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Effects of hand span size and right-left hand side on the piano playing performances: Exploration of the potential risk factors with regard to piano-related musculoskeletal disorders

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ABSTRACT

This study used biomechanical techniques to objectively investigate the effects of the size of hand span and right/left hands on the kinematic and kinetic performances when playing the piano. Twenty pianists were recruited and assigned to two hand-size groups. The parameters of interest, such as ratio of maximal digit-to-digit abduction angle (RD-D_{abd}), range of motion (ROM) of finger and wrist flexion-extension (F/E), radial-ulnar deviation (R/U), and movement units of F/E of finger joints ($MU_{F/E}$), were measured while striking the piano keys. The fingertip force was also estimated by a kinetic model. The RD-D_{abd} was significantly larger for the small hand-span pianists when playing both chords and octaves. The ROM of wrist F/E was significantly larger for small hand-span pianists when playing chords. There was no significant difference in the fingertip force between two groups. However, the values for $MU_{F/E}$ and fingertip force of the right hand were significantly larger than those of left hand. Pianists with a small hand-span should aware that they have higher exposure risks for hand injuries while playing the piano.

Relevance to industry: Hand anthropometric issue might be one of potential risk factors which result in piano-related musculoskeletal disorders. This study provides preliminary evidence that can be used to aid in injury prevention and music education for pianists as well as to reconsider issues with regard to the piano design.

1. Introduction

In recent years, there has been a dramatic proliferation of research concerned with the work-related musculoskeletal disorders (Collins and O'Sullivan, 2015; Lee et al., 2013; Vieira et al., 2015; Vignais and Marin, 2014; Widanarko et al., 2011). Musicians are a professional group with a number of specific characteristics, such as perfectionism and a culture of silence with regard to certain physical issues (Bragge et al., 2006a). As a result, musicians sometimes play through pain, neglect physical discomfort, or possess poor medical awareness, which may lead to the development or worsening of playing-related musculoskeletal disorders (PRMDs), thus threatening their professional careers (Bragge et al., 2006a; Furuya et al., 2006; Pak and Chesky, 2001; Zaza, 1998; Zaza et al., 1998; Zaza and Farewell, 1997). Among all musician-related injuries, the incidence of musculoskeletal disorders in pianists is the highest (Pak and Chesky, 2001; Goodman and Staz, 1989). The injured pianists' chief complaints are tenderness or discomfort in the wrist and digits (Bragge et al., 2006a; Blackie et al., 1999; Lederman, 2003; Revak, 1989; Shields and Dockrell, 2000; De Smet et al., 1998; Yoshimura et al., 2006), especially the thumb, ring and little fingers (Furuya et al., 2006; Pak and Chesky, 2001; Goodman and Staz, 1989; Blackie et al., 1999; Lederman, 2003; Revak, 1989; Shields and Dockrell, 2000; De Smet et al., 1998;

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Grieco et al., 1989; Sakai, 1992). Furuya et al. found that 109 of the 206 Japanese pianists in their sample reported musculoskeletal pain in their palms and digits. A total of 89 pianists reported pain in their digits, with 57% reporting pain in the little finger and thumb, and 37% reporting it in the ring finger (Furuya et al., 2006). The most common diagnoses related to playing the piano include tendonitis, de Quervain's disease and 2nd–5th flexor tenosynovitis (Zaza, 1998; Zaza and Farewell, 1997; Sakai, 1992, 2002; Dawson, 2002). In addition, a number of peripheral nerve entrapment syndromes, such as carpal tunnel syndrome, ulnar neuropathy and other nervous system impairment (e.g. focal dystonia), are also often reported in the literature (Zaza, 1998; Zaza and Farewell, 1997; Lederman, 2003; Dawson, 2002; Sakai, 2002; Bejjani et al., 1996). Although previous epidemiologic reports have indicated that musicians often suffer from PRMDs due to the great amount of rapid and repetitive movements of the hands, the literature remains unclear as to risk factors that result in various piano playing-related symptoms (such as pain, weakness and numbness) or diseases (Furuya et al., 2006; Zaza, 1998; Zaza and Farewell, 1997; Shields and Dockrell, 2000; Bragge et al., 2006b; Bruno et al., 2008; Yoshimura et al., 2008; Zaza, 1993). In addition to the risk factors related to PRMDs, some demographic and anthropometric parameters of the pianists, such as gender, flexibility and hand span, as well as various ergonomic and environmental factors, such as the right-left hand side, the physical dimensions of the piano, and the pianist‘s playing skills (Shields and Dockrell, 2000; Sakai, 1992; Chung et al., 1992; Parlitz et al., 1998; Sakai et al., 1996, 2006), also need to be considered in this context.

Several biomechanical investigations have been carried out in an attempt to understand the impacts of various physical factors on task-related performance, with the results being used to explore the related pathogenesis and develop strategies of injury prevention and clinical interventions. However, there are few biomechanical studies of pianists, and little work has been done on the relationship between hand injuries and biomechanical variables. Chung et al. (Chung et al., 1992) and Wristen et al. (Wristen et al., 2006) investigated the wrist joint flexion/extension angle and radial/ulnar deviation angle of pianists while playing assigned musical compositions using a electrogoniometer. Bejjani et al. investigated three different hand postures of a professional pianist while playing the piano using two 30 Hz camcorders, and proposed that relationships existed between injuries and finger kinematics, including wrist radial-ulnar deviation range, flexion-extension range and adduction-abduction range of middle finger joints (Bejjani et al., 1989). Sakai et al. used a motion capture system to analyze the kinematic performance of the hand (e.g. flexion/extension angle of middle finger joints and wrists) when carrying out two basic skills, playing scales and chords (Sakai et al., 1996), and also investigated the relationship between hand span and the spreading angle of the thumb/little finger (Sakai et al., 2006). Lee (Lee, 2010) examined the relationships of pianists‘ hand anthropometry and wrist ulnar deviation with the performance of a scale in thirds. However, most previous studies focused on the performance of a single joint or segment, without attempting any comprehensive or systematic exploration of hand performance while playing the piano.

The aim of this study was to use biomechanical techniques to objectively investigate the effects of the size of hand span and right/left hands on the kinematic and kinetic performances when playing the piano. Based on this, the following two research questions were examined in this study: (a) whether small-hand pianists play the piano with excessive finger movements and larger striking force. and (b) whether the right hands of pianists show more joint excursions and larger striking forces than the left hands, It is anticipated that the results of this study could help in developing better injury prevention and adaptation strategies for pianists, and thus reduce the prevalence of PRMDs.

2. Methods

2.1. Participants

Before the formal experiment to collect biomechanical data while playing the piano, an anthropometric investigation was conducted to classify the size of the female pianist's hand spans into two groups, large and small. Sixty female college students (22.17 ± 3.12 years old) were recruited as the participants at this stage of the study. Each participant was asked to spread both hands as wide as possible, and the examiner measured the distance between the fingertips of the thumb and little finger using a caliper placed on the experimental table. Based on the distribution of the hand spans obtained from the participants, the first and fourth quartiles of right hand spans were determined as the criteria for the small hand span (<18.2 cm) and large hand span (>20.2 cm), respectively.

According to the above criteria, ten pianists with large hand span (LHS) and ten pianists with small hand span (SHS) were recruited into this study. A total of twenty female pianists (mean age: 23.6 ± 6.34 years old) with an average of 17.45 ± 4.65 years of playing the piano took part in the study. These pianists, who were recruited from music schools and majored in piano performance, had no history of hand injuries, present hand pain or arthritis, and were all right-handed. The average hand spans of the LHS group were 21.33 ± 0.56 and 21.57 ± 0.48 cm for the right and left hands, respectively. The average hand spans of the SHS group were 17.97 ± 0.17 and 18.79 ± 0.29 cm for right and left hands, respectively. All participants were informed of the aims and experimental details of the study, and all signed consent forms approved by the Institutional Review Board of National Cheng Kung University Hospital.

2.2. Experimental apparatuses

This study used a Casio CDP-100 digital piano (Casio, Taiwan Co., Ltd) as the main tool for piano playing, and this model has the same number of keys (eighty-eight) and same physical dimensions as a conventional upright piano, with each white key being 2.2 cm wide. This study used eight cameras in the Eagle motion analysis system (Motion Analysis Corporation, Santa Rosa, CA, USA) at a 60 Hz measuring frequency to record the hand movements of the participants while playing the piano. The motion captured data was tracked and processed using the EVaRT 4.2 software (Motion Analysis Corporation, Santa Rosa, USA), and filtered using the low pass second-order Butterworth filter at a cutoff frequency of 6 Hz via a custom MATLAB7.1 program.

Forty 2 mm-diameter retro-reflective surface markers were attached on the dorsal surfaces of the fingertips and distal interphalangeal (DIP), proximal interphalangeal (PIP), and metacarpophalangeal (MCP) joints of the subjects, as well as at the midpoints of the dorsum of the metacarpal bones of the index, middle, ring and little fingers. Another 16 surface markers were attached to the tip, interphalangeal (IP), MCP, and carpometacarpal (CMC) joints of the thumb. To account for the greater degree of freedom of the thumb, we defined the coordinate systems of the MCP and the CMC joints via two T-bar marker sets. In addition, six markers were also attached to the dorsal surface proximal to both wrists (Fig. 1).

As well as the kinematic measurement, this study also used FlexiForce pressure sensors connected with ELF Force Measurement System (Tekscan Inc., Boston, MA) and the Digit Performer