line is less steep for the 15/16 keyboard condition.

Further illustrating the influence of the ergonomic change, mean of pain and tension scores shown in Table 17 were always smaller on the 15/16 keyboard than scores associated with the standard keyboard regardless of the hand size. However, the mean differences for

each pair of questions were significantly different ($p < 0.05$) only for the smaller-handed group. In other words, when compared to students with larger hands, students with smaller hands report higher levels of pain and tension when using the standard keyboard and more dramatic reductions in pain and tension when using the 15/16 keyboard.

Table 17: Mean Difference of Pain and Tension Between Standard and 15/16 Keyboard

Left Hand Span (mean = 212.4 mm)		N	Mean (SD)	t	Sig. (2-tailed)
Larger than mean	Did you feel any **pain** while playing the **standard** keyboard?*	18	0.45 (0.89)	0.296	0.771
	Did you feel any **pain** while playing the **15/16** keyboard?*	18	0.39 (0.70)		
	Did you feel any **tension** while playing the **standard** keyboard?*	18	1.79 (1.91)	0.837	0.414
	Did you feel any **tension** while playing the **15/16** keyboard?*	18	1.36 (1.91)		
Smaller than mean	Did you feel any **pain** while playing the **standard** keyboard?*	17	3.78 (3.00)	3.497	0.003
	Did you feel any **pain** while playing the **15/16** keyboard?*	17	1.55 (1.85)		
	Did you feel any **tension** while playing the **standard** keyboard?*	17	4.63 (3.14)	3.060	0.045
	Did you feel any **tension** while playing the **15/16** keyboard?*	17	3.08 (2.86)		
Right Hand Span (mean = 209.7 mm)		N	Mean (SD)	t	Sig. (2-tailed)
Larger than mean	Did you feel any **pain** while playing the **standard** keyboard?*	18	0.61 (1.047)	0.864	0.400
	Did you feel any **pain** while playing the **15/16** keyboard?*	18	0.39 (0.70)		
	Did you feel any **tension** while playing the **standard** keyboard?*	18	2.07 (2.14)	1.151	0.266
	Did you feel any **tension** while playing the **15/16** keyboard?*	18	1.39 (1.89)		
Smaller than mean	Did you feel any **pain** while playing the **standard** keyboard?*	17	3.61 (3.13)	3.175	0.006
	Did you feel any **pain** while playing the **15/16** keyboard?*	17	1.55 (1.85)		
	Did you feel any **tension** while playing the **standard** keyboard?*	17	4.34 (3.23)	2.708	0.071
	Did you feel any **tension** while playing the **15/16** keyboard?*	17	3.05 (2.89)		

*Subjects answered on VAS (0-10 cm)
Significance level ($p < 0.05$)

Conclusions

From the data presented above, this study demonstrates that the ergonomically modified keyboard (the 15/16 keyboard) helps small-handed pianists (1) to avoid extreme stretching of their hands and (2) to play with less pain and tension. These results justify serious consideration for embracing ergonomic principals into the world of piano. However, implementation will be difficult until pianists come to understand and believe in the utility and effectiveness of the ergonomically modified keyboard. To help highlight the importance of attitudes and perception among students, the following statements were provided by a few small-handed subjects (hand span – less than 200 mm) who reported that they were either unsure about the modified keyboard or who prefer to use the standard keyboard over the 15/16 keyboard. Subjects were asked, *If you were given a choice, which keyboard would you prefer to use? And why?*

Prefer the standard keyboard

- I am used to playing the standard piano (x 3)
- Accuracy is easier, to me [sic], because it is really just as comfortable as the 15/16, and I am more at ease with the standard
- Less slips

Pending

- 15/16 is comfortable and any tension for forearm, but I already know standard piano and my muscle also know that piano [sic]
- Depends on the piece, if it requires big chord sound, I would like to use 15/16 because it makes my hands and shoulders more relaxed and less pain

Although more research is needed, these quotes provide some insights into the attitudes and perceptions among small-handed pianists. Some seemed to choose the standard keyboard simply due to its familiarity. This concern is understandable because pianists are accustomed to the standard keyboard. Another concern is that they may be at a disadvantage when they

travel to a new location or venue that does not offer or allow use of an ergonomically modified keyboard.

Several approaches are suggested to overcome these obstacles. First, to reduce students' fear of the unfamiliar, faculty and teachers need to inform students that it is not difficult to adjust technique especially when their hands fit more naturally to the smaller keyboard. In fact, students should consider that practicing on both the standard and the reduced-sized keyboard may help a pianist to approach the keyboard with a more relaxed hand and arm positions. This observation was experienced and confirmed by the author (hand span = 185 mm). However, research studies are needed to assess the effectiveness of establishing technique on the small keyboard before transferring to the standard.

Secondly, all NASM (National Association of Schools of Music) accredited institutions and concert facilities should make the ergonomically modified keyboard available for student pianists as an option. This goal is challenging because of financial hurdles. However, considering the piano budgets of most major music schools, an investment in this option is reasonable, especially considering the size and scope of this problem.

Beyond these logistical considerations, the most challenging obstacle for embedding this idea into the piano world is the culture. Ever since the current keyboard size became labeled as the "standard," anything outside "normal" may be discriminated against. For this reason, the piano world should eliminate the term "standard" and rename keyboards based on key size. Under this rule, the standard keyboard should be called the "188 keyboard;" the modified keyboard, the "174 keyboard." Another concern is that pianists who are genetically fortunate enough to have been born with larger physical traits might label the use of a modified

keyboard as “cheating.” This perspective has been observed and should be considered irresponsible and unsympathetic. Perhaps representing the pinnacle of such negligent perspectives, some small-handed pianists are considered “less-talented” because they struggle with a repertoire that requires playing larger chords or because they are no longer able to play due to pain.

These issues reflect an unfortunate cultural phenomenon and they need to change on behalf of current and future pianists. Understanding beliefs and attitudes through survey research would be one approach to normalizing opinions and acceptance levels towards the use of ergonomics. Hopefully all pianists would eventually agree that an ergonomic intervention to compensate for hand size is feasible and essential, just like adjusting the height of a piano bench to compensate for leg length and body height.

Having options when one’s health is concerned is invaluable. Moreover, being aware of the existing problems and available resources is an essential component to protect the health of students and professionals. To encourage awareness of music-related health risks and wellness through education, Health Promotion in Schools of Music (HPSM) was established by the University of North Texas (Texas Center for Music and Medicine) and Performing Arts Medicine Association (PAMA).[33, 34] In response to HPSM recommendations, some NASM Accredited Institutions are now offering “Occupational Health” or wellness courses.[35, 36, 37]

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[33] Health Promotion in Schools of Music, "Initial Recommendations for Schools of Music"; available from http://www.unt.edu/hpsm/; Internet; accessed 18 June 2009.

[34] Kris Chesky, William Dawson, Ralph Manchester, “Health Promotion in Schools of Music: Initial Recommendations for Schools of Music,” *Medical Problems of Performing Artisst* 21, no. 3 (2006): 142-144.

[35] Ralph Manchester, ed., “Health Promotion Courses for Music Students: Part 1,” *Medical Problems of Performing Artists* 22, no. 1 (2007): 26-29.

Some large organizations, such as MTNA (Music Teachers National Association)[38], The Frances Clark Center for Keyboard Pedagogy[39], and the National Association for Music Education[40], support this project and encourage increased efforts to educate student musicians about occupational health and wellness.

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[36] Ralph Manchester, ed., "Health Promotion Courses for Music Students: Part II," *Medical Problems of Performing Artists* 22, no. 2 (2007): 80-81.

[37] Ralph Manchester, ed., "Health Promotion Courses for Music Students: Part III," *Medical Problems of Performing Artists* 22, no. 3 (2007): 116-119.

[38] Music Teachers National Association, "Musician Wellness"; available from http://www.mtna.org/Resources/MusicianWellness/tabid/470/Default.aspx; Internet; accessed 18 June 2009.

[39] Frances Clark Center for Keyboard Pedagogy, "Wellness Resources"; available from http://www.francesclarkcenter.org/NationalConferencePages/resources/wellnessResources.html; Internet; accessed 18 June 2009.

[40] National Association for Music Education, "Health in Music Education"; available from http://menc.org/connect/surveys/position/health.html; Internet; accessed 18 June 2009.

DISCUSSIONS

Pianists have a simple goal: "play well." To accomplish this goal, "being well" is rarely included in the process; instead, unhealthy conditions and habits (pain, lack of physical exercise. etc) sometimes become part of the learning process. Historically, piano teaching and learning can be viewed as mostly subjective activities that rely heavily on the senses (touch, hearing, sight etc). This approach has been successful and effective in achieving the "play well" part that most pianists care about and is perhaps one reason why the piano world is still behind on wellness development. In other words, when it comes to the "being well" part, the piano community cannot rely exclusively on the traditional approaches and learning methods. Subjectivity will not serve pianists completely. To identify and verify group and individual needs and approaches for improvement towards better health, objective data and scientific research are necessary.

Moreover, the piano community must be critical of the many advocates who endeavor to address the "being well" part without scientific research. Because so much is at stake, information about how to play or what to do should be viewed critically because of its potential to mislead pianists who try to exercise well-being. For example, numerous publications suggest stretching before playing the piano as a method to reduce the risk of musculoskeletal injury.[41, 42, 43, 44] As discussed in an earlier section of this paper, the research data is insufficient to verify

[41] Margaret Redmond and Anne Tiernan, "Knowledge and Practices of Piano Teachers in Preventing Playing-related Injuries in High School Students," *Medical Problems of Performing Artists* 16 (2001): 32-42.

[42] Jacqueline Csurgai-Schmitt, "Pushing the Physiological Envelope," in *A Symposium for Pianists and Teachers,* ed. Kris Kropff (Ohio: Heritage Music Press, 2002), 147-155.

[43] Norman B. Rosen, "Overuse, Pain, Rest, and the Pianist," in *A Symposium for Pianists and Teachers,* ed. Kris Kropff (Ohio: Heritage Music Press, 2002), 156-166.

that stretching actually helps to prevent injury. On the contrary, my research showed that stretching increases the risk. Additional evidence suggests that static stretching should be excluded from warm-ups for strength and power activities[45] and that stretching significantly decreases muscular strength.[46, 47, 48]

Another example of misguidance is offered by Mr. Thomas Mark in his book *What Every Pianist Needs to Know about the Body.* Contrary to the findings from the current and previous studies showing that the etiology to piano-related pain is multidimensional, Mr. Mark proclaims that playing-related pain is caused by only three factors as indicated in the quote below:

> Pain in playing the piano can come from any of three causes. 1) It can come from a medical condition or illness, such as arthritis. 2) It can come from a trauma such as a sprain or fracture. Pain from either of these causes is appropriately treated by medical science. 3) Pain can come from inefficient use of the body – poor habits of movement. Almost all pain experienced by musicians falls in this third category. Pain caused by poor habits of movement is relieved by discovering and correcting those habits. If poor habits are not corrected, they can lead to injury, which in turn can cause permanent damage.[49]

This book suggests that hand size or any other risk factors that have been reported in the scientific literature have nothing to do with playing related pain; it is "poor habits of

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[44] A Grieco, E Occhipinti, D Colombini, O Menoni, M Bulgheroni, C Frigo, and S Boccardi, "Muscular Effort and Musculoskeletal Disorders in Piano Students: Electromyographic, Clinical and Preventive Aspects," *Ergonomics* 32, no. 7 (1989): 713-714.

[45] Warren B Young and David G Behm, "Should Static Stretching Be Used During a Warm-up For Strength and Power Activities?," *Journal of Strength and Conditioning* 24 (2002): 33-37.

[46] Janne Avela, Heikki Kyröläinen, and Paavo V Komi, "Altered Reflex Sensitivity After Repeated and Prolonged Passive Muscle Stretching," *Journal of Applied Physiology* 86 (1999): 1283–1291.

[47] Tammy K Evetovich, NJ Nauman, Donovan S Conley, and Jay B Todd, "Effect of Static Stretching of The Biceps Brachii on Torque, Electromyography, and Mechanomyography During Concentric Isokineticmuscle Actions," *The Journal of Strength & Conditioning Research* 17 (2003): 484–488.

[48] Jeni R McNeal and William A Sands, "Acute Static Stretching Reduces Lower Extremity Power in Trained Children," *Pediatric Exercise Science* 15 (2003): 139–145.

[49] Thomas Mark, *What Every Pianist Needs to Know about the Body* (Chicago: GIA Publications, Inc., 2004), 1.

movement." The piano community must consider the ramifications of young pianists, perhaps with small hands, who read and trust these statements. Unfortunately, it is possible that advice like this increases self-perceptions of guilt and inadequacy and a long-term struggle to find the "right" way to play the piano.

Overall, the current paper was successful in presenting the objective, scientific data that pianists can depend on and use as their resources. In the near future, hopefully all pianists and educators will agree that more data are warranted to promote wellness of pianists and to ensure a balanced life as a great performer and a healthy human being.

APPENDIX A

SUBJECT QUESTIONNAIRE

Subject Questionnaire

Subject Number: _____

Date: _____

Section 1: Demographics and Music Background

1. Age: _____
2. Gender (Circle) Male Female
3. Ethnicity/Race (Circle) African-American Asian Caucasian Hispanic

   Other_____
4. Marital status (Circle) Single Married Separated Divorced Widowed
5. Number of children _____
6. Average amount of sleep _____ (hours/day)
7. Average amount of exercise _____ (hours/week)
8. Average travel (days away from home overnight) _____ (days/month)
9. Health insurance (Circle) Yes No
10. Approximate age you started playing piano: _____
11. Total number of years of private lessons: _____(years)
12. Years of college instruction in piano: _____(years)
13. Instrument you play other than piano: _____
14. Size of your hands:

    Very small |————————————————————————| Very large

Section 2: Practice Habits

1. Number of hours you spend at the piano per week during semester:

   Practice _____ (hours/week)

   Lesson _____ (hours/week)

   Accompanying _____ (hours/week)

   Chamber music/Ensemble _____ (hours/week)

   Teaching _____ (hours/week)

   Keyboard related activities (Church, Gig – restaurant, wedding etc.)

   _____Time Spent _____ (hours/week)

   _____Time Spent _____ (hours/week)

   _____Time Spent _____ (hours/week)

2. Average number of performances (departmental, recital), competitions, and jury per semester: In school _____ (times) Outside of school _____ (times)

3. Do you own a piano at home? (Circle) Yes No

4. If answered yes, what kind of piano? (Circle) Upright Grand

   Other _____

5. Where do you practice normally?

   _____

6. Hours you spend on Upright Piano: _____ (hours/week)

   Grand Piano: _____ (hours/week)

7. Do you warm-up before practice?

   Never Always

8. Describe your warm-up and time you spend:

   Physical/Non-musical warm-up (i.e., stretch, apply heat)

   _____Time spent: _____ (min)

   Psychological warm-up (i.e., meditation)

   _____Time Spent: _____ (min)

   Musical warm-up (i.e., scales, etudes, exercises, slow piece)

   _____ Time spent: _____ (min)

   Other _____

   Time spent: _____ (min)

9. Do you take breaks during practice?

   Never |————————————————————————| Always

10. What do you do on your break?

   _____

   How long and how often? _____ (min) every _____ (hours)

11. Do you stop daily practice because you feel physical fatigue?

   Never |————————————————————————| Always

12. Do you stop daily practice because you feel mental fatigue?

   Never |————————————————————————| Always

13. List work, leisure activities or sports in which you regularly participate that use hands or arms:

   _____ Time spent _____ (hours/week)

   _____ Time spent _____ (hours/week)

   _____ Time spent _____ (hours/week)

Section 3: Medical History and Background

Musculoskeletal Problems Associated with Piano

1. Do you experience pain when playing?

   Never |————————————————————————| Always

2. Do you experience pain after playing?

   Never |————————————————————————| Always

3. Does pain stop you from playing the piano?

   Never |————————————————————————| Always

4. How much of your playing is affected by your pain? – consider speed, dynamics, repertoire, time spent i.e.,)

   0 % |————————————————————————| 100 %

****

Please review the drawing on the next page and mark where you experience both current and past pain using the appropriate markings, as noted on the page, and the 1 to 5 grading scale as noted below.

Grade 1: Pain while playing; should be consistent rather than occasional; pain ceases when not playing.

Grade 2: Pain while playing; slight physical signs of tenderness; may have transient weakness or loss of control; no interference w/other uses of 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.

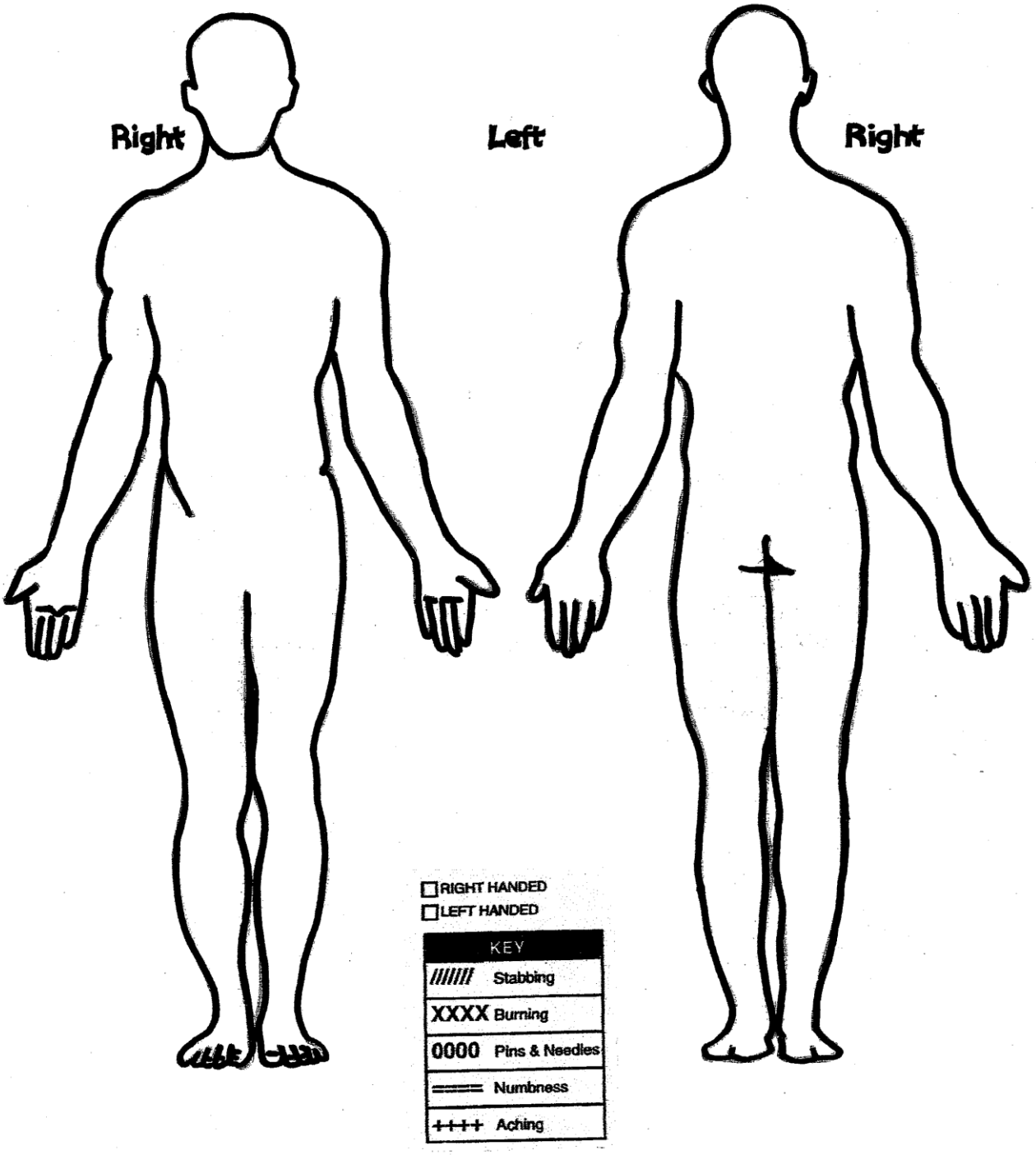
Grade 4: As for Grade 3; all common uses of the location cause pain – housework, driving, writing, turning knobs, dressing, washing, etc. – but these are possible as long as pain is tolerated.

Grade 5: As for Grade 4; including loss of use of location due to disabling pain.

****

Possible locations:

Right Fingers Left Fingers Right Wrist Left Wrist Right Forearm Left Forearm Right Hand Left Hand Right Elbow Left Elbow Right Shoulder Left Shoulder Right Neck Left Neck Right Upper Back Left Upper Back Right Middle Back Left Middle Back Right Lower Back Left Lower Back Right Hip Left Hip Right Knee Left Knee Right Calf Left Calf Right Ankle Left Ankle Right Foot Left Foot Right Toes Left Toes


Right
Left
Right
RIGHT HANDED
LEFT HANDED
KEY
/////// Stabbing
XXXX Burning
0000 Pins & Needles
==== Numbness
++++ Aching

Non-Musculoskeletal Problems

Do you experience any of the following? (circle answer):

Acquired Dental Malocclusion	No problem	Mild	Severe
Acute Anxiety	No problem	Mild	Severe
Asthma	No problem	Mild	Severe
Blackouts/Dizziness	No problem	Mild	Severe
Chest Discomfort	No problem	Mild	Severe
Chin Rest Sore	No problem	Mild	Severe
Depression	No problem	Mild	Severe
Earaches	No problem	Mild	Severe
Eye Strain	No problem	Mild	Severe
Fatigue	No problem	Mild	Severe
Headache	No problem	Mild	Severe
Hearing Loss	No problem	Mild	Severe
Heart Condition	No problem	Mild	Severe
Hemorrhoids	No problem	Mild	Severe
High Blood Pressure	No problem	Mild	Severe
Inguinal Hernia	No problem	Mild	Severe
Loss of Lip	No problem	Mild	Severe
Loss of Seal	No problem	Mild	Severe
Mouth Lesions	No problem	Mild	Severe
Respiratory Allergies	No problem	Mild	Severe
Sleep Disturbances	No problem	Mild	Severe
Stage Fright	No problem	Mild	Severe
TMJ Syndrome	No problem	Mild	Severe
Ulcer	No problem	Mild	Severe
Varicose Veins	No problem	Mild	Severe
Weight Problems	No problem	Mild	Severe

Section 4: Anthropometric Measures

1. Height __ ft ___ in
2. Weight _____ lbs
3. Hand Dominance (Circle) Left Right
4. Left upper arm length _____ (mm)
5. Right upper arm length _____ (mm)
6. Left forearm length _____ (mm)
7. Right forearm length _____ (mm)
8. Left hand length _____ (mm)
9. Right hand length _____ (mm)
10. Left wrist circumference _____ (mm)
11. Right wrist circumference _____ (mm)
12. Left Index finger diameter _____ (mm)
13. Right Index finger diameter _____ (mm)
14. Left hand volume _____ (mL=cc)
15. Right hand volume _____ (mL=cc)
16. Left hand span _____(mm) [filename: take digital photo and measure]
    Biggest intervals you think you can reach on keyboard _____ (th)
17. Right hand span _____(mm) [filename: take digital photo and measure]
    Biggest intervals you think you can reach on keyboard _____ (th)
18. Left thumb-Index finger active span _____ (degree)
19. Right thumb-Index finger active span _____ (degree)
20. Left Digit 2-3: Active span _____ (degree)
21. Right Digit 2-3: Active span _____ (degree)
22. Left Digit 3-4: Active span _____ (degree)
23. Right Digit 3-4: Active span _____ (degree)
24. Left Digit 4-5: Active span _____ (degree)
25. Right Digit 4-5: Active span _____ (degree)

Basic Elements of Performance (BEP XII)

Range of Motion (deg)	Left side	Right side
	Pronation (CW) Supination (CCW)	Pronation (CCW) Supination (CW)
Rotation Speed (deg/sec)	Left side	Right side
	Pronation (CW) Supination (CCW)	Pronation (CCW) Supination (CW)
Isometric Strength (N-m)	Left side	Right side
	Pronation (CW) Supination (CCW)	Pronation (CCW) Supination (CW)

Pinch Strength (N)	Left side	Right side
Standard BEP Pseudo-pulp		

APPENDIX B

QUESTIONNAIRE FOR BEFORE AND AFTER PERFORMANCE

Performance Day _____ Subject Number: _____

- **<u>Before</u>** Playing - **<u>Standard</u>**:

1. Number of hours you spent at the piano today: _____ (hours)
2. How long ago did you play the piano today? _____ (hours ago)
3. Did you do anything other than playing the piano in which you used your hands or arms before you came in here? (Circle) Yes No

   What? _____

4. Do you feel tired today?

   Not at all |————————————————————————| A lot

5. Do you feel pain today?

   None |————————————————————————| A lot

6. Do you feel nervous today?

   None |————————————————————————| A lot

7. How well are you prepared today?

   Not at all |————————————————————————| Very well

8. Date of last performance (playing for an audience), competition, or jury:

   _____

9. Date of next scheduled performance, competition, or jury: _____

Performance Day _____ Subject Number: _____

- **<u>Before</u>** Playing – **<u>15/16</u>**:

1. Number of hours you spent at the piano today: _____ (hours)
2. How long ago did you play the piano today? _____ (hours ago)
3. Did you do anything other than playing the piano in which you used your hands or arms before you came in here? (Circle) Yes No

   What? _____

4. Do you feel tired today?

   Not at all |————————————————————| A lot

5. Do you feel pain today?

   None |————————————————————| A lot

6. Do you feel nervous today?

   None |————————————————————| A lot

7. How well are you prepared today?

   Not at all |————————————————————| Very well

8. Date of last performance (playing to an audience), competition, or jury:

   _____

9. Date of next scheduled performance, competition, or jury: _____

Performance Day _____ Subject Number: _____

After playing – **Standard**:

1. Do you feel tired now?

   Not at all |————————————————————————| A lot

2. Do you feel pain now?

   None |————————————————————————| A lot

3. Do you feel nervous now?

   None |————————————————————————| A lot

4. Did you feel any pain while playing?

   Never |————————————————————————| Always

5. Did you feel any tension while playing?

   Never |————————————————————————| Always

6. Where did you feel tension? – use the pain locator and explain when and where it occurred

Answer only after playing both standard and 15/16

7. If you were given a choice, which keyboard would you prefer to use? And Why?

   (Circle) Standard 15/16

   Reason:

_____

Performance Day _____ Subject Number: _____

_____

_

Performance Day _____ Subject Number: _____

After playing – **15/16**:

1. Do you feel tired now?

   Not at all |————————————————————————| A lot

2. Do you feel pain now?

   None |————————————————————————| A lot

3. Do you feel nervous now?

   None |————————————————————————| A lot

4. Did you feel any pain while playing?

   Never |————————————————————————| Always

5. Did you feel any tension while playing?

   Never |————————————————————————| Always

6. Where did you feel tension – use the pain locator and explain when and where it occurred

Answer only after playing both standard and 15/16

7. If you were given a choice, which keyboard would you prefer to use? And Why?

   (Circle) Standard 15/16

   Reason:

_____

Performance Day _____ Subject Number: _____

_____

_

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