ORIGINAL ARTICLE

# EMG Changes During Graded Isometric Exercise in Pianists: Comparison with Non-musicians

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**Background:** Long-term piano training might induce some biochemical and structural adaptations in the intrinsic muscles of the hand or change the motor strategy of the nervous system. The main purpose of this study was to analyze whether the intrinsic muscles of the hands of pianists and sedentary controls differ in electromyographic characteristics at different strengths.

**Methods:** Fifteen college piano students and 15 sedentary controls were asked to sit on an examination bench and perform first dorsal interosseous muscle contractions for 1 minute. The motor unit potentials were recorded during various percentages of maximal voluntary muscle contraction (MVC) by automatic decomposition electromyography.

**Results:** The pianists demonstrated a significantly higher firing rate, shorter duration, and higher amplitude of motor unit potentials during minimal muscle contractions than the sedentary controls. But when comparing all the parameters at other degrees of contractions, the pianists were found to have significantly higher firing rate only at 25% and 50% of MVC, and higher amplitude at maximal contraction than the control group. The amplitude at maximal control contraction was higher in pianists than in controls.

**Conclusion:** These results imply that high-frequency and highly efficient muscle fibers are recruited in pianists when minimal muscle contractions are performed, which also indicate that by using smaller motor units, pianists may delicately control their fine motor performance. [*J Chin Med Assoc* 2008;71(11):571–575]

**Key Words:** first dorsal interosseous muscle, motor unit potential, pianist

## Introduction

Musicians can be regarded as small-muscle athletes. Their distal muscles are able to perform adequately for hours at a time—the equivalent of running a marathon.[1] During music training, motor programs are optimized to achieve the highest accuracy with a minimum of effort.[2] Piano playing is a learned ability which links natural hand and finger movements in a complex pattern. Pianists can be regarded as super-athletes of the upper extremities. As with athletes, it is reasonable to anticipate that long-term piano training might induce some biochemical and structural adaptations in the intrinsic muscles of the hand and/or changes in the motor strategy of the nervous system. Piano playing requires fine control of submaximal movements rather than rapid production of powerful movements. Using frequency domain electromyography (EMG) for power spectrum analysis, Penn et al found that during fatigue, the median frequency shifted toward low frequencies in both pianists and controls. The median frequencies of 50% and 25% maximal voluntary contractions (MVC) subsequent to fatigue were significantly lower than those before fatigue in the control group. Their study indicated that piano training should not be recognized as power training, but rather as endurance training.[3]

The majority of the literature has used the frequency domain method to investigate corticomuscular interactions, tremor, dystonia, etc. However, a separate body of literature has focused specifically on the

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low-frequency common drive, which indicates a common excitation to the motor neuron pool that results in concurrent fluctuations in the firing rates of motor units from the same pool. A number of subsequent studies have utilized this technique to investigate the relationship of this drive to handedness, exercise, and task. The present study extends this line of our previous investigation to answer the question: "Will the magnitude of time domain neurophysiologic activity in pianists be more easily affected during various grades of isometric muscle contractions than that of sedentary controls?" To address this question, our experiment compared the firing rate, duration, number of turns and amplitude of motor unit potentials during isometric contractions of the right first dorsal interosseous (FDI) muscles of all participants.

## Methods

The participants recruited for this study were 15 college piano students (12 females, 3 males) with a mean age of $19 \pm 0.14$ years (range, 17–22 years), and 15 non-musicians matched for sex and age (all female; mean age, $18.9 \pm 1.2$ years). All the college piano students had played piano for 8–15 years, and the duration of each student's practice was 2–4 hours per day. The control group was composed of students without a history of long-term piano playing or special hand activities. None of the subjects had symptoms or signs of neuromuscular disease. Informed consent was obtained from all subjects.

All measurements were performed with the subjects in a sitting position, the elbow joint at a right angle, and the forearm in a neutral position. The force of the FDI of the right hand of both groups was measured using a force transducer. The transducer was composed of a strain gauge (Gedge Systems 1650, Melbourne, Australia) mounted on a brass plate on which the hand and forearm were fixed to ensure that the forearm, the hand, the thumb, and fingers 3, 4 and 5 could not be moved. The MVC force was measured at the proximal phalanx. After these initial trials, sustained static contractions of the FDI were performed at minimal contraction, which was defined as the appearance of a few separated, identifiable motor unit action potentials, and at 10%, 25%, and 50% of MVC in random orders by draw, with a 2-minute rest interval between each isometric contraction. Myoelectrical signals were transferred to a Viking IIe (Nicolet Instrument Corp., Madison, WI, USA) with an automatic decomposition EMG (ADEMG) and Dantec 13 L 50 concentric needle.

ADEMG was used because there is interference between motor units with traditional EMG analysis, and it cannot focus on a single motor unit. ADEMG was first presented by Dorfman and McGill,[4–6] and allows a clearer identification of a single motor unit, even with increased interposed noise.[7] In this study, the ADEMG was set to record 4-second intervals at each degree of muscle contraction, and each subject underwent repeated ADEMG recording until at least 20 motor unit potentials (MUPs) were collected at each degree of contraction. The recording parameters of MUP included peak-to-peak amplitude, duration, turns and firing rate.

In this study, we recorded myoelectrical signals in FDI. Interossei are the main power source in loaded instrumental movements and is essential for piano playing.[8] The FDI muscle was chosen to represent intrinsic hand muscle activity because its distinct belly is readily accessible for EMG recording and has less signal contamination from other muscles.[3,8]

### *Statistical analysis*

Statistical analyses were performed using SPSS version 12 (SPSS Inc., Chicago, IL, USA) for Windows, mostly using *t* test and Mann-Whitney test. The mean and standard deviations of amplitude, duration, number of turns, and firing rate of MUPs during FDI contractions at minimal, and 10%, 25%, 50% and 100% of MVCs were calculated in all cases. A $p$ value $< 0.05$ was considered significant.

## Results

Statistical significance was noted in the amplitude ($p < 0.001$), duration ($p < 0.001$) and firing rate ($p < 0.001$) of MUPs at minimal contraction (Table 1). The pianists also had significantly higher firing rate at 25% ($p < 0.001$) and 50% of MVC ($p = 0.009$). Borderline $p$ value ($p = 0.057$) was noted in firing rate at 10% MVC (Figure 1). The amplitude at maximal control was higher in pianists than in the control group ($p = 0.015$). However, the amplitude was higher in the control group than the study group, though there was only significant difference for 25% MVC ($p = 0.01$). Positive correlation was found between force and firing rate (study/control: $r = 0.533$, $p < 0.01$/$r = 0.546$, $p < 0.01$, by Spearman's rho), and between force and amplitude (study/control: $r = 0.425$, $p < 0.01$/$r = 0.400$, $p < 0.01$, by Spearman's rho) in both groups. (Figures 2–5). Negative correlation (study/control: $r = -0.333$, $p < 0.01$/$r = -0.319$, $p < 0.01$, by Spearman's rho) was found between force and firing rate (Figure 6).

**Table 1.** First dorsal interosseous motor unit action potential parameters

| MVC | MUP no. | | Amp (μV) | | Dur (ms) | | Number of turns | | Firing rate (Hz) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | P | SC | P | SC | P | SC | P | SC | P | SC |
| MC | 400 | 302 | 385.2±14.9 | 322.2±14.6* | 9.0±0.2 | 10.4±0.2* | 1.4±0.0 | 1.6±0.0 | 12.9±0.8 | 8.9±0.6* |
| 10% | 386 | 339 | 408.1±16.8 | 448.3±19.8 | 7.8±1.7 | 8.1±1.8 | 1.7±0.0 | 1.7±0.0 | 12.3±3.5 | 13.8±4.5 |
| 25% | 390 | 356 | 451.7±18.9 | 514.9±18.5* | 7.2±1.8 | 7.4±1.6 | 1.8±0.0 | 1.9±0.0 | 15.7±2.0 | 14.3±1.9* |
| 50% | 392 | 345 | 597.7±19.9 | 631.3±22.4 | 6.9±1.8 | 6.7±1.8 | 1.9±0.0 | 2.1±0.0 | 17.3±3.4 | 16.2±4.3* |
| 100% | 340 | 334 | 801.8±24.2 | 784.2±22.3* | 6.3±1.8 | 7.2±1.8 | 2.2±0.0 | 2.1±0.0 | 18.6±2.5 | 18.1±2.4 |

*$p < 0.05$. MVC = maximal voluntary contraction; MUP no. = motor unit potential number; Amp = motor unit amplitude; Dur = motor unit duration; P = pianists; SC = sedentary controls; MC = minimal contraction.*

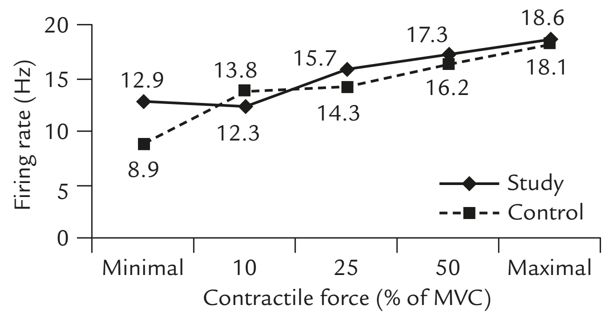


**Figure 1.** Firing rate at specific contractile force.

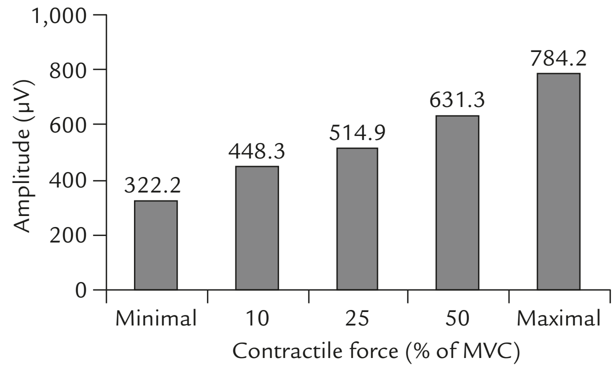


**Figure 2.** Motor unit potential amplitudes at specific contractile force in the control group.

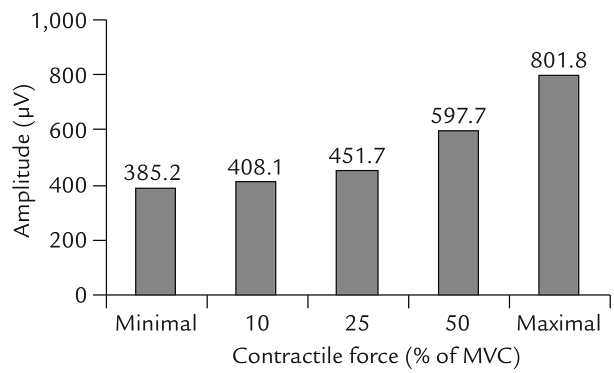


**Figure 3.** Motor unit potential amplitudes at specific contractile force in the study group.

## Discussion

Most instrument training programs are optimized to achieve the highest accuracy with a minimum of effort. Years of experience enables the pianist to perform precise and reproducible motion patterns with an independent coordination of playing and non-playing fingers.[2] In our study, all pianists practiced at least 2–4 hours per day, which may have induced both strengthening and endurance training effects.

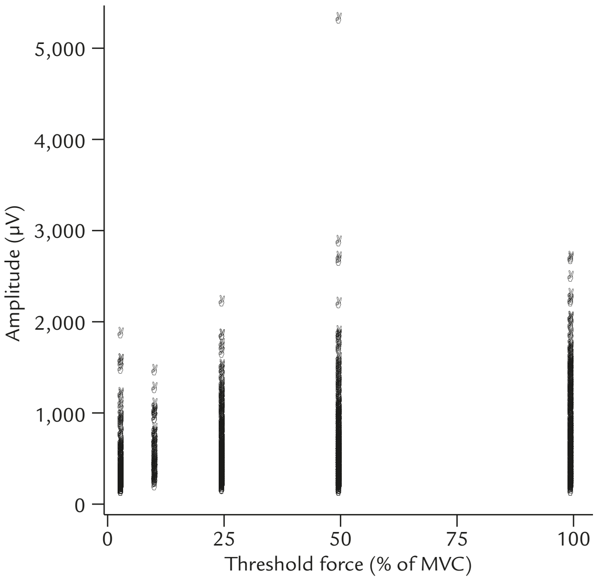


**Figure 4.** Motor unit potential amplitudes in the control group at specific percentages of contractile force.

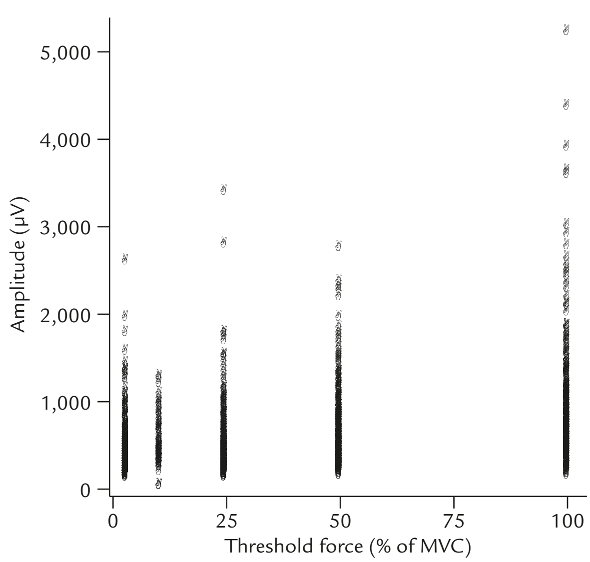


**Figure 5.** Motor unit potential amplitudes in the study group at specific percentages of contractile force.

This study revealed that the pianists had a significantly higher firing rate, shorter duration, and higher amplitude of MUPs during minimal contractions than did the controls. The increase in amplitude and decrease in duration can be explained by better synchronization in motor unit components, while higher firing rate may reflect a central enhancement effect after long-term and repetitive piano training. On submaximal contraction (10–50% of MVC), however, the sedentary control group may have needed to recruit larger motor units earlier to accomplish the contraction

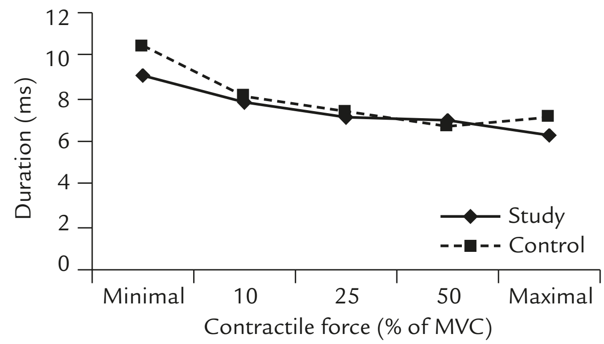


**Figure 6.** Motor unit potential duration at specific percentages of contractile force.

task, and hence the amplitudes of MUPs were higher in the control group. Due to infrequent use and poorer contraction efficiency, the sedentary subjects had a lower fatigue tolerance than the pianists.[3] In maximal contraction, both groups used the largest motor units without selection, and the long-term training effect appeared again in the study group, leading to a higher amplitude in MUP as a result of better muscle fiber synchronization.

There are 3 phases in physiologic changes after exercise training.[9] In the first phase, the main change is laid down as motor planning in the central nervous system, and neural adaptations, including increased motor unit discharge rates in long-term but not short-term training,[10,11] result in higher MUP amplitudes with higher discharge rates. In addition, the kinematic study also found that there is an anticipatory modification of sequential movements of the hand.[12] In the second phase of training, there is an increase in muscle strength without an increase in anatomic cross-section. The mechanism involved in this phase is not clear at this stage; however, the recruitment of more efficient motor units might explain, in part, this phenomenon. In the third phase, there is an increase in both the size and strength of the exercised muscle. Increasing microvascular adaptation,[13] and increasing mitochondrial content and enzymes, such as citrate synthase and hexokinase, were reported to improve muscle oxidative potential.[14] Other changes include increasing gene expression, such as myosin heavy chains, phosphagen,[15] mRNA of mitochondrial genes,[16] and upregulated energy pathways and downregulated protein catabolism,[17] and increasing Na-K pump concentration.[18] These changes in muscle hypertrophy and changes in neuron and muscle membrane are another reason for increasing amplitudes in the motor units.

This study had a cross-sectional design, and prospective organization after long-term piano-playing is needed to differentiate whether there is muscle size change and/or congenital impact on EMG characteristics. Another method to differentiate between congenital and acquired effect is to compare the MUP characteristics of other muscles in these 2 groups (femoris such as deltoid); if congenital factors lead to the difference, the same finding as in the FDI muscle would be found in other muscles.

In Boe et al's study, which recorded EMG signals of the FDI muscle with decomposition quantitative EMG,[19] the amplitude of MUPs were smaller than ours but increased suddenly from 20% of MVC to 50% MVC. Besides the possible race and age group differences, we reviewed and screened out the distant MUPs that had obviously flatter slope to increase reliability and avoid interference from distant motor unit activities. Thus, in our study, the average MUP amplitude was higher than in Boe et al's study. And as in Dorfman and McGill's study,[4–6] as the contraction force increases, the signal-to-noise ratio of the extracted MUP decreases on ADEMG study analysis. Noise from distant MUPs may interfere with the mean MUP amplitude. If contraction force is greater than 30% MVC, the baseline would be interfered with and affect the interpretation. To avoid baseline interference, we reviewed and screened distant MUPs which had lower amplitude, higher threshold and higher firing rate to increase reliability and avoid interference from distant MUPs. Thus, in our study, mean MUP amplitudes were higher than in Boe et al's study. But the linear relationship of all the MUP parameters and contractile force was consistent. This also explains the lower firing rate in our study compared to Boe et al's and Doherty and Stashuk's studies.[19,20] Other possibilities that caused the difference in results between these studies include the difference in dynamometers and subject population.

The shortcomings of this study include the use of few EMG needle insertions, thus making a thorough evaluation of the MUPs of the whole FDI difficult. Since needle insertions for EMG are painful, there is an ethical consideration to limit the collection of EMG data. Second, all of the participants in the study group were piano performance students majoring in music in the same college, which limits the generalizability and external validity of the results.

In conclusion, these observations are discussed in terms of training-induced metabolic adaptations, changes in strategy of motor unit recruitment, and possibility of differences in muscle fiber composition. Piano-playing improves coordination and central drive of motor control, reflected in higher firing rate, shorter duration, and higher amplitude of MUPs in EMG characteristics.

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