

Hand Size and the Piano Keyboard.
Literature Review and a Survey of the Technical and Musical Benefits for
Pianists using Reduced-Size Keyboards in North America

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For around 100 years, there has been a 'one size fits all' approach to the piano keyboard, despite the wide variation in hand sizes within the human population. Much of the literature relating hand size to piano playing is in the performing arts medicine field, identifying small hand size as one of the possible causes of pain and injury among pianists. Adopters of reduced-size keyboards, available since the mid-1990s, report relief from pain and tension, and other benefits, such as improvements in specific technical and musical skills, faster learning times, and greater comfort and security.

This paper includes a review of data on hand size in relation to piano keyboards, epidemiological and other literature relating to injury risk for small-handed pianists, and individuals' accounts of how reduced-size keyboards have benefited their own playing. The authors conducted a questionnaire survey of North American adult pianists who play reduced-size keyboards. The aim was to explore the nature of the technical, musical and health benefits, focusing on their experiences with reduced-size compared with the standard keyboard. Finally, the paper summarises one of the author's (Rhonda) initial reactions to playing on a 7/8 keyboard, and suggests further areas for research.

At the end of 2007, I (Rhonda) was searching the internet for information on piano playing technique for small-handed pianists. I came across an article by Christopher Donison, a pianist, composer, conductor and lecturer in British Columbia. The following words, in particular, caught my attention:

There are two great secrets in the world of piano playing. The first is how much easier the instrument is to play with larger hands and the second is how impossible it can be with smaller hands. If one can divide the world into roughly two constituencies; a smaller half and a larger half, one can see that the larger half never really knows what the difficulties of their small-handed counterparts are, and the smaller half never really finds out how much easier all the difficulties are with larger hands. This is because small-handed people never wake up the next morning with larger hands, no matter how hard they may pray for that to happen, and the larger handed people have never experienced the difficulties of the smaller-handed people. Their hands were already big enough long before they were attempting repertoire that was challenging enough to betray the secret. (Donison, 1998, p. 41).

Donison, having particularly small hands for a male, had had a custom-made smaller keyboard made for his Steinway grand piano. His published papers (1998, 2000) on this subject elaborate on the significant technical and musical benefits for his own piano playing. In the early 1990s, Donison met up with Pennsylvanian textile

manufacturer and engineer, David Steinbuhler. Together they created a second official keyboard size (the *DS standard*TM), with the long term aim of it becoming universally available.

During the two and a half years since that internet discovery, I have studied the literature relating to hand size and the piano keyboard, established contact with David Steinbuhler and ordered my own 7/8 keyboard. This was custom-made to fit my Bernstein grand piano and was installed in early April 2009.

This paper covers a review of readily available data on hand size in humans and how this relates to keyboard size, a review of literature that links hand size with piano playing, results of a survey of pianists in North America who use reduced-size keyboards, and my initial perceptions of the benefits of the reduced-size keyboard for my own playing.

Hand Size and Piano Keyboard Size

Between 1998 and 2005, Steinbuhler & Company invited adult pianists to experiment with a complete range of piano keyboard sizes at their centre in Titusville, Pennsylvania. Participants were able to spend hours or days experimenting and swapping between the different size keyboards. It became clear there was a strong desire for at least two smaller keyboard sizes in addition to the conventional keyboard. To determine the most practical size keyboard for the smaller-handed pianists, a detailed study was conducted using five keyboards measuring between 38 and 42 inches in overall width. About 15 pianists experimented with these keyboards. Although there was a general desire to play the smallest keyboards, it was found that below 40 inches, the space between black keys became too cramped for all but those with the smallest hands with thin fingers. Hence, 41 inches was selected as the best available choice for the smallest hand-size. Three standards were subsequently defined as follows:

- Conventional keyboard – 6.5 inch octave¹, 48.29 inch total width
- 15/16 Universal keyboard – 6.0 inch octave, 44.57 inch total width
- 7/8 *DS Standard*TM keyboard – 5.54 inch octave, 41.14 inches total width

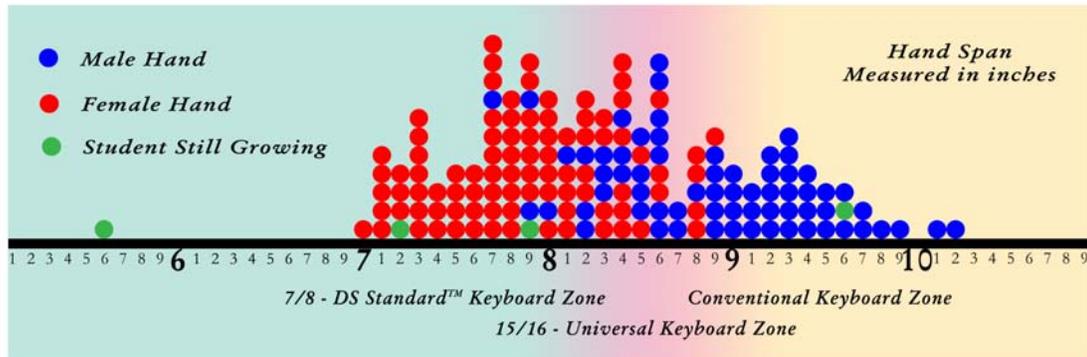
In addition, at the US Music Teachers National Association (MTNA) 2004 National Conference, attendees were invited to play these keyboard sizes and have their hand spans measured. Of the 160 who agreed to participate, 90 were adult females, 66 were adult males and four were students still growing. The distribution of their ‘active 1-5 hand spans’² is shown in Figure 1, a chart created by David Steinbuhler. A mix of left and right hands were measured. While not a random sample, the gender difference is obvious from the graph.

¹ Octave measurements given represent the total width of 7 white keys.

² Distance in inches from thumb to fifth finger stretched to the maximum

What is your Hand Span?

Using the Hand Gauge on the back of this card, a pianist can measure the span of his or her hand to see how it compares with the hands and zones represented in this chart.



The hand span data in this chart was collected at the 2004 MTNA National Convention.

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Figure 1: Pianists' hand spans measured at the MTNA Convention in 2004 (www.steinbuhler.com)

Comparing earlier anthropometrical data on pianists' hands (Wagner, 1988) with the MTNA data, the results are broadly consistent, although there were no females with hand spans of 9 inches and above measured at the MTNA Convention. Assuming hand span data for a sufficiently large sample would approximate a normal distribution, various summary measures can be derived. Table 1 summarises the differences between males and females for the two data sets.

Table 1: Steinbuhler and Wagner hand span data (inches)

	Steinbuhler 2004		Wagner 1988	
	Male	Female	Male	Female
Number of respondents	66	90	110	104
Minimum	7.7	7.0	7.8	7.2
Maximum	10.2	8.9	9.9	9.3
Arithmetic mean	8.9	7.9	8.9	8.1
Median	8.9	7.9	8.9	8.1
First Quartile	8.5	7.5	8.6	7.8
Third Quartile	9.3	8.2	9.3	8.4

It is interesting to consider whether the size distribution of pianists' hands reflects the human population as a whole, and the influence of ethnic origin. From measurements of many different features of the human hand in the US (Garrett, 1971), depending on the characteristic measured, differences between males and females generally range between 10% and 20%. However, for the active 1-5 span, he does not give gender differences; he gives an overall mean of 8.5 inches for males and females combined. Wagner (1988, p.117) notes that based on previous studies, musicians tend to have greater finger spans than non-musicians.

It is commonly stated that people of Asian ethnicity have smaller hands than those of Caucasian origin (e.g. Sakai, 1992, Furuya et al., 2006). However, the only reviewed paper with original data is on the hand anthropometry of Indian women (Nag et al., 2001). Results of that study indicate that the hands of Indian women are significantly smaller than those of British, American and West Indian women. The mean active 1-5 span of the sample of Indian women was only 6.8 inches.

A significant proportion of subjects (95% of males and 86.5% of females) measured by Wagner (1988) were of Caucasian origin. The ethnic background of MTNA pianists (Figure 1) is unknown, but is likely to be mixed.

In the absence of other data, and recognising that the data do not come from scientifically-based random samples, from Table 1 one could postulate that:

1. Comparing the first quartile of males with the first quartile of females, approximately 75% of adult females have hand spans smaller than the 75% of adult males with the largest spans, and
2. Comparing the arithmetic means and medians, the average hand span of an adult male is approximately one inch greater than that of an adult female (representing almost the width of one key on the conventional keyboard).

Figure 2 illustrates these findings.

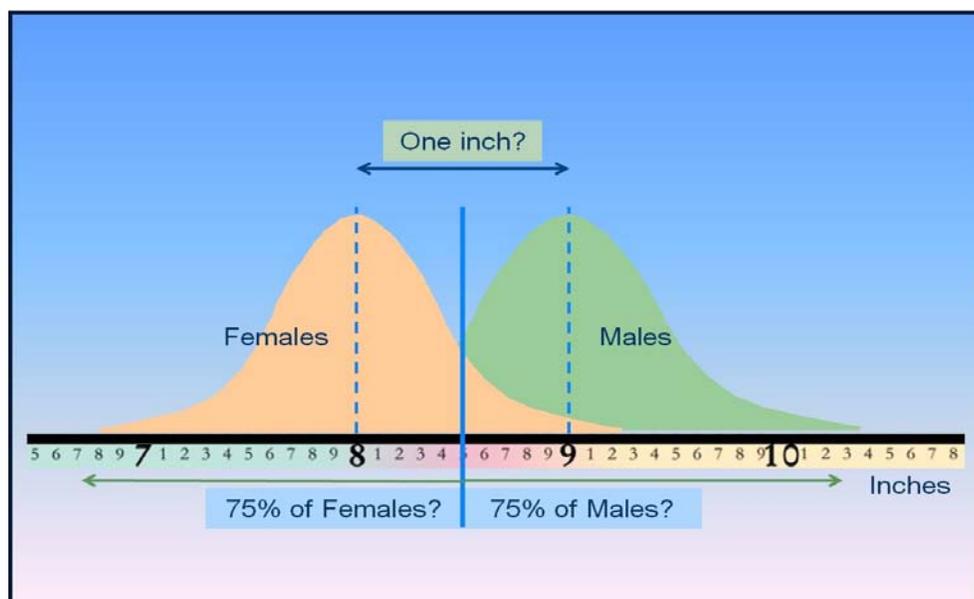


Figure 2: Pianists' hand spans – male versus female

It is useful to relate hand span to the capacity to stretch a specified interval on the conventional keyboard. [Although ability to reach certain intervals is only one of the many suggested benefits of reduced-size keyboards, it is a fundamental constraint on the ability to perform certain repertoire.] To calibrate 1-5 active hand span against ability to play different intervals, in March 2009 we measured the hand spans of around 25 adult pianists and documented the largest white key interval they were able to play – either comfortably (ability to slide thumb and fifth finger in towards the black keys) or just reaching (‘on the edge’ of the white keys). The results are shown (without gender differences) in Table 2. Note that the total widths of these three intervals, as measured across a conventional keyboard, is approximately the same as the threshold hand span, e.g. width of a 9-note white key interval (covering 10 notes in total) is 8.4 inches.

Table 2: Hand span and white key interval calibration

Approximate threshold - active hand span (1-5)	Capacity to play white key intervals
7.5 inches	Octave: comfortable, 9 th : ‘on edge’
8.4 inches	9 th : comfortable; 10 th : ‘on edge’
9.3/9.4 inches	10 th : comfortable; 11 th : ‘on edge’

Relating these findings to the statistical summary measures shown in Table 1 and in Figure 2, it is postulated that a significant minority of females cannot play an octave comfortably on the conventional keyboard, and a significant majority cannot play a ninth comfortably, nor a tenth even ‘on the edge’. On the other hand, it seems that a significant majority of males can play an octave and a ninth comfortably and a tenth ‘on the edge’ using the conventional keyboard. (See Figure 3.)

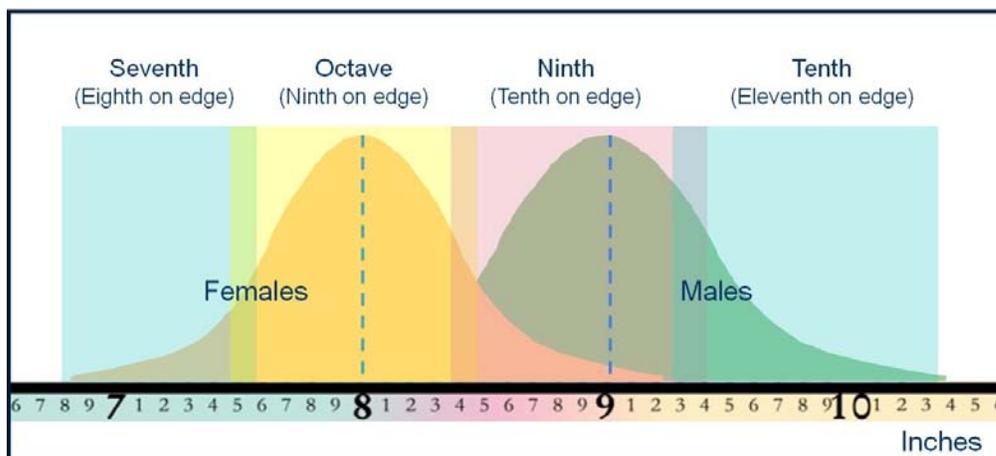


Figure 3: Intervals that can be played comfortably according to hand span

It is postulated that by transferring to a 7/8 keyboard, one extra white note is added to the maximum interval that can be played by any individual, i.e. in effect, their hand span becomes one inch larger, compared with playing the conventional keyboard. For example, someone with a 7-inch span becomes (on the 7/8), equivalent to a person with an 8-inch span on the conventional keyboard. The average 8-inch female hand span on the 7/8 is approximately equivalent to the average 9-inch male

hand span on the conventional keyboard. The female hand distribution graph (Figure 2) effectively moves to the right to the position of the male hand span distribution. This means that the female hand is approximately in the same proportion to the 7/8 keyboard as the male hand is to the conventional keyboard.

In the absence of comprehensive data on ethnic differences, if the Indian data set is any guide, one can speculate that there may be a significant proportion of women of Asian origin with spans smaller than 7 inches. Below this threshold, it would not seem possible to play classical piano repertoire at any more than an elementary level.

Piano keyboards have not always been the size they are today. In the 18th century they were not only smaller than today (similar in size to current day harpsichords) but at that time, repertoire rarely contained intervals larger than an octave. At the beginning of the 19th century the piano keyboard was gradually extended in range and size (Deahl & Wristen, 2003) and the use of cast iron frames led to an increase in string tension, resulting in heavier and deeper action. During the 19th century, a Czech company designed a smaller keyboard ‘for ladies’. The great pianist Josef Hofmann used a reduced-size keyboard designed for him by the Steinway Company early last century.

As the piano evolved, the need for standardisation increased as pianists (professional or amateur) started to travel outside their own communities, hence the ‘one size fits all’ approach that has prevailed over the last century.

Hand Size as a Risk Factor in Piano-Related Pain and Injury: Epidemiological Studies

Much of the literature linking hand size with piano playing is in the field of performing arts medicine, with the focus on hand size as a possible risk factor in piano-related pain and injury based on epidemiological studies.

Many such studies published during the 1980s and 1990s covered a mix of instrumentalists rather than just pianists. These included clinical studies (Fry 1987, Manchester & Flieder, 1991; Cayea & Manchester, 1988), a survey of teachers (Quarrier, 1995) and a detailed case-controlled study of risk factors (Zaza & Farewell, 1997). Likely causes of pain or injury were identified as being technique, time and intensity of practice, posture and genetically based factors. Females were found to be disproportionately affected and keyboard players among those most at risk.

Zaza & Farewell’s landmark case-controlled study of physical, psychological and behavioural risk factors for piano-related musculoskeletal disorders (PRMDs) involved measurements of anthropometric characteristics including hand span, and the psychological characteristics of 281 musicians. Univariate and multivariate analytical techniques were used and established that females were found to be at higher risk of PRMDs overall. Zaza & Farewell proposed (p. 293) an operational definition of PRMDs which has been adopted in many subsequent studies.

Sakai (1992) conducted a clinical study of pianists who presented with hand or forearm pain due to piano playing. Sakai was one of the first authors to suggest that hand size may be a risk factor for piano-related pain and injury, and that Japanese pianists may be at a disadvantage compared with American and Europeans. Thirty of the 40 pianists studied attributed their problems to specific keyboard techniques including playing octaves, chords and fortissimo playing. Sakai (2002) later reported on a larger clinical study of 200 Japanese pianists, confirming the earlier findings regarding keyboard techniques leading to hand pain. He noted that playing octaves and chords involves hyperabduction³ of the thumb and fifth finger, which in turn affects the wrist, potentially causing de Quervain's disease or other overuse problems.

A survey of 66 pianists in Belgium (De Smet et al., 1998) investigated the incidence of overuse syndromes, compared with a control group of 66 volunteers. Overuse problems were significantly higher in the pianists compared with the control group, and the wrist was most often affected. Injury risk was significantly higher for pianists with small hands. A study of 341 pianists in Spain (Farias et al., 2002) also found that hand size was a risk factor.

Shields & Dockrell (2000) investigated the prevalence of injuries among pianists in music schools in Ireland via a questionnaire survey. They did not find a statistically significant difference in injury between males and females, although the number of males included was relatively small. However, over 50% of those affected nominated the playing of double octaves as a cause of pain and suggested that their small hand span and required stretch was a factor.

Pak and Chesky's (2001) internet survey of the prevalence of upper-extremity musculoskeletal problems among keyboard instrumentalists again found a significantly higher prevalence among females. The survey did not gather data on hand size. Although there were a large number of respondents (455), limitations of the study included the possible inclusion of non-piano related injuries and self-selection bias.

Bragge et al. (2005) undertook a systematic review of the literature on prevalence of risk factors associated with PRMDs. They noted common limitations of previous work including sampling or measurement bias, inadequate reporting of outcome measures, lack of a common definition of PRMDs, and lack of statistical significance testing. They also mentioned the need to focus on specific instruments rather than just mixed groups of musicians. At that time, the only statistically significant risk factors identified were previous upper quadrant injury, hand size (De Smet et al., 1998), increasing age, and female gender (Pak & Chesky, 2001).

In a survey of piano teachers' perceptions of risk factors for injury in elite pianists at the University of Melbourne and the Victorian College of the Arts (2006), Bragge et al. (2006) found that the top five risk factors identified were technique, muscular tension, teacher, seat height and repertoire. Hand size was nominated in sixth position.

³ Maximum movement away from a neutral position

Since the publication of Bragge's review in 2005, further investigations of risk factors for piano-related pain in injury have been published. Yoshimura et al. (2006) investigated the relationships between pain and several independent playing-related and anthropometric variables, adopting a definition of PRMDs consistent with that proposed by Zaza & Farewell (1997). Although the sample size was relatively small (35), correlation, regression and factor analysis established a statistically significant relationship between piano-related pain and a general 'size/strength/speed' risk factor. Hand size and in particular, the 3-4 digit span, were encompassed within this risk factor. Although 40% of the variance was unaccounted for, the authors noted that factors not measured, such as biomechanical force exerted and technique (especially for octaves and chords), could be important.

Furuya et al. (2006) conducted a questionnaire survey of Japanese female pianists and found a high rate of PRMDs. Risk factors identified were prolonged daily practice and forceful playing of chords. Hand size did not emerge as a risk factor, but Chesky et al. (2007) queried this conclusion in that hand size was not measured but relied on a subjective assessment by the respondents, and also that, as only Asian females were included, the sample group was likely to be highly skewed towards the smaller end of the size spectrum.

Bruno et al. (2008) conducted a case-controlled survey of PRMDs among piano students in Italy. Multivariate analysis found a statistically significant correlation between disorders of the upper limbs and hand size. Long practice times without breaks also emerged as a risk factor, consistent with previous studies.

Hand Size and Injury Risk: Evidence from the Disciplines of Ergonomics and Biomechanics

The recently developed sciences of ergonomics and biomechanics can be used to analyse piano technique and determine how the human body can be used most efficiently. The basis of ergonomics is that 'form follows function', i.e. the design of tools and appliances need to be in accordance with the dimensions of the human hand. Apart from the epidemiological evidence, biomechanical and ergonomic studies have determined that degree, repetitiveness and forcefulness of wrist motions are risk factors in tendinitis, carpal tunnel and other nerve entrapments, and that women are more susceptible to these ailments than men.

Wristen (2000) reviewed established quantitative data from biomechanical studies to describe and analyse the execution of selected piano tasks. From this review she found that several motions and practice habits have the potential to contribute to injury. These include applying pressure after a key has bottomed out, static finger or hand positions, wrist angle (radial and ulnar deviation, extreme pronation or supination) and repetitive motions of high force.

Deahl & Wristen (2003), in developing strategies for small-handed pianists, noted that small-handed pianists are at higher risk due to greater degrees of lateral wrist motion, flexion, extension and deviation that are required than for larger-handed players. Large chords, octaves and arpeggios repeatedly force small hands out of an

‘anatomic neutral’ position. This is consistent with the conclusions of Sakai’s (1992, 2002) clinical studies where he identified the playing of octaves and chords as likely causes of pain and injury.

Pilot Studies of the Benefits of Reduced-Size Keyboards

Use of reduced-size keyboards in research is a very new field of activity. Apart from two recent university-based pilot studies (Wristen et al., 2006; Davis & Evans, 2007), the remaining evidence of benefits to pianists is derived from personal experiences of those who play them regularly. While the bulk of the literature described above links hand size to pain and injury among pianists, the potential benefits of reduced-size keyboards are much wider – extending into the execution of technical skills with required speed and accuracy, ease of learning and musicality.

Wristen et al. (2006) conducted a study of small-handed pianists (defined as having active 1-5 spans of 8 inches or less) that involved the use of electromyography to provide empirical data on physical ease. Measurements were taken of muscle loading, hand span, wrist flexion and extension, and radial and ulnar deviation during performance of specified musical excerpts. The trials involved playing a particular keyboard, structured practice sessions, and transitioning to the other keyboard. The trials were also recorded and assessed by a panel of experts and results were compared with self-assessments. Both the 7/8 and conventional keyboards were used for comparative purposes.

The results of this study indicated that the subjects’ self-reported best performance matched the expert assessment. The 7/8 keyboard was preferred by all pianists based on their overall feeling of comfort, and this was substantiated by the expert assessment based on missed keys, pauses and the empirical data including range of hand span required, measured joint angles and force loadings. The authors concluded that use of the 7/8 keyboard would result in easier and more enjoyable practice for these pianists.

Davis & Evans (2007) studied the adaptability of five small-handed pianists to the 7/8 keyboard. After learning two Chopin Preludes, set exercises and a piece of their choice, their performances were recorded on the conventional keyboard and immediately after (with no practice) on the 7/8. Following a week of structured practice on the 7/8, their performances were again recorded on the 7/8 keyboard. Blind assessments of accuracy and continuity were made by a panel of three teachers and an attitudinal survey of the pianists was also conducted.

Results indicated an initial drop in performance quality when moving from the conventional keyboard straight to the 7/8, but a subsequent improvement on both initial performances at the end of the week. Four of the five pianists agreed that initial adaptation was as hard as they expected, but also agreed that after a little practice, adaptability was easier than expected.

Individual Users' Accounts of the Benefits of Reduced-Size Keyboards

Two North American pianist-academics, Carol Leone (2003) and Christopher Donison (1998, 2000), have commented on the significant benefits of reduced-size keyboards for their own playing. Both Leone and another academic, Lora Deahl (personal communication), have also commented on the experiences of their students. Testimonials are also available from a number of others in the US and Canada.

(See for example: http://www.sciencedaily.com/videos/2005/1001-perfectfit_piano.htm; www.steinbuhler.com; <http://web3.unt.edu/news/story.cfm?story=9708>; http://www.pianoworld.com/forum/ubbthreads.php/ubb/showflat/Forum/1/topic/022437/Number/0/site_id/1#import)

A summary of comments from Leone and Donison is as follows:

Adjustment and swapping between keyboards

- Surprisingly, adjusting to the new keyboard size generally takes no more than one hour. The most challenging interval to get used to is the new octave. The most gifted pianists and children tend to adjust almost immediately.
- Going back and forth between the two keyboards, assuming both are played regularly, also presents little problem. It is described as like swapping between two different family cars. Organists and harpsichordists deal with this issue regularly, as do violinists who play the viola regularly.
- Some students have elected to use a specific keyboard for different repertoire, for example Bach and Beethoven on the conventional and Ravel on the 7/8.
- Learning a piece on the 7/8 prior to playing on the conventional can help the learning process and result in less tension after making the transition.

Technical differences

- Playing on the smaller keyboard involves smaller movements and less use of throwing, pivoting, rotating and general “flying about”.
- Fingers are closer to the keys and wrists do not have to strain in a high position to reach a greater span.
- Hand position changes are reduced and marked fingering is more likely to make sense.
- Rolled cords and pedalling to mask notes not held manually are reduced or eliminated.
- Leaps and wide spread arpeggio-type figures feel much more secure.
- Chords and octave passages lie much more “under the hand”, which is more compact and less stretched.
- Learning, memorisation and sight-reading are improved or accelerated, particularly for technically difficult sections.

Musical differences

- Improved legato and musical line with less reliance on the pedal.

- Ability to perform legato octaves.
- Increased power due to the hand being more compact.
- Improved voicing of chords and balance.
- Ability to spend more time on musical aspects rather than just focusing on hitting the right notes.

Lora Deahl gathered preferences from 100 students, including children, regarding preferences for the conventional versus 7/8 keyboard. There were statistically significant differences between females and males in their preferences when performing four specific tasks: C major 4-note chord (root), C major 4-note chord (first inversion), diminished seventh arpeggios (root) and dominant seventh arpeggios (root). In each case, females preferred the 7/8 and males preferred the standard. Children also preferred the 7/8 keyboard.

Survey by the Authors of Pianists in North America Who Use Reduced-size Keyboards

Method

Early in 2009 we developed a questionnaire (Appendix 1) to gather information on the range of benefits of the reduced-size keyboard for adult pianists in the US and Canada who play on them regularly. The aim was to substantiate and add to the commentary from the individuals discussed above. Contact names of people who agreed to take part in the survey were provided by Steinbuhler & Company, and email contact was made with key academics/performers who were known to use the reduced-size keyboards. One of the academics also provided additional names of current and ex-students. Participants were informed that names of individuals would not be published.

A draft questionnaire was reviewed by several fellow pianists in Melbourne prior to commencement. The survey was emailed to North American participants who emailed back their responses, with the exception of two individuals with limited computer literacy: one of these returned her survey by post and the other gave her responses by telephone. A total 16 surveys were emailed out and 14 adults responded. In addition, one nine-year old boy (the grandson of one of the respondents) provided responses to some questions.

Background information about the respondents

The 14 adult respondents were all female and spread among all age groups from the 20s to the 70s. Eleven lived in the US and three in Canada. Twelve respondents held graduate or post-graduate qualifications. Piano-related occupations included eight piano teachers (four at university level), one graduate piano student, one piano tuner/technician, and one church pianist/organist. Not all performed for others; some were involved in amateur/community/church performances, three were involved in professional chamber music performances and two were solo performers. (Table 3, Appendix 2.)

The age at which they started learning to play the piano ranged from three to 10. Eleven had reached university level standard and the remaining three reached an ‘advanced’ level (Table 4, Appendix 2). Hand sizes – both 1-5 and 2-5 active spans for the left hand – as measured by the respondents, are recorded in Table 5.

All 1-5 hand spans are below 8 inches and so are generally classified as ‘small’. The 2-5 digit span reflects the degree of flexibility between the non-thumb fingers, an important attribute influencing the ability to play large chords, broken chords and arpeggios.

Circumstances regarding reduced-size keyboards

Table 6 indicates how respondents became aware of reduced-size keyboards, most commonly word-of-mouth or the internet. The length of time between first hearing about the keyboard and trying it for the first time ranged from a few minutes to four years. Nine had purchased their own keyboard; the remainder played them at university or at a teacher’s residence.

Of those who had made the decision to purchase, four decided immediately. Reasons for purchase included the immediate relief from pain/injury, research purposes, one who “always wished for it”, another (with a 7.1 inch span) who had “come to the conclusion that playing the conventional size keyboard is futile for me”, and for another, the decision was a “no-brainer”. All except two play the 7/8 keyboard, the remaining two a 15/16, and commencement time ranged from mid 1996 to November 2008.

Practice routine, initial adjustment and swapping between keyboards

Most respondents generally practise daily or several times a week on the reduced-size keyboard; times ranging from one hour to 6-8 hours per day. Seven had significantly increased their total practice time since playing the reduced-size keyboard – often linked to relief from pain and/or greater enjoyment.

The initial adjustment period was reported as being ‘almost immediate’ or within 1 and 2 hours by nine respondents. Five others reported adjustment times of between 5 days and 3 weeks. All 14 said they still play the conventional keyboard from time to time for a range of reasons, the most common being ‘practising for performances elsewhere’ (See Tables 7 and 8).

Respondents were asked how long they would need to adapt a piece already learnt on the conventional keyboard to the reduced-size keyboard. Eleven reported ‘within a day/one practice session’; two others reported slightly longer (Table 9), saying that it depended on the piece and the need for complete security if octaves and leaps were involved.

Perceptions of degree of improvement in pianistic skills

Questions 15 to 36 of the questionnaire asked respondents to think about specified aspects of piano playing and compare their experience on the conventional

versus reduced-size keyboard by rating the degree of improvement (if any) for them. Results are shown in the form of bar charts (Appendix 2).

The two skills where all respondents agreed that the degree of improvement was 'considerable' or 'dramatic' were:

- ability to hold down notes as intended rather than releasing early and masking with sustaining pedal
- feeling of power where needed.

Two further skills for which 13 out of 14 respondents rated the degree of improvement as 'considerable' or 'dramatic' were:

- fast passages of octaves or large chords, and
- time taken to master technically difficult passages

Other skills for which more than 50% of those who responded rated the perceived degree of improvement as 'considerable' or 'dramatic' were:

- leaps
- legato playing
- broken octaves
- broken chords/arpeggios
- changes of hand position
- time taken to learn new repertoire
- awkward or non-ideal fingering
- accuracy
- overall feeling of security

Skills for which more than 50% those who responded thought that the degree of improvement was 'nil' or 'slight' were:

- sight-reading
- scale passages
- double thirds
- double sixths
- trills and similar ornaments
- ease of memorisation
- general tone quality
- balance
- evenness of rhythm and tone

Discussion of ratings of degree of improvement in pianistic skills

An obvious question is why there was considerably less agreement in responses to some questions than others. One factor would be the repertoire played by the pianists. Some said that they did not play repertoire including double-thirds or double-sixths, or noted that they did not need to memorise pieces, so did not respond on those skills. Aspects such as 'time taken to master technically difficult passages' would obviously depend very much on the degree of difficulty of pieces being learnt, in relation to the particular ability of a pianist. One respondent wrote: "I feel that for

items 30-34 [accuracy, security, time taken to master technically difficult passages, feeling of power, general tone quality] would depend on the type of music played, as all of these would be significantly improved if the piece is 'difficult' for small hands, but for music played easily with small hands, I think the change would be nil/slight."

'Legato playing' could also depend on whether the respondent was thinking of simple legato lines or trying to achieve a legato line within a progression of chords or octaves. One respondent noted this saying: "When playing general legato, I feel there is no change. However, for wide intervals that I cannot reach the notes for legato, the improvement is clearly considerable."

Another reason for the variation could be the relatively subjective nature of some skills, such as 'balance' and 'tone quality' and the self-awareness of the pianist in relation to the quality of their playing. The skills for which there was the greatest level of agreement were those which could be more objective or easier to judge, such as: 'ability to hold down notes...', 'fast passages of octaves and chords', 'double thirds', 'feeling of power...'

There were only two instances where the degree of improvement was considered 'negative': one respondent nominated 'scale passages', (qualified as being 'slight'), and another, 'leaps'. The variation in responses on 'scale passages' and 'trills and similar ornaments' is interesting as one may not expect a reduced-size keyboard to affect these skills noticeably. It is possible that different responsiveness of keyboard actions may be a complicating factor.

It could be postulated that those with smaller hands would notice more improvement than those with larger hands. However, an analysis of the data comparing hand span with the number of responses in each category gave no reason to draw that conclusion. Although only a small sample size, those with the larger hands (>7.5 inch span) reported a similar number of 'considerable' or 'dramatic' improvements (considering all skills together) than those with smaller hands (<7.5 inch span).

While most respondents considered the improvement in memorisation to be 'nil' or 'slight', one considered it to be 'dramatic', commenting: "I anticipated that the smaller keyboard would make technical problems easier, but I was very surprised by the difference it made in my ability to memorise music. Because everything was more natural and less awkward on the smaller keyboard, it was easier for my hands and muscles to learn the patterns and commit them to memory."

No-one rated the improvement in sight-reading to be 'dramatic', although the responses ranged from nil to considerable. By comparison, one of the first purchasers of the 7/8 keyboard (Linda Gould) commented: "Sight-reading probably has the most dramatic effect. When you are sight-reading difficult music (especially with other chamber musicians) you do not have the time to work out the easiest way of playing a passage, you just plow through it. I am talking about pieces like Brahms Horn Trio, Saint Saens Piano Trios"www.steinbuhler.com). It is possible that sight-reading would be more dramatically affected for people with the smallest hands, particularly

if there is also poor flexibility between fingers, to the extent that many basic chords cannot be played on the conventional keyboard without dropping notes.

One respondent noted an additional skill: ‘voicing of chords’, for which she considered there was ‘dramatic’ improvement. The nine-year old boy, who plays an upright with 7/8 keyboard, noted the considerable improvement in his feeling of security. He also wrote: “I was little and I was desperate to play octaves but my hands were too small. That’s when they got it for me.”

When asked about the experience of playing the conventional keyboard after having played the reduced-sized keyboard, some still found it equally enjoyable, while others were far more negative. The respondent with the smallest hand span (7.1 inches) wrote: “There is a sense of rejection towards the conventional keyboard, as my repertoire is severely limited, my hands feel over-stretched with larger intervals, I cannot put power into octave/chord playing, and I have to be careful to prevent injuries/aches.” Some noted that it depended very much on the piece. (Refer to Table 10.)

Disadvantages of the reduced-size keyboard

Relatively few disadvantages were recorded, apart from the inconvenience of having to swap between keyboards to practise or play elsewhere, a piano teacher needing to come to their home, and the expense and extra space required for two keyboards.

Specific individual comments included:

- black keys would ideally be wider
- fundamental skills (e.g. scales) learnt from childhood require extra practice
- problems with acceptability for examination requirements
- experience of duet playing due to the respondent’s size
- lighter action
- negative perceptions of others

Feedback from others

Respondents were asked if they had received feedback from others, including teachers, colleagues, friends and family members. The nature of this feedback covered comments about greater power, greater appearance of comfort and control, improved accuracy, technique and sound quality.

Pain and injury

Thirteen of the 14 respondents had suffered some form of pain or injury attributed to playing the conventional keyboard in the past. These included:

- muscle pain in forearms
- scar tissue in trapezius muscle
- tendon injuries of thumb, finger and hand
- trigger finger

- hand and arm cramps
- aches in joint connected to 5th finger
- minor wrist pain after extended practice
- mild back pain

Virtually all reported that the previous problems had disappeared since moving to the reduced-size keyboard.

Repertoire changes and preferences

Nine of the 14 respondents reported some change in their repertoire since beginning to play the reduced-size keyboard. All reported improvements with at least some existing repertoire. Romantic works were frequently mentioned as being tackled for the first time or becoming much easier, including Chopin, Liszt and Rachmaninoff Etudes, other Chopin repertoire such as the opus 53 Polonaise and Ballades, and works by Brahms, Debussy and Ravel. Others nominated any repertoire with large chords or octaves requiring a fast tempo or legato playing, as well as Bach (where inner voices needed to be held), Beethoven, and some 20th century composers. One mentioned improved security with Mozart.

When asked if there was any repertoire for which they would prefer to play on the conventional keyboard, three nominated Baroque and early classical works, the remainder did not prefer the conventional keyboard for any repertoire. One reported keeping two distinct sets of repertoire.

Overall benefits

In summing up the overall benefits, many mentioned the ability to play an expanded repertoire, increased power, ability to play octave passages and large chords, and overall performance excellence. Several also mentioned the relief from pain, stretching and tension, and greater comfort. Specific comments included:

“Everything improved for me; it is so much fun to practice.”

“My small hand size is no longer a handicap or the main criterion in choosing a piece of music to play.”

“I never knew this was a possibility so it seems like a miracle to me. After over 30 years of playing, to have this opportunity is heavenly.”

“Relief from stretching most of the time.”

“A significant reduction of tension (psychological and physical) associated with octaves and great spans has resulted in a far more pleasant and more secure playing experience...Subsequently, I found myself focusing more on tone and technique and mostly, the music itself. Joy.”

“For me, the most enjoyable aspect of playing on the reduced-size keyboard is how it felt: finally I was playing on a piano that was the right size for me. It was as if I had been trying to walk around in shoes that were a size too big and then at last I got a pair that was the right size. Everything, from runs and leaps to sound and memorisation, was easier. Also, I had to spend less time working on the technical issues, which allowed me to focus more on the musical issues. My senior recital that I played on the reduced-size keyboardwas by far the strongest piano performance I ever gave.”

Author Reaction to the 7/8 Keyboard

At the time of writing, I (Rhonda) had had a few weeks of playing the 7/8 keyboard since its installation. My own hand size is as follows:

- active 1-5 span – 7.0 inches
- active 2-5 span – 4.7 inches.

The implications of this hand size are, that on a conventional keyboard, I can only play octaves ‘on the edge’ of the white keys, which precludes the playing of any fast octave passages. The particularly poor flexibility between my non-thumb digits also means that many octave-based 4-note chords are not playable. Essentially, I can only play second inversion chords with the right hand and root position chords with the left hand. I cannot stretch a 6th using digits 2 and 5. I have not suffered any injury – perhaps partly due to a previously very restricted repertoire.

My first attempt at playing the new keyboard resulted in over-shooting octaves, but this tendency was much reduced after 30 minutes or so. Within an hour, I felt reasonably comfortable and was able to play existing repertoire with no great difficulty. The narrower black keys were not an issue. With some repertoire, I am now able to play previously omitted notes or use more appropriate fingering. Becoming secure with such changes requires just a few practice sessions, as is normally the case when making these sorts of changes.

Overall, the improvements I expected to feel were immediately apparent, in particular:

- ability to play octaves with comfort (probably the most dramatic improvement)
- ability to play nearly all chords as written, rather than constantly deciding which notes to omit
- ability to hold notes down as intended
- much greater ease with broken octaves, broken chords and arpeggios
- the much greater feeling of power
- reduction in uncomfortable stretching with the hands being in a more relaxed position for a much greater proportion of playing time
- improved legato lines within chords (e.g. Brahms Intermezzo Op. 117, No.1) linked to the ability to use appropriate fingering rather than successive thumbs or 5th fingers
- easier sight-reading of pieces containing large chords/octaves.

Other types of playing that also felt much easier, but were less expected, include:

- for chords that are meant to be rolled (e.g covering a 10th or more), the reduced distance to roll has a big impact on the feeling of security, particularly when the other hand is performing something fast or complex (for example Chopin Prelude No. 10 in C# minor)
- sweeping passages (such as in Chopin Preludes Nos. 3, 11, 18 and 23) feel much more secure as a result of the hand being more compact
- the wide-ranging implications of being able to stretch a 6th using the 2nd and 5th fingers, whether within chords or in single legato lines
- less unevenness of rhythm, (such as in Mozart or Beethoven pieces), due to the hand being more compact and not having to suddenly jolt into a stretched position when moving to or from an octave.

The experience of playing the 7/8 keyboard provides an appreciation of the real impact of hand size. My 7-inch hand on the 7/8 is equivalent to an 8-inch hand (average for females and well below average for males) on the conventional keyboard. As an example, when playing the Chopin Etude Op.10 no.5 (a piece I have played since the age of 17), the difference between the two keyboards is dramatic. The improvements include extra speed (from 80 crotchet beats per minute to over 90), significantly improved legato and shaping in the right hand, disappearance of any right forearm pain due to excessive tension from stretching (bars 57-64), and a much better feeling of comfort and control. Crucial to these improvements is the ability to use appropriate fingering instead of successive thumbs and fifth fingers in many parts of the piece. I believe that a larger hand would lead to even greater facility and ease. An 8-inch span is inadequate when attempting to play the final left-hand triplets (which span 10ths) accurately and at speed.

Conclusions

This paper has reviewed data on hand size among pianists, examining the range of differences between individuals and genders. Data on the distribution of hand size within the general population are not readily available, but it is self-evident that there is much variation between individuals, and between males and females, and between adults and children. The authors raised the possibility that approximately 75% of adult males have hand spans greater than the 75% of adult females with the smallest spans. The authors also cited evidence of differences based on ethnic origin.

From a review of the epidemiological literature, there is strong evidence for a link between hand size and pain and injury rates among pianists. This is supported by evidence from the sciences of ergonomics and biomechanics, and the personal experiences documented in the survey conducted by the authors.

Technical and musical benefits of reduced-size keyboards for smaller-handed pianists appear to be far-reaching. The results of the survey support the accounts of other individuals and are consistent with very recent research documenting greater comfort and improved performance quality for pianists using a 7/8 keyboard. Improvements which appear to be among the most dramatic (ease with fast passages

of octaves and large chords) have also been documented as a major factor leading to pain and injury among small-handed pianists.

Based on this evidence, small hand size appears to be a significant impediment to many pianists. It seems the conventional keyboard especially disadvantages females, often preventing them from reaching their full potential. It is likely that a significant minority of females, particularly those of Asian ethnicity, cannot play octaves with comfort, and a majority of females are unable to play 10^{ths}. From the results of the survey conducted by the authors and other research described in this paper, one could postulate that at least 50% of adult female pianists (those with hand spans of 8 inches or less) could perform at a higher level on a reduced-size keyboard.

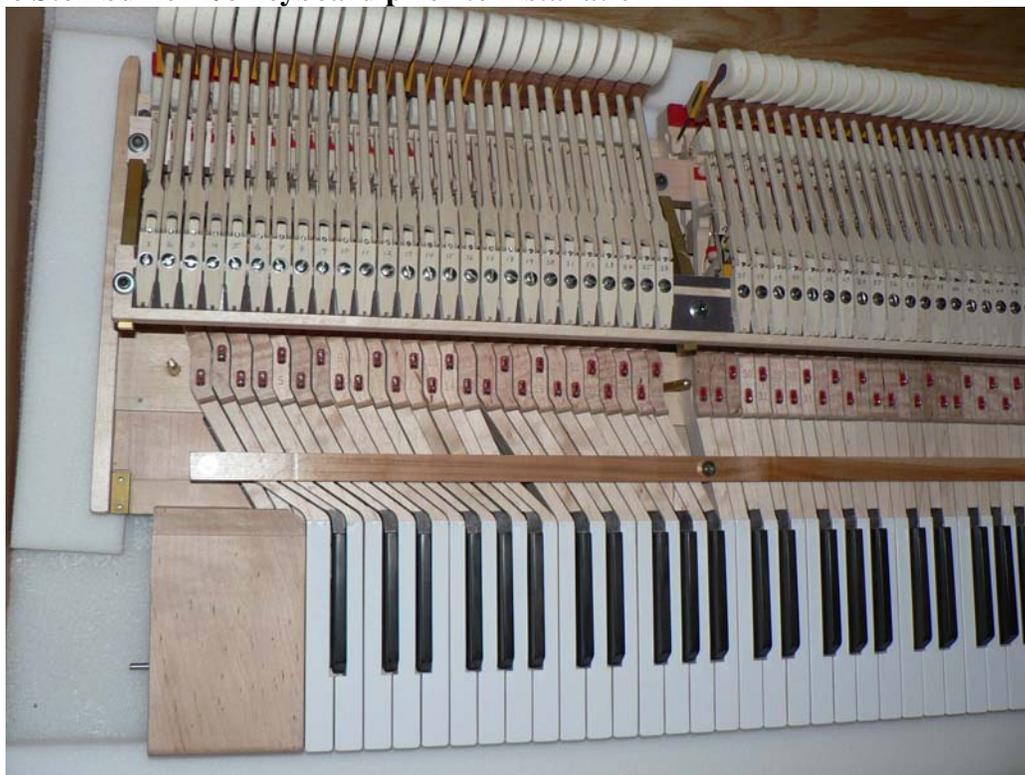
Based on the statistical analysis, it is possible that the proportion of pianists who would benefit from reduced-size keyboards may be even greater. This would apply particularly to Romantic and 20th century repertoire where being able to play a 10th is frequently expected. This requires a hand span of at least 8.4 inches which rules out a significant minority of males in addition to the majority of females. Indeed, the Steinbuhler Company (personal communication) indicates that approximately 20% of customers for reduced-size keyboards are male.

The availability of reduced-size keyboards opens up research opportunities that have not been practicable in the past. This provides a way of testing how the performance of a particular player might change according to keyboard size. This would enable enables researchers to isolate hand size as a factor influencing performance quality.

Further detailed research could explore technical and musical skills and how these vary on reduced-size compared with conventional keyboards. A rigorous approach could involve standard repertoire and practice routine and blind assessments of recordings by expert panels. It may also be possible to relate specific skill improvement to hand size within the 'small-hands' group, for example, in relation to sight-reading. There are also research opportunities involving children and teenagers.

Finally, one could invent and test the performance of exercises for larger-handed pianists that replicate the experience for small-handed pianists, such as broken 10ths compared with broken octaves.

The Steinbuhler 7/8 keyboard prior to installation



About the Authors

Rhonda Boyle (née Jones) studied the piano as a child in Geelong, winning prizes at eisteddfods and completing AMEB examinations with honours. She studied science at Melbourne University, majoring in geophysics, and later completed masters' degrees in environmental science and urban planning. Her career has mostly been with the Victorian State Government where she has worked in the fields of metropolitan planning, environmental science and policy development. Her publications include a research paper commissioned by the OECD. Rhonda returned to piano studies ten years ago as a private student of Robert Chamberlain, a well-known concert pianist and university level teacher. She recently purchased a 7/8 keyboard for her grand piano.

Robin Boyle lectures in statistics in the Faculty of Business and Law, Deakin University. He studied economics and mathematics at the University of Tasmania and later completed a master's degree in administration at Monash University. His principal academic pursuit has been the writing of statistical software. His research interests are restricted to practical applications of statistics in investigating real world problems, such as the dilemma facing small-handed pianists. He has always had a love for classical music, the piano in particular. He completed elementary piano studies, and has been learning singing in the classical tradition for the last nine years.

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Appendix 1 – Questionnaire

INSTRUCTIONS

Please save the document on your computer then type in your answers to each question. Where only one of two or more options is required, please place a cross (X) in the appropriate square. For open-ended questions, simply start a new paragraph and type your answer after the question. On completion, please email back your completed questionnaire.

PART A: BACKGROUND INFORMATION

1. At what age did you start learning to play the piano? _____ years
2. Approximately what standard have you reached?

Beginner	
Intermediate	
Advanced	
University level	

3. Your hand size (please measure your hand size as shown on the Steinbuhler website charts:

<http://www.steinbuhler.com/html/handsizepage.html> and
<http://www.steinbuhler.com/html/handratio.html>):

- (a) Total span (thumb to 5th finger) [e.g. 7.6 inches] _____ inches
- (b) Four finger span (2nd to 5th finger) [e.g. 6.1 inches] _____ inches

4. How did you first find out about the Steinbuhler reduced-size keyboards?

Word of mouth	
Surfing the internet	
Journal article/s	
At a conference	
A keyboard was available at my university	
Piano teacher or instructor	
Other (please describe)	

5. What was the length of time between first hearing about the reduced-size keyboard and trying it for the first time?

_____ Months or _____ Years

6. Did you purchase your own reduced-size keyboard?

Yes [] Please continue to Q.7 No [] Please go to Q. 9

7. After trying the keyboard for the first time, how long did it take you to make the decision to purchase?

_____ Months or _____ Years

8. Please summarise the reason(s) for your decision to purchase. _____

Please go to Q. 10

9. Where have you been playing a reduced-size keyboard?

University/College	
My teacher's house	
Other (<i>please specify</i>)	

Playing the reduced-size keyboard

10. When did you start playing the reduced-size keyboard regularly?

Date _____ (*Give approx month and year.*)

11. Do you play:

a 7/8 size keyboard, or	
a 15/16 size keyboard?	

Practice routine

12. Before playing the reduced-size keyboard, what was your normal practice routine?

	Normal frequency	Average hours per session
Daily		
4-5 times a week		
2-3 times a week		
Weekly		
Less often than weekly		

13. Since playing the reduced-size keyboard, what is your normal practice routine?

	Normal frequency	Average hours per session
Daily		
4-5 times a week		
2-3 times a week		
Weekly		
Less often than weekly		

Initial adjustment

14. How long did it take you to adjust to the reduced-size keyboard initially?

Almost immediate	
Number of days <i>(please specify)</i>	
Number of weeks <i>(please specify)</i>	
Longer <i>(please specify)</i>	

PART B: YOUR EXPERIENCES WITH THE REDUCED-SIZE KEYBOARD COMPARED WITH THE CONVENTIONAL PIANO KEYBOARD

For each of the following aspects of piano playing, please think about your experience on the conventional compared with the reduced-size keyboard, and put an X in the relevant column to indicate how you perceive the degree of improvement (if any) for you. Provide additional comments on any aspect below the table if you wish.

	Degree of Improvement				
	Negative	Nil	Slight	Considerable	Dramatic
15. Sight-reading					
16. Time to learn new repertoire					
17. Scale passages					
18. Legato playing					
19. Ability to hold down notes as intended rather than releasing early and masking with sustaining pedal					
20. Leaps					
21. Fast passages of octaves or large chords					
22. Broken octaves					
23. Broken chords/arpeggios					
24. Changes of hand position					
25. Awkward or non-ideal fingering					
26. Double thirds					
27. Double sixths					
28. Trills and similar types of ornaments					

29. Ease of memorization					
30. Accuracy					
31. Overall feeling of security					
32. Time taken to master technically difficult passages					
33. Feeling of power where needed					
34. General tone quality					
35. Balance					
36. Evenness of rhythm and tone					
Other (specify)					
Other (specify)					
Other (specify)					

Please provide further comments on any of these aspects if you wish. _____

Switching between the conventional and reduced-size keyboard

37. Do you still play the conventional keyboard from time to time?

Yes [] *Please continue to Q. 38* No [] *Please go to Q. 40*

38. How often do you play the conventional keyboard?

Daily	
Weekly	
Monthly	
Spasmodically (<i>please elaborate</i>)	
Rarely or never	

39. Why do you still sometimes play the conventional keyboard?

My teacher's piano does not have a reduced-size keyboard	
Practising for performances elsewhere	
Friends' pianos (which are the conventional size)	
I prefer the conventional keyboard for some repertoire (<i>Q. 52 covers this in more detail</i>)	
Other (<i>please describe</i>)	

40. For a composition that you are able to play on the conventional keyboard, how quickly can you play it as well (or better) on the reduced-size keyboard?

Within a day/after one practice session	
Within 2-3 days/practice sessions	
Within 4-5 days/practice sessions	
Within 6-7 days/practice sessions	
Longer (<i>please specify</i>)	

41. How would you describe the experience of playing the conventional keyboard now that you have played the reduced-size keyboard?

(please put a cross in more than one box if appropriate)

Challenging	
Unfulfilling	
Frustrating	
Less enjoyable than it was previously	
Still enjoyable, but I prefer the reduced-size keyboard	
Equally enjoyable	
Other (<i>please describe</i>)	

Disadvantages

42. Please summarise the disadvantages of the reduced-size keyboard if any, (apart from the lack of opportunity to play at other locations)._____

Feedback from others

43. Who has provided you with feedback about your piano playing on the reduced-size keyboard compared with the conventional keyboard?

(please put a cross in more than one box if appropriate)

I have not received any feedback	
Piano teacher	
Fellow students	
Piano playing friends and acquaintances	
Family members	
Other (<i>please specify</i>)	

44. Please summarise this feedback._____

Pain and injury

45. Have you suffered from pain and/or injury when playing the conventional keyboard?

Yes [] *Please continue to Q. 46* No [] *Please go to Q. 48*

46. Please describe the type and severity of the pain and/or injury in general terms, and how it affected your ability to practise and/or perform. _____

47. Please describe how this pain and/or injury has changed, if at all, since you have been playing the reduced-size keyboard. _____

Repertoire

48. Has your repertoire changed since you started playing the reduced-size keyboard?

Yes [] *Please continue to Q. 49* No [] *Please go to Q. 50*

49. Please describe the types of repertoire you now play that you would not have attempted previously, giving examples if you wish. _____

50. Please describe the types of repertoire that you played previously but now feel you can play more successfully on the reduced-size keyboard, giving examples if you wish. _____

51. Is there any type of repertoire that you would prefer to play on the conventional keyboard?

Yes [] *Please continue to Q. 52* No [] *Please go to Q. 53*

52. Please describe the type of repertoire that you would prefer to play on the conventional keyboard. _____

Overall benefits

53. How would you summarise the most significant benefits of the reduced-size keyboard for you? _____

PERSONAL INFORMATION

54. Your gender: [] Male [] Female

55. Your age range (years):

15-19	
20-29	
31-39	
40-49	
50-59	
60-69	
70-79	
80+	

56. Your main place of residence:

Country
State
Town/city

57. Your highest level of general education reached:

Secondary school	
Trade/technical qualification	
College/university degree	
Post-graduate degree	

58. Please describe your profession. _____

59. What is your role in relation to piano playing?

(please put a cross in more than one box if appropriate)

Amateur, not involved in performing for others	
Amateur performer (e.g small fund-raising concerts)	
Private music teacher	
School music teacher	
University level piano teacher	
Professional performer – solo	
Professional performer – chamber music	
Other <i>(please describe)</i>	

THANK YOU VERY MUCH FOR YOUR HELP!

Appendix 2: Survey results

Note: Totals may vary due to unanswered questions and the possibility of multiple responses to some questions.

Table 3: Piano standard reached

Level	Number
Beginner	0
Intermediate	0
Advanced	3
University level	11

Table 4: Role in relation to piano playing

Role	Number
Amateur, not involved in performing	3
Amateur performer	4
Private music teacher	7
School music teacher	1
University level teacher	4
Professional performer - solo	2
Professional performer - chamber	3
Other – church organists/pianist	1
Other – piano technician/tuner	1

Table 5: Hand sizes of adult survey respondents

Respondent number	Active 1-5 LH span (inches)	Active 2-5 LH span (inches)
1	7.25	5.5
2	7.8	5.6
3	7.6	6.6
4	7.8	5.5
5	7.5	5.5
6	7.25	5.75
7	7.2	5.5
8	7.1	5.6
9	7.5	6.0
10	7.25	5.5
11	7.5	5.75
12	7.6	5.2
13	7.45	6.0
14	7.9	5.5

Table 6: Source of awareness of the reduced-size keyboards

Source	Number
Word-of-mouth	4
Surfing the Internet	4
Journal article/s	1
At a conference	2
A keyboard was available at my university	2
Piano teacher or instructor	2
Other – piano donated to church	1

Table 7: Frequency of playing the conventional keyboard

Frequency	Number
Daily	8
Weekly	3
Monthly	2
Spasmodically	
Rarely or never	1

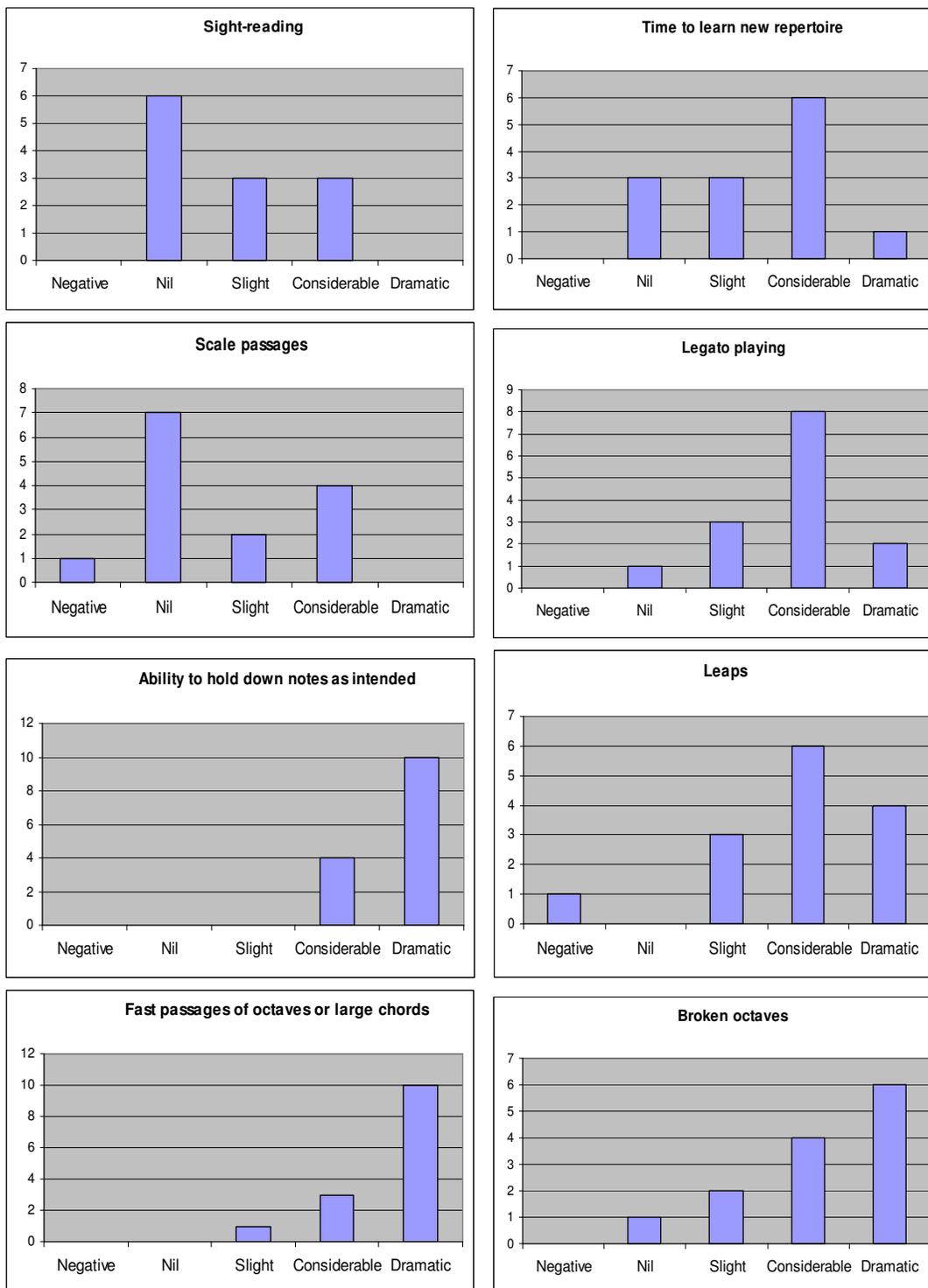
Table 8: Reasons for playing the conventional keyboard

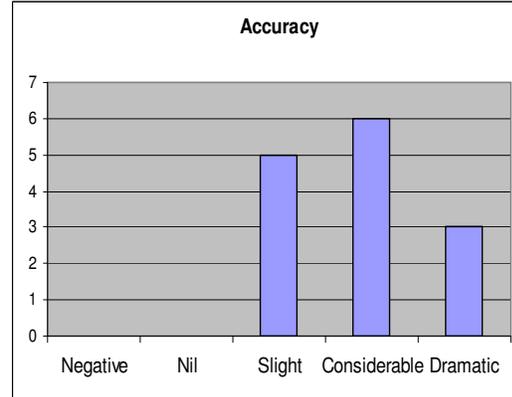
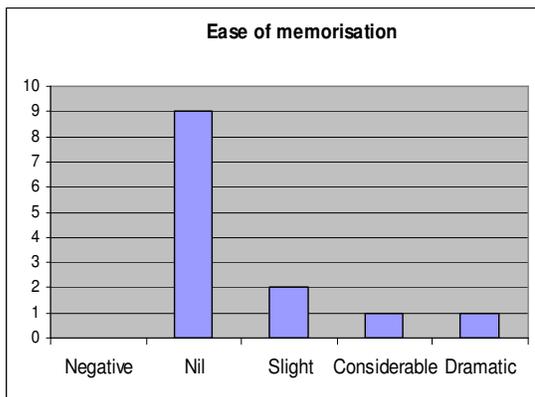
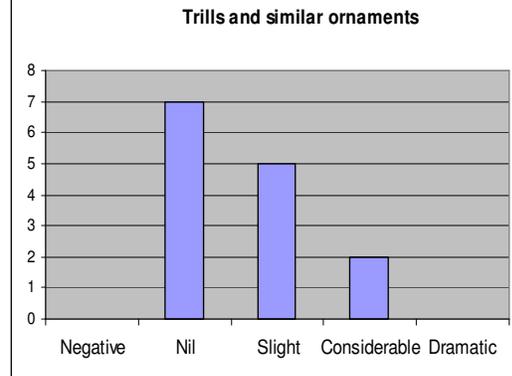
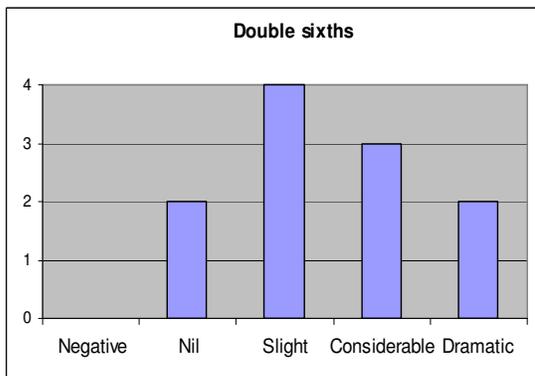
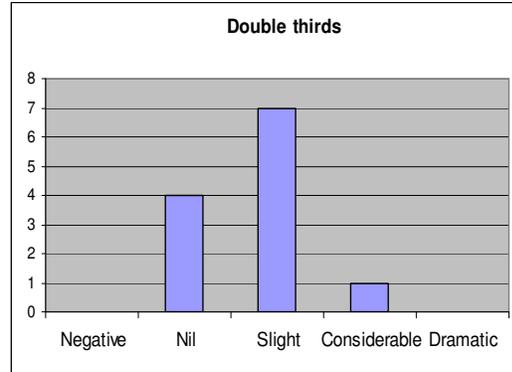
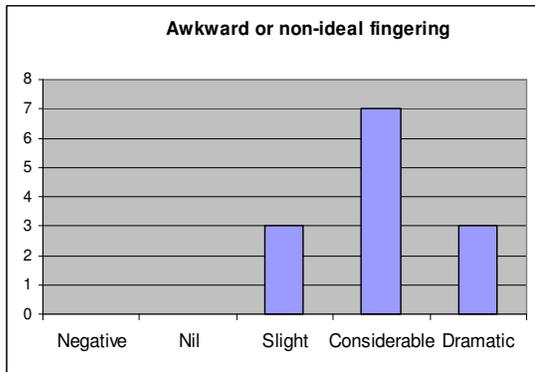
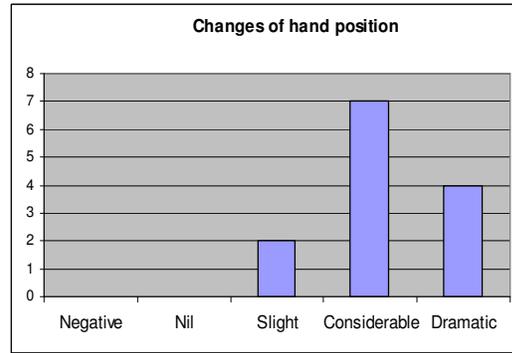
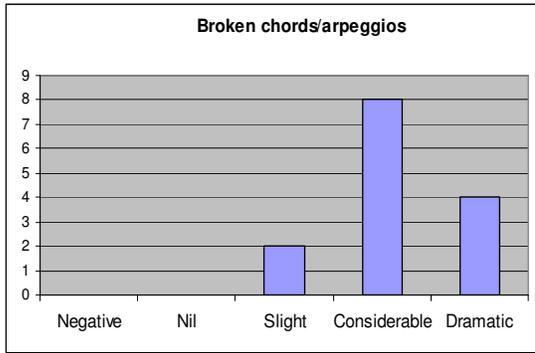
Reason	Number
Teacher's piano is conventional size	1
Practising for performances elsewhere	8
Friends' pianos	2
Prefers conventional for some repertoire	3
Practising at work	1
Practising at holiday house	1
Teaching	1
Piano tuning	1
Digital piano used for church sometimes	1
Conventional keyboard has better tone	1
Keeping up skills	1
No longer seriously studying piano/can't justify purchase now	2

Table 9: Time to adapt a piece learnt on conventional keyboard to reduced-size keyboard

Time needed	Number
Within a day/one practice session	11
Within 2-3 days/practice sessions	1
Within 4-5 days/practice sessions	1
Within 6-7 days/practice sessions	0
Longer	0

Figure 2: Results of questions 15-36 on perceptions of degree of improvement in pianistic skills





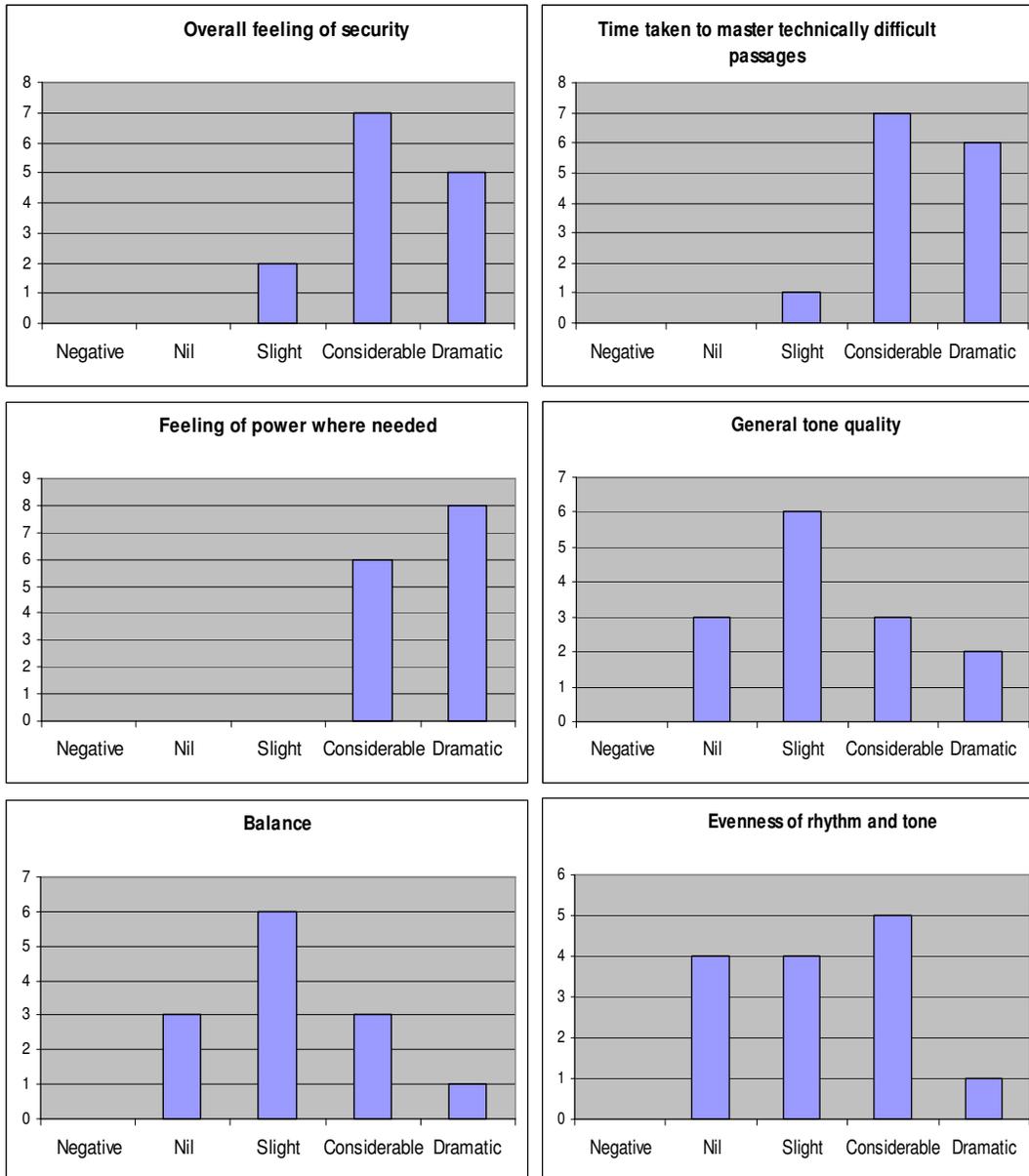


Table 10: Experience of playing conventional keyboard having played the reduced-size keyboard

Experience	Number
Challenging	1
Unfulfilling	0
Frustrating	5
Less enjoyable than it was previously	3
Still enjoyable, but I prefer the reduced-size keyboard	5
Equally enjoyable	5

Appendix 3: Inches and centimetre equivalents

Note: One inch equals 2.54 centimetres; one centimetre equals 0.39 inches.

Inches	Cms												
5.0	12.7	6.0	15.2	7.0	17.8	8.0	20.3	9.0	22.9	10.0	25.4	40	101.6
5.1	13.0	6.1	15.5	7.1	18.0	8.1	20.6	9.1	23.1	10.1	25.7	41	104.1
5.2	13.2	6.2	15.7	7.2	18.3	8.2	20.8	9.2	23.4	10.2	25.9	42	106.7
5.3	13.5	6.3	16.0	7.3	18.5	8.3	21.1	9.3	23.6	10.3	26.2	43	109.2
5.4	13.7	6.4	16.3	7.4	18.8	8.4	21.3	9.4	23.9	10.4	26.4	44	111.8
5.5	14.0	6.5	16.5	7.5	19.1	8.5	21.6	9.5	24.1	10.5	26.7	45	114.3
5.6	14.2	6.6	16.8	7.6	19.3	8.6	21.8	9.6	24.4	10.6	26.9	46	116.8
5.7	14.5	6.7	17.0	7.7	19.6	8.7	22.1	9.7	24.6	10.7	27.2	47	119.4
5.8	14.7	6.8	17.3	7.8	19.8	8.8	22.4	9.8	24.9	10.8	27.4	48	121.9
5.9	15.0	6.9	17.5	7.9	20.1	8.9	22.6	9.9	25.1	10.9	27.7	49	124.5