Characteristics of keystroke force in the piano

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INTRODUCTION

Music is a field that definitely requires more biomechanical attention. Biomechanical factors related to musicians' injuries as well musical instruments are poorly understood. As an entry to this, we recently started to investigate biomechanics of piano playing. In the present study, we will present our recent findings from a study of key-reaction force during striking the piano key at varied levels of sound pressure (SPL) with different modes ("pressed" and "struck") of key touch. A review of the literature revealed that very little work has been done on this issue..

METHODS

The finger force was measured from 10 expert pianists using a miniature uniaxial force transducer installed on a C4 key of an upright piano. Vertical displacement and radiated piano sound were also recorded (sampling freq.=900 Hz). The experimental task was a series of slow-and self-paced repetitive keystrokes (60 times) at varied SPLs (from *pianissimo* to *fortissimo*) with staccato articulation for each of the pressed and struck touch modes. The pressed-mode keystroke was performed by depressing the key with the fingertip initially resting on the key surface, and the struck-mode strike was by hitting the key from a certain distance above the key. Severn variables were evaluated, which included the finger-force application time, maximum force, average force, total impulse, maximum key displacement, impulse before the maximum key displacement, and maximum acceleration of the key.

RESULTS AND DISCUSSION

The force profiles for the struck touch were characterized by a rapid rise in force immediately after the finger contacted the key, which was followed by multiple of peaks (Fig 1, *mezzo forte* case: SPL = 103 dB). The force profiles for the pressed touch, on the other hand, developed more slowly and smoothly, and thus its initial peak was less clear and commonly had one-peaked pattern (Fig 1, SPL = 103 dB). In both modes of key touch, the sound signal was generated after the maximum finger force at all SPLs. The key displacement data showed that the key reached the lowest position toward the end of the force application time. These findings indicated that active application of the depressing force ends before the sound was generated. The force application thus can be a preprogrammed motor action based on a memorized the finger force-sound relationship.

The maximum finger force observed during each strike by the pressed and struck touch modes was ranged from 2 N at *pianissimo* to around 70 N at *fortissimo*. For both touch modes, the maximum and average force, and impulses increased curvilinearly with an increased SPL. An attempt to model these relationships (max force vs. SPL and total impulse vs. SPL) revealed that a simple exponential function could be the best predictor for both individual (r^2=0.81-0.98) and group (Fig 2, r^2=0.72) data irrespective of the touch mode used.

The proportion of the impulse before the maximum key displacement relative to total impulse can provide information about the efficiency of sound generation. The computed value was nearly 100% at lower SPLs, indicating all force application was terminated before the key reached the bottom. The value was decreased to 65% at higher SPLs, and the mean value was around 80% for both touch modes. The results indicated that the keystroke becomes less efficient at louder sound production.

A comparison between the two touch modes revealed a significantly higher maximum force and impulse (Fig 3), and a smaller descending acceleration for the pressed touch than for the struck touch at the highest SPL range (*fortissimo* = above108 dB). The results demonstrated that more forceful key action is required for the pressed mode than the struck mode for the same level of sound generation, indicating efficiency difference of the two touch modes. This also explains well about more frequent overuse injuries in the pianists who predominately apply the pressed technique.

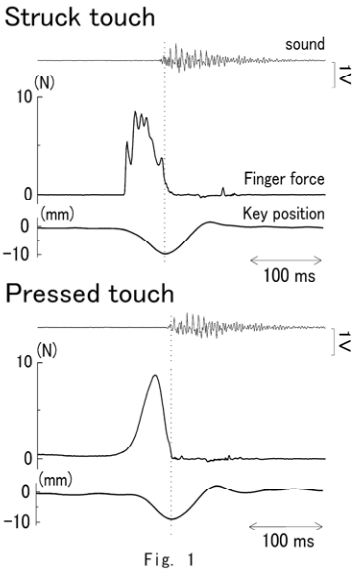

Fig. 1

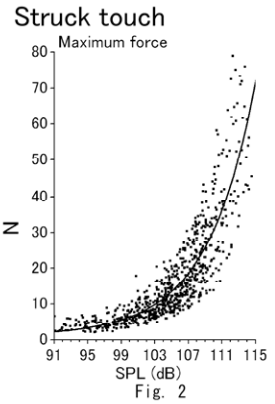

Fig. 2

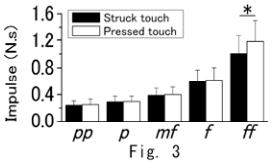

Fig. 3