

Effect of daily piano practice on finger kinematics and muscular load

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The present study aimed at assessing impacts of daily piano practice on kinematics and muscular activity of finger movements while musically-naïve individuals played the piano. Six participants were asked to play a certain melody with metronome with the non-dominant left hand. They practiced fifty trials per day over four successive days. Time-varying joint positions at the hand were recorded using a motion-capture system consisting of 13 high-speed cameras. Extrinsic finger muscular activities were also recorded using a surface electromyography (EMG). The amount of agonist-antagonist muscular co-activation was then computed. The joint angle averaged within each trial was also computed at the MCP, PIP, and DIP joints for each of the fingers. With practicing, the mean angle at the MCP joint became more flexed while the angles at the PIP and DIP joints became more extended. One-way repeated measures ANOVA confirmed significant changes in the joint posture with daily practice. The amount of co-activation of the finger flexor and extensor muscles also displayed a decrease, which indicates a reduction in joint stiffness. This study provided the first evidence demonstrating that daily piano practice reorganizes hand posture in playing and economizes muscular work for stiffening joints.

Keywords: motor control; motor learning; electromyography; kinematics; motion capture

Successful tone production in piano playing requires muscular compensation for the mechanical interaction between the fingertip and piano key. A previous study demonstrated that, while depressing a key, expert pianists configured more upstanding finger posture compared with novice piano players

(Furuya and Kinoshita 2008a). In addition, the pianists with superior skill produced smaller finger joint torque elicited by the key-reaction force as well as finger muscular torque (Furuya and Kinoshita 2008b). A simulation study also identified mechanical efficiency of the upstanding finger posture in piano keystrokes (Harding *et al.* 1993). It is therefore likely that pianists learned to configure upstanding finger posture during key-depression through practice. However, there remain several confounding factors, such as the effect of explicit instruction of the optimal finger posture by piano teachers and genetic effects. A longitudinal study is needed to directly assess whether extensive piano practice yields organization of the upstanding finger posture in piano playing.

To test a hypothesis that piano practice reorganizes hand posture so as to minimize muscular effort, the present study addressed the effect of daily piano practice on finger posture and finger muscular activity while playing a simple melody. To investigate this provides insights into not only the neural optimization process of the organization of redundant motor systems, but also into pathological mechanisms yielding repetitive strain injuries such as tendonitis, carpal tunnel syndrome, and focal hand dystonia that have been prevalent among pianists (Altenmuller and Jabusch 2009, Furuya *et al.* 2006).

METHOD

Participants

Twelve musically-naïve adult individuals (10 males and 2 females, $M=22.4$, $SD=1.2$ years, all right-handed) participated in the present study.

Procedure

The experimental task was to play a certain melody with metronome (two strokes per second) with the non-dominant left hand. They practiced fifty trials per day over four successive days. The target loudness for the tone was set to approximately 90 MIDI velocity during the task and was monitored by an experimenter during each trial.

Data acquisition procedures and analysis

The experimental apparatus used was a digital piano with a touch response action (P-250 YAMAHA Co.), a motion-capturing system consisting of 13 high-speed cameras (eight Eagle and five Hawk Eye, Mac3D system, Motion Analysis Co.), and a two-channel electromyography (EMG) system (Harada

Electronics Industry Ltd.). To collect positional data on anatomical landmarks, spherical reflective markers (5 mm in diameter for the hand and key and 9 mm in diameter for the wrist and elbow) were attached to 5 separate keys and on all joint centers of the right hand and arm (see Figure 1A, 1B). The joint angle averaged within a trial was also computed at the metacarpo-phalangeal (MCP), proximal-phalangeal (PIP), and distal-phalangeal (DIP) joints for each of the fingers. The amount of agonist-antagonist muscular co-activation was then computed based on the methods that we developed previously (Furuya *et al.* 2011).

Using the day as the independent variable, a one-way analysis of variance (ANOVA) with repeated measurements was performed for each of the dependent variables (joint angle and co-activation). We defined trials 1-5 as pre 5 trials and trials 46-50 as post 5 trials. Newman-Keuls post hoc tests were performed where appropriate to correct for multiple comparisons. Statistical significance was set at $p < 0.05$.

RESULTS

Joint angles of the striking fingers

Figure 2 shows the mean joint angle at the MCP, PIP, and DIP joints of the striking fingers (index, middle, ring, and little fingers) during keystrokes across participants at practice. ANOVA confirmed a practice effect on the MCP joint at the index and middle fingers, on the PIP joint at the index, middle, and ring fingers, and on the DIP joint at the middle finger (Table 1), which confirmed that the daily piano practice reorganized the hand posture in piano playing.

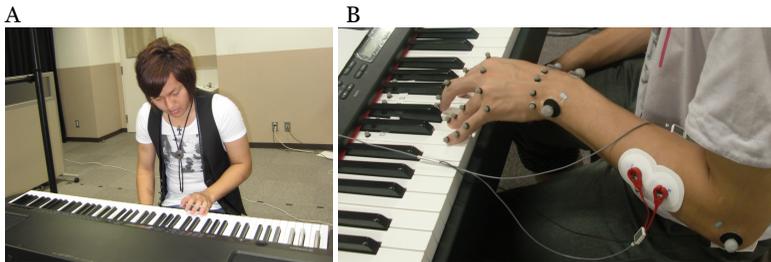


Figure 1. (A) Experimental appearance. (B) Reflective markers for the motion-capture system and surface electromyography. (See full color version at www.performance-science.org.)

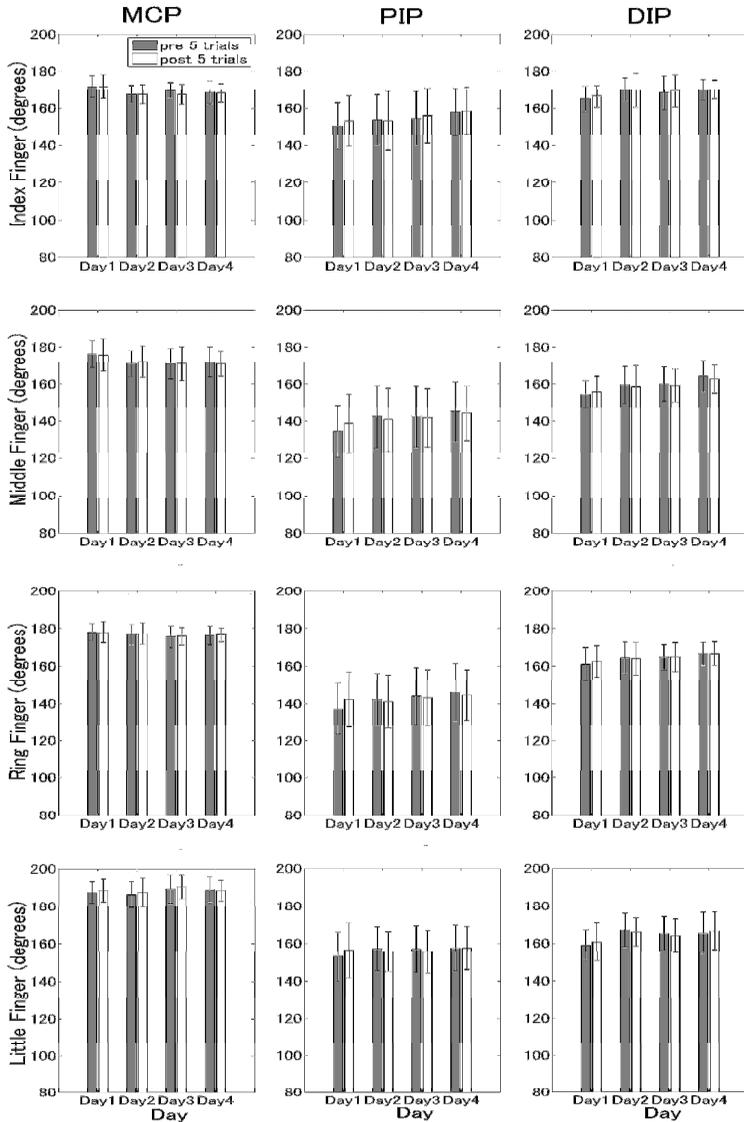


Figure 2. Group means of changes in the mean angle of joints during the training session over the four successive days. The 1st, 2nd, 3rd, and 4th rows correspond to the index, middle, ring, and little finger, respectively. 1st, 2nd, and 3rd columns correspond to the MCP, PIP, and DIP joint, respectively. A bar in grey and white indicates pre and post 5 trials the mean angle of joints, respectively.

Table 1. Results of 1-way ANOVA.

	MCP $F_{7,35}$	PIP $F_{7,35}$	DIP $F_{7,35}$
Index	2.86*	5.11**	1.82
Middle	6.60**	9.06**	4.12**
Ring	1.71	5.66**	1.70
Little	1.33	0.76	1.46

Note. * $p=0.05$, ** $p=0.01$.

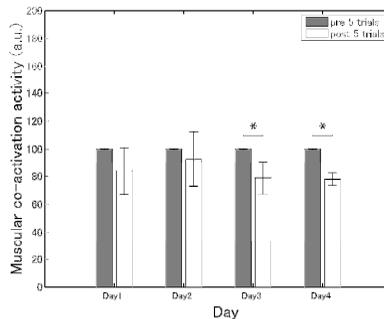


Figure 3. Group means of changes in the amount of agonist-antagonist muscular co-activation during the training session over the four successive days. A bar in grey and white indicates the amount of agonist-antagonist muscular co-activation of pre and post 5 trials. The value was normalized so that the pre-trials of each day became 100%.

Muscular Activity

Figure 3 illustrates the group mean of the co-activation of the finger flexor and extensor muscles over four training days. The amount of co-activation also displayed a decrease with practice, which indicates reduction of finger muscular stiffness. A paired t-test confirmed significant changes in the muscular load on the third ($p=0.02$) and fourth ($p<0.001$) days of practice.

DISCUSSION

We found that the mean joint angle was increased at the MCP joint of the index and middle fingers. In addition, it decreased at the PIP joint of the index, middle, and ring fingers, and at the DIP joint of the middle finger. Furthermore, there was a significant decrease of the amount of muscular co-activation through the daily practice. These findings suggest that the practice reorganized the hand posture so as to make piano performance more effi-

cient. This idea is in agreement with previous findings that pianists with superior proficiency play more efficiently (Furuya and Kinoshita 2008b, Furuya *et al.* 2011). The novelty of the present study is that the learning-dependent economization of movements occurred even without explicit instructions with respect to the optimal piano technique, suggesting spontaneous optimization process of the nervous system (Osu *et al.* 2002).

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