MUSCULAR FORCES AND JOINT ANGLES IN SMALL-HANDED PIANISTS: A PILOT STUDY ON THE 7/8 SIZE KEYBOARD VERSUS THE FULL SIZED KEYBOARD

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Abstract

This pilot study examined whether the use of a 7/8 keyboard contributed to the physical ease of small-handed pianists in comparison with the conventional piano keyboard. A secondary research question focused on the transition from one keyboard to the other. For the purposes of this study, we adopted David Steinbuhler's postulated hand span of 8 inches or less as defining a "small-handed" pianist. The goal was to measure muscle loading and hand span during performance of the excerpt. Data collection included each participant being monitored using electromyography via surface electrodes, which were attached to the upper back/shoulder, parts of the hand and arm, and the masseter muscle of the jaw. Subjects were also fitted with electrogoniometers to capture how the span from the first metacarpophalangeal (MCP) joint to the fifth MCP joint moved according to performance demands, as well as recording wrist flexion and extension, radial and ulnar deviation. The findings were that small-handed pianists preferred the smaller keyboard and were able to transition smoothly between it and the conventional keyboard. The maximal angle of hand span while playing a difficult piece averaged about 5º smaller on the radial side and 10º smaller on the ulnar side for the 7/8 keyboard, leading to perceived comfort (ease) and better performance as rated by the subjects.

Introduction

This pilot study examined whether the use of a 7/8 keyboard, invented and manufactured by David Steinbuhler, contributes to the physical ease or comfort of small-handed pianists in comparison with the conventional piano keyboard. A secondary research question focused on the progression of physical ease in making the transition from one keyboard to the other. The technical problems encountered by small-handed pianists are directly related to the size of the piano keyboard. Other instruments, most notably string instruments, are available in various sizes (i.e. 7/8, 15/16 etc.), primarily for pedagogical reasons. Unfortunately, with regard to the size of the piano keyboard, a "one size fits all" mentality has prevailed. Players having small-sized hands have historically been dedicated amateurs. Aside from Wagner's notable study (1988) on hand anthropometrics among pianists, writings addressing hand size issues have primarily concerned themselves with suggesting adaptive strategies for small-handed players (Deahl & Wristen, 2003).

In recent years, several studies have examined motions employed at the piano from a biomechanical or ergonomic perspective with an underlying motivation of understanding mechanisms that lead to playing-related injury or pain. Biomechanical approaches have also been used preventatively to diagnose problematic aspects of playing technique or to improve efficiency of healthy technique. Previous studies examining pianists' motions have typically concentrated on one small part of the anatomy or one clearly defined technical motion, often addressing occurrence of injury or pain correlated with this anatomical area or motion. For example, Chung et al. (1992) quantified average range of motion of the wrist in various playing activities. Harding et al. (1989) investigated the relationship between joint and tendon use and distribution of force while playing. Studies of this nature have contributed to a growing understanding of how the human body interacts with the piano.

The use of electrogoniometry in combination with surface electromyography (sEMG) has not previously been used to assess performance on keyboards. To date, surface EMG has been primarily utilized as a means of providing biofeedback to musicians so that they can become aware of and learn to control the level of muscular tension in various parts of their bodies. Morasky, Reynolds, and Clarke (1981) used sEMG biofeedback to help string players learn to reduce tension in their left arm, which string players use to hold and finger their instruments. Zinn and Zinn (2004) applied biofeedback in pianists to alleviate playing-related pain. In contrast to the applied biofeedback studies cited above, our pilot investigation used sEMG to capture and quantify muscular exertion in a specific task (excerpt performance). In addition, electrogoniometry was used to quantify joint angles during performance of the specific excerpt which constituted the task.

Methods

Subjects. For this pilot study, 2 small-handed participants were recruited. Once small-handedness was established using Steinbuhler's Hand Gauge (establishing 22cm full hand abduction [span] or less), participants were assigned a primary keyboard to practice the excerpt on. One participant was assigned the conventional (full) keyboard and the other the 7/8 (small) keyboard as illustrated in Figure 1. Both subjects in this pilot study were advanced level piano majors at the University of Nebraska—Lincoln.

Experimental design. The dependent variables of subjective ratings by participant and expert rater, as well as the objective measures of average joint angle and average RMS EMG converted to force in Newtons for each location measuring hand span and wrist deviation as well as forces in the forearm, neck and jaw were analyzed. There were several different analyses performed. For the initial three performances of the excerpt on the assigned keyboard, the following data were collected: 1) the ease of performance (comfort) and perceived mastery was correlated with the expert assessment ratings to determine the best trial, 2) the average joint angles over each excerpt trial by location, and 3) RMS for the sEMG, which were converted to force measurement (N) via personal calibration using resting EMG, static weights and a regression analysis. All data were analyzed using descriptive statistics.

The transition to the other keyboard (the one not used in practice prior to the test), was examined descriptively for all the subjects ratings, both participant and expert, by time (7 trials spaced 5 minutes apart) with the following data collected: 1) the ease of performance and perceived mastery related to the expert assessment ratings to determine best trial, 2) the "comfort level" a 1-10 Likert-type measure of a combination of performance execution and physical ease, 3) the average joint angles over all excerpt trials by location, and 4) RMS for the sEMG converted to force measurement (N) via personal calibration using resting EMG, static weights and a regression analysis. All data were analyzed using descriptive statistics to examine the shape of the learning or adaptation curve.

In addition, after trials were performed on both the assigned keyboard and the other (transition) keyboard, subjects were asked about their practice experience on the assigned instrument and preference for keyboard size. Finally a comparison, by subject, of the subjective ratings, joint angles and sEMG (converted to force) data were graphed.

Apparatus. During data collection, each participant was connected to electromyography (sEMG) and electrogoniometry data collection devices (Biometrics, Ltd) to measure muscular exertion, via surface electrodes (SX320). These bipolar electrodes were attached bilaterally to the upper trapezius and forearm flexors and extensors, using disposable sticky collars. Electrodes were also placed bilaterally on the masseter muscle of the jaw, a frequent site of tension when other parts of the body are unduly stressed. Subjects were also fitted with electrogoniometers (Biometrics, Ltd), devices that measure range of motion, including the span from the first metacarpophalangeal (MCP) joint to the fifth MCP joint according to performance demands using the F35 finger electrogoniometers on the radial and ulnar side of the hand and flexion/extension and radial/ulnar deviation at the wrist using SG65 electrogoniometers. After sEMG and goniometer placement, the subject was asked to play the assigned piano as shown in Figure 2. Hand size was measured using GPM anthropometers and compared to the Steinbuhler hand gauge. The goal was to measure muscle loading and hand span during performance of a musical excerpt that stresses the small-handed pianist due to its inclusion of large chords requiring the subject to play with full hand extension at maximum volume.

Procedure. Prior to the test session, each subject was assigned the first 1.5 minutes of the Tchaikovsky Piano Concerto in B-flat Minor, Opus 23 to practice on either the conventional(full) scale keyboard or the 7/8 (small) keyboard. They were to practice a maximum of 10 hours on the excerpt, which consists of passages of large chords covering the full range of the keyboard that is difficult for the small-handed pianist due to the great span of hand abduction throughout.

Each subject was asked to complete three trials of the excerpt on the instrument s/he practiced on, either the 7/8 or conventional piano keyboard. The subject was allowed to choose his/her best trial, which was then related with expert assessment of best performance. Trials were tape-recorded for independent verification of "best performance". Since we were also interested in the amount of time required to adapt to the 7/8 size keyboard from the conventional piano keyboard and vice versa, after initial three performances of the excerpt each participant was then asked to transition to the keyboard s/he did NOT practice on (either the 7/8 or conventional sized piano keyboard). Subjects played for a period of 30 minutes on the unfamiliar keyboard. Performances of the excerpt were measured every 5 minutes. These multiple performances of the excerpt were interspersed with other repertoire of the participant's choice to reduce any fatigue effect that might have resulted from the participant simply playing the excerpt repeatedly and to allow them to adapt using more familiar repertoire. After each performance of the excerpt, the subject was asked to rate his/her level of comfort/ease and perceived mastery of the excerpt on a scale of 1 (least comfortable) to 10 (most comfortable). In addition, joint angles and sEMG were measured for each excerpt performance for each of the 7 trials.

Results

The actual hand size of subject 1 was approximately the 4th percentile in digit 3 to wrist crease and approximately the 25th percentile in hand breadth; subject 2's hand was approximately the 20th percentile in digit 3 to wrist crease and approximately 3rd percentile in hand breadth when compared to the US Army personnel data (Greiner, 1991).

The subject's self-reported best performance matched the expert assessment rating. The self-reported "comfort level" rating (1-10) measured using the first transition excerpt performance trial as the baseline (0) is shown in the chart in Figure 3. The average joint angles over the excerpt trials are shown in Figure 4 by hand and subject. The average radial deviation was 5º larger and ulnar deviation was 10º larger for the full sized keyboard than the 7/8 (smaller) keyboard, on average. The force exertions for the full and 7/8 keyboards are shown in Figure 5. Both the average angle (degrees) and average force (Newtons, as calculated from RMS sEMG) are plotted by side for each subject.

Discussion

The small-handed participants in this pilot study preferred the 7/8 keyboard according to subjective measures and anecdotally after completion of the study. These findings were substantiated by the expert rating for both missed notes (incorrect pitches) and pauses during play as well as by the range of hand span required to play the excerpt. The divergence of the "comfort level" as rated by the participants shows that on the full-sized piano the comfort level went down, while the 7/8 piano became more comfortable as the subject continued to adapt to the smaller keys. The average difference in the amount of stretch or the maximal hand span between the full sized and 7/8 sized keyboards was 15º for the two subjects. The average joint angles for the smaller (7/8) keyboard were smaller across the board than those employed in playing the full-sized keyboard. The forces for the subjects were about the same for the two keyboards except for subject 2 on her right side. A likely explanation for this observation is that subject 2 demonstrated a consistently high degree of wrist flexion when playing an octave. This extreme flexion is likely an adaptive response to the demands of reaching the octave on a full-size keyboard with a small hand. This high degree of wrist flexion was carried over onto the playing of the octave of the 7/8 size keyboard, even though this adaptive strategy was not necessary on the smaller keyboard. The subject used this high degree of wrist flexion throughout her performances on all trials. Unfortunately, this flexion at the wrist interfered with both radial and ulnar angle measurement on the hand span. Regardless of this complication observed with subject 2, the findings regarding joint angle and force loading as measured in this pilot study lead us to believe that reduction in the size of the conventional keyboard will lead to easier, more enjoyable practice and performance for the small-handed pianist. This hypothesis will be more fully investigated in a study using a larger research population in Fall 2005.

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Figure 1. Subject holding an octave on the full-sized piano keyboard (left) and on the 7/8 keyboard (right).

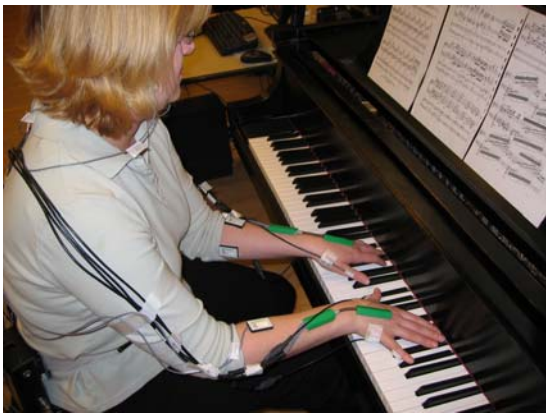

Figure 2. Subject wearing electrogoniometers and sEMG instrumentation while performing the excerpt

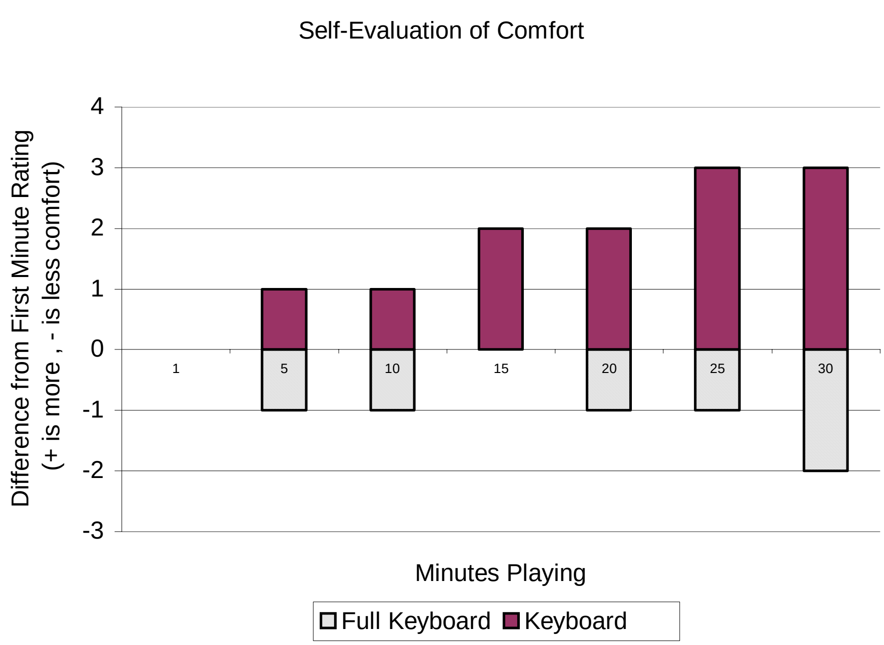

Figure 3. Graph of subjective rating of comfort for each trial (1-3 for the assigned keyboard; 1-7 for the transition keyboard)

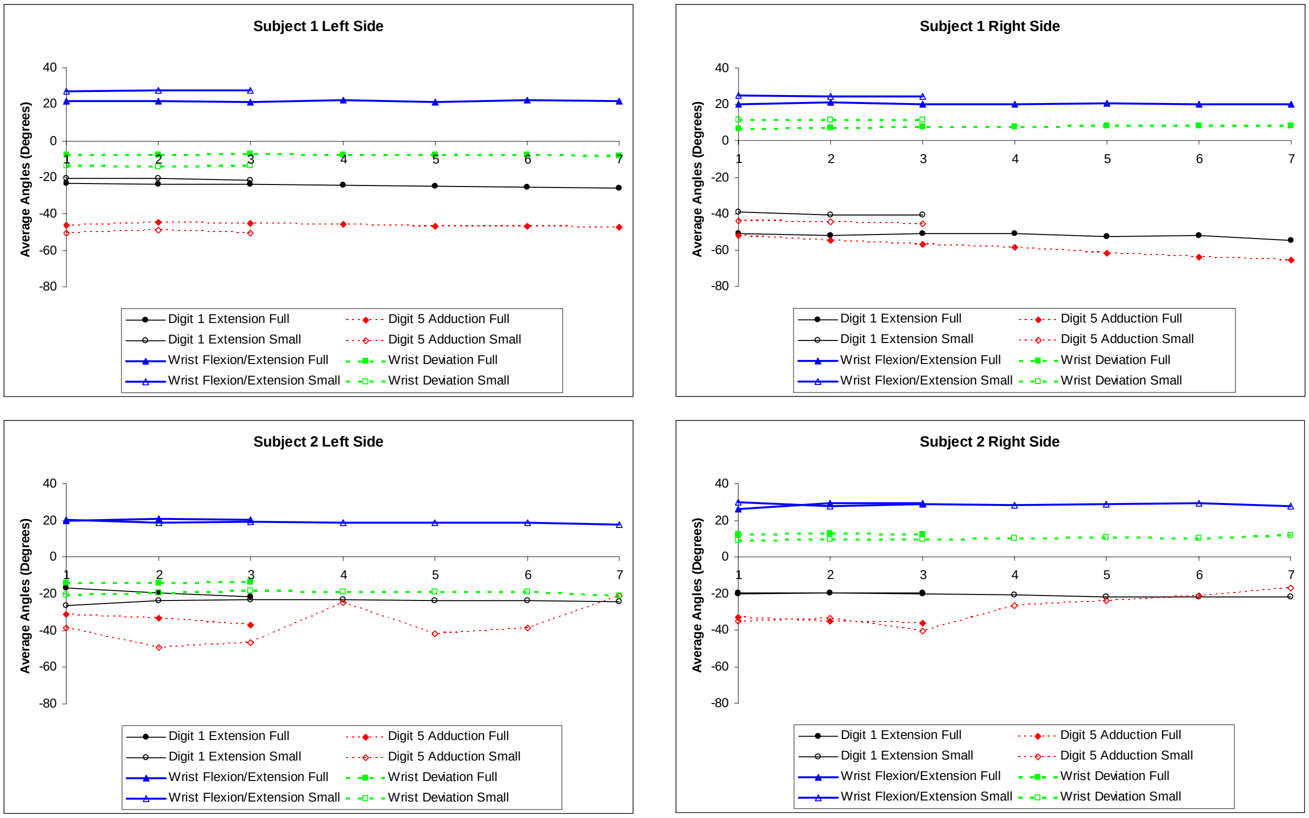

Figure 4. Average Angles by trial. Subject 1, left and right at top; Subject 2, left and right beneath.

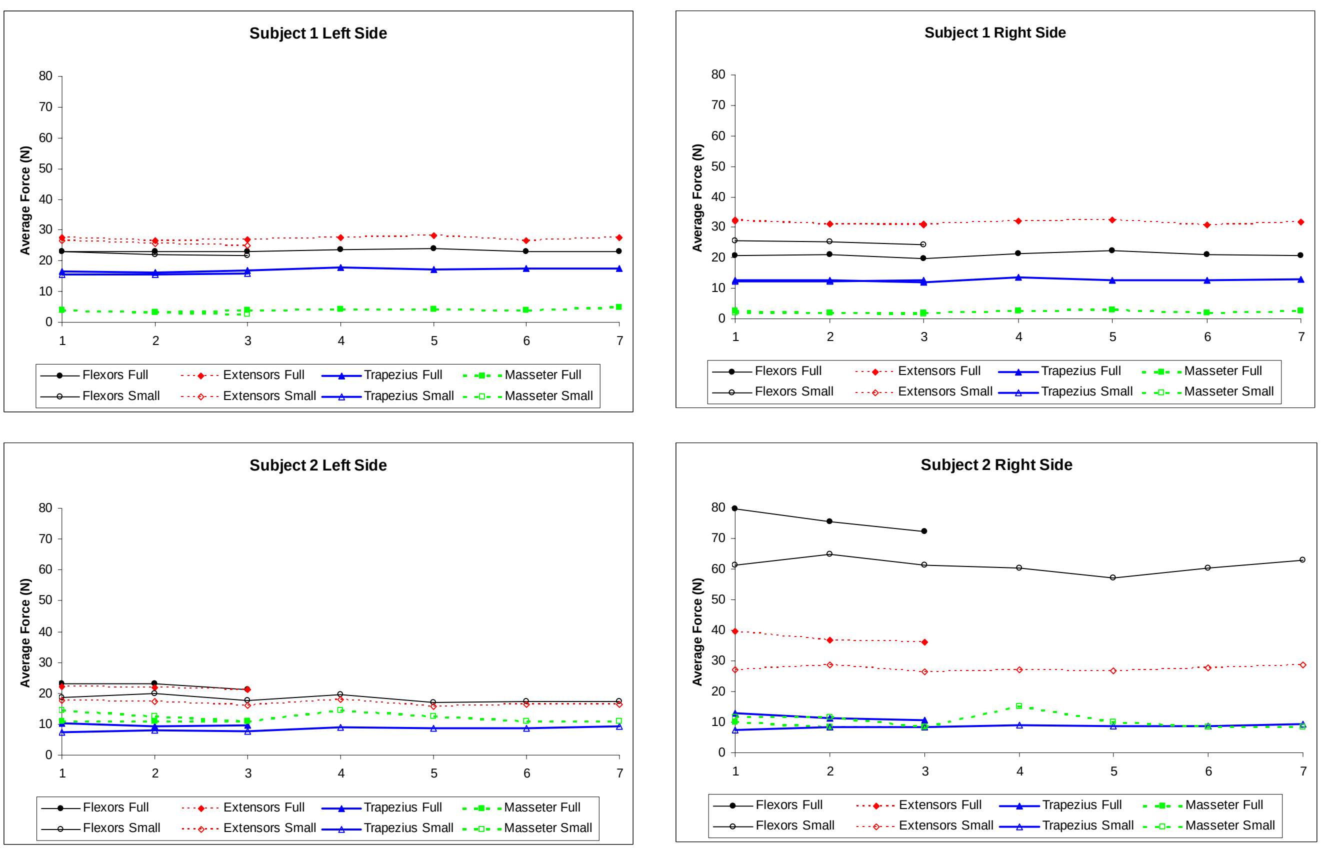

Figure 5. Average Force (from sEMG) by trial. Subject 1, left and right at top; Subject 2, left and right beneath