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Original Article

Anteroposterior perception of the trunk position while seated without the feet touching the floor

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Abstract. [Purpose] The purpose of this study was to investigate the trunk position perception in the anteroposterior direction in young participants sitting without their feet touching the floor to avoid the influence of the hamstrings tension and the feet pressure on the perception. [Subjects and Methods] Fourteen healthy volunteers were seated on a chair fitted with an original manual goniometer. There were 7 reference positions set at 5° increments, from −15° to 15°, and reproductions of each position were conducted 5 times. Trunk position perception was evaluated by the absolute error between the reproduced trunk angle and the reference position angle. [Results] The results revealed a significant effect of reference position on the absolute error. The absolute error at the −5° reference position was significantly larger than at the −15° and 15° positions, and the absolute error at the 0° position was significantly larger than at the −15°, 10°, and 15° positions. [Conclusion] These results suggest that the perception of extreme forward- and backward-leaning trunk positions while sitting without the feet touching the floor would be higher than in a neutral sitting position. The relationship between the stability of the posture and the perception may be involved in the sitting position.

Key words: Trunk, Perception, Sitting

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INTRODUCTION

Sitting positions can be categorized into two types: the quiet sitting posture and the functional sitting posture. The functional sitting posture is the position used to execute activities of daily living, occupational activities, and other physical activities mainly using the upper extremities. The anticipatory postural control plays an important role in stabilizing the sitting posture while activity is performed using the upper extremities[1–4)]. The assumed role of the anticipatory postural control is to counteract the expected mechanical effects of perturbation in a feedforward manner[5)]. The existence and characteristics of the anticipatory postural control depends on mechanical factors such as the initial and final position of the body[2)]. In the standing position, the anticipatory postural control aspect changes according to the body position in the anteroposterior direction[6)]. The anticipatory postural control is also performed based on the perception of the body just before moving the body segments. Hence, the accuracy of the perception during various standing positions in the anteroposterior direction has been investigated[7)]. The anticipatory postural control may also differ in accordance with the sitting position just before moving the upper extremities. It has been indicated that investigating the anticipatory postural control while sitting is important[1)]. The accuracy of perception of the trunk position in the sitting position may therefore be an important factor influencing the anticipatory postural control.

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The trunk position just before moving the upper extremities is perceived through the reference frame of the moment[8]. In the targeted muscles, the activation pattern and contraction intensity are determined based on the reference system. The measurement of the accuracy of the perception during various trunk positions while seated is necessary to investigate the anticipatory postural control in accordance with various sitting positions. It has been shown that the perception of the trunk position in stroke patients is lower than that in normal subjects based on the reproducibility of the trunk position in a sitting posture[9, 10]. The reproducibility of the lumbar position in low back pain patients has also been investigated[11, 12]. In these reports, the reproducibility of the reference position at one or two positions was investigated, with the following reproduction method usually adopted: subjects reference a target position from the start position and return to the start position, after which they reproduce the target position from the start position. In this method, the magnitude of the range from the start position to the reference position affects the reproduction error, which is known as the range effect[13]. Therefore, adopting a method that does not set a strict start position and does not require the subject to return to the exact start position each time is more appropriate for evaluating the reproducibility of the reference position. The magnitude of error in the reproduced angle was shown to be affected by the trunk flexion angle[14]. The perception of the trunk position should therefore not be evaluated based only on one or two positions but on a number of different positions.

Since the hamstring muscles originate at the ischial tuberosity of the pelvis, the tension in the hamstring muscles has an effect on pelvic posture[15, 16]. The forward pelvic tilt according with forward trunk leaning may thus increase the tension in the hamstring muscles when seated with a fixed knee angle and the plantar aspect of the foot in contact with the floor. This increased tension in the hamstring muscles may restrict pelvic forward tilt. Because the present study focused on the perception of the trunk position, it was required that the trunk and pelvis move simultaneously as a single segment while in the sitting leaning posture. In addition, we avoided having the feet touch the floor in order to minimize the hamstring tension effect on the pelvis. Furthermore, as the trunk leans forwardly with the feet touching the floor in sitting position, the feet pressure increase, which is observed in sit-to-stand movement. These increments of the hamstrings tension and the feet pressure may lead to change of the sensory information and to sustaining the sitting stability. The standing perception of extreme forward- and backward-leaning positions is very high, whereas standing positions close to the quiet standing position show the lowest perception[7]. The perception of the standing position therefore seems to be negatively related to the stability of the standing posture. Such a relationship between the perception and the stability of the posture should also exist in the sitting position, particularly when sitting without the feet touching the floor.

In the present study, we investigated the perception of the trunk position in the anteroposterior direction in young participants sitting without the feet touching the floor. We hypothesized that the perception of extreme forward- and backward-leaning trunk positions while sitting without the feet touching the floor would be higher than the perception of the neutral sitting (vertical trunk) position.

SUBJECTS AND METHODS

Fourteen healthy young adults 21 to 25 years of age (6 females, 8 males) volunteered for this study. Their mean (± standard deviation [SD]) age, height and weight were 22.1 ± 1.0 years, 164.6 ± 9.4 cm and 61.3 ± 10.2 kg, respectively. Participants were free from neurological and orthopedic impairments. All participants gave their informed consent to the experimental protocol, which was approved by the institutional ethics committee of Kanazawa University in accordance with the Declaration of Helsinki (No. 462-2).

All measurements were taken with the participants seated on a chair with a hard, 50 cm ×50 cm seat surface. The participants first sat down on the chair, aligning the front edge of the seat surface with the point 60% along the length of the thigh from the greater trochanter to determine the initial quiet sitting posture.

In this study, the trunk angle was defined as the angle between the vertical line and the longitudinal axis through both the right trochanter and the right acromion. An original manual goniometer attached to an inclinometer with a resolution of 0.1° (BM-801, Ito, Miki, Japan) was used to measure the trunk angle (Fig. 1A). This goniometer was able to move horizontally on a sliding rail set on the right edge of the seat (Fig. 1A). In addition, the axis of the goniometer was also able to move vertically (Fig. 1A). Therefore, the axis of the goniometer was moved manually in these two directions to match precisely with the right trochanter of the participant in the sitting position (Fig. 1B–D). The reference point of the goniometer's movable arm was matched with the right acromion (Fig. 1B, 1D).

Measurements were performed with the participants wearing short leggings, sitting barefoot, and with eyes closed. The subjects sat, keeping both arms crossed on the chest, with no support for the trunk or arms. The chair seat height was 1.5 times the subject's lower leg length to allow for free movement of the knee joints and avoid any contact of the feet with the floor.

The participant's reproductions of reference positions were measured as follows: Perception of the reference position was evaluated based on the accuracy of its reproduction. There were 7 reference positions, set at 5° increments from −15° to 15°, and reproductions of each position were conducted 5 times. The experiment consisted of seven sets of five random positions with three minutes of rest time between each set. Each reference position was reproduced in accordance with the following procedure (Fig. 2): (1) The participants maintained the quiet sitting (QS) posture for 3 s. (2) They then voluntarily and slowly (within 10 s) adjusted their sitting position by leaning forward or backward with the hips as pivotal axes until the experimenter gave the verbal instruction "OK" (reference position angle) and then maintained and perceived the position for 3 s.

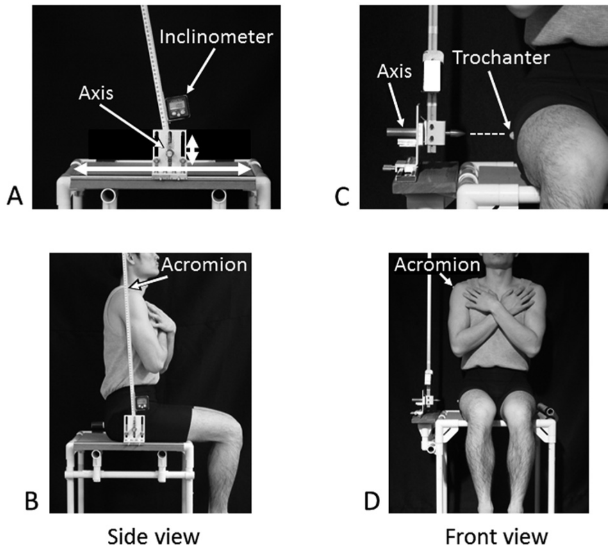

Fig. 1. Experimental setup showing the goniometer (arm, axis, inclinometer, and axis moving system in two directions), acromion, and trochanter

A and B show the side view, and C and D show the front view of the goniometer and setup.

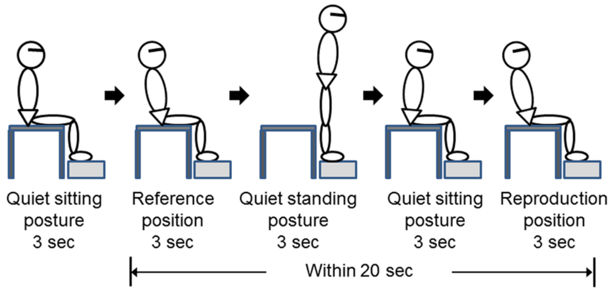

Fig. 2. Experimental protocol for reproducing reference positions

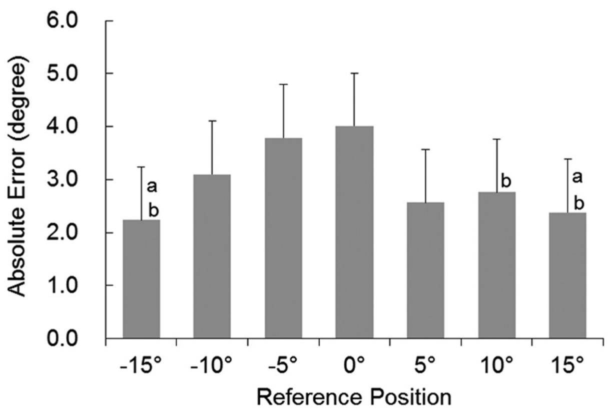

Fig. 3. The means and standard deviations of reproduction absolute error for reference positions

a: Smaller than the −5° reference position. b: Smaller than the 0° reference position. a, b: p<0.05

(3) Without returning to the QS posture, they stood up for 3 s. (4) They then sat down again, maintained the QS posture for 3 s, and (5) were asked to reproduce the reference position (reproduced trunk angle). They were instructed to say "yes" when they judged themselves to be sitting in the reference position and maintained this position for 3 s. In each case the time elapsed from initially memorizing the reference position to reproducing it was within 20 s, within the limits of short-term memory[17].

The measured reproduction absolute error (absolute error) was calculated using the following formula: Absolute error=|(reproduced trunk angle) − (reference position angle)|.

Shapiro-Wilk tests confirmed that all data were normally distributed. The effects of the reference position on absolute error were tested using a one-way repeated measures analysis of variance (ANOVA). A post-hoc multiple comparison analysis using Holm's test was used to assess significant differences found by the ANOVA. The alpha level was set at $p<0.05$. All statistical analyses were performed using the SPSS 14.0 J software program (SPSS Japan, Tokyo, Japan).

RESULTS

The results revealed a significant effect of the reference position on the absolute error (Fig. 3). The absolute error at the −5° reference position was significantly larger than those at the −15° ($p<0.05$, $t=-3.51$) and 15° positions ($p<0.01$, $t=-3.68$), and the absolute error at the 0° position was significantly larger than those at the −15° ($p<0.01$, $t=-4.94$), 10° ($p<0.05$, $t=-3.31$), and 15° positions ($p<0.01$, $t=-4.20$). The absolute error distribution was mountain-shaped as represented in Fig. 3.

DISCUSSION

In this study, the perception of seven positions of the trunk in the anteroposterior direction while sitting was investigated. Almost all previous studies have adopted only one or two target positions and a starting position to investigate the trunk position perception[9–12]. However, our study adopted a method in which participants were instructed to stand up right after referencing the target position instead of returning to the starting position. This method may reduce the range effect. Furthermore, the goniometer used in this investigation was specially developed to support our method. A unique property of this goniometer is that the axis was able to move in both the horizontal and vertical directions. This study adopted a method in which the subjects stood up right after memorizing a reference position and then sat down to reproduce the reference position. For this reason, the sitting posture, particularly the pelvic angle, and the buttocks position changed in every sitting trial. These changes caused displacement of the trochanter major in both the horizontal and vertical directions. The axis of the goniometer was made to be movable in order to match the trochanter major precisely in every trial. Therefore, in this study, the measurements were conducted with greater precision and accuracy than in other studies due to the mobility of the goniometer axis in dual directions. Ryerson et al. used a magnetic sensor placed on the skin over the spinous process of the first thoracic vertebra to measure the trunk position[10]. The reproduction error in the sagittal plane of the control subjects was 3.2 ± 1.8°, which was similar to our data.

In this study, the absolute errors at the −5° and 0° reference positions were larger than those at the −15°, 10°, and 15° positions. The sitting position at −5° and 0° may be located close to the QS posture and may be normally adopted with high frequency. Standing positions located close to the quiet standing position show the lowest perception with a high frequency and stability[7]. Therefore, the trunk position perception in the sitting position may also be lower at positions located close to the QS posture, similar to the reduced standing position perception at positions located close to the quiet standing posture.

At least two factors may be involved in posture perception: the stability of the posture and the muscle activity to maintain the posture. In the standing position, the stability was relatively low in high-perception standing positions[7]. While sitting without the feet touching the floor, the high-perception positions were largely forward- and backward-leaning positions from the QS posture, and the stability of these positions may contribute to the perception. Therefore, the relationship between the stability of the posture and the perception may be involved in the sitting position perception, similarly to the standing perception.

On the other hand, because the trunk stability and the aspect of the sensory information in the sitting with the feet touching the floor may be different from those in the sitting without the feet touching the floor, the relationship between the stability of the posture and the perception also may behave discretely between these sitting postures.

In terms of the relationship between the standing position and the magnitude of muscle activity, the magnitude of the trunk muscle activity may be lower at trunk sitting positions located close to the direction of gravitational force. In contrast, the magnitude of the trunk muscle activity may be higher at trunk positions located largely forward- and backward-leaning from the QS posture. The trunk muscle sensation may play an important role in perceiving the trunk sitting position.

This study investigated the perception of the trunk position in the anteroposterior direction of sitting reference positions from −15° to 15°. If this range of reference positions is extended, the perception of more extreme forward- and backward-leaning trunk positions may differ more clearly from that located close to the QS position. Both the relationship between the trunk position and its stability, and the relationship between the trunk position and the muscle activity must be investigated in future studies. In addition, the accuracy of perception of the trunk position in the sitting position with the feet touching the floor also is necessary to be investigated. Hence, comparing results of the accuracy of perception of the trunk position in the sitting both with and without the feet touching the floor may reveal the importance of the feet touching the floor while sitting in physical therapy. The trunk perception in elderly people and subjects with low back pain or stroke may differ from these study results.

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