

EFFECT OF TRADITIONAL FLOOR SITTING ON POSTURAL CONTROL AFTER STANDING

SHINICHI DEMURA¹ AND MASANOBU UCHIYAMA^{2*}

¹Faculty of Education, Kanazawa University,
Kakuma, Kanazawa, Ishikawa 920-1164 Japan

²Graduate School of Natural Science & Technology, Kanazawa University,
Kakuma, Kanazawa, Ishikawa 920-1164 Japan

*E-mail: masanobu@ed.kanazawa-u.ac.jp

Seiza is a Japanese traditional floor sitting style, sitting down with both legs set at about a 180 degree angle and both femurs on both lower legs.

We examined the influence of the somatic dysesthesia and decrease in voluntary toe flexion strength (VTF) induced by Seiza on the center of pressure (COP) sway. Fifteen adults participated in this experiment. COP Sway was measured immediately after a chair resting (pre-test), when a plantar dysesthesia occurred (post-test A), and when a decrease (under 30% of maximal voluntary contraction (MVC)) in the VTF set in (post-test B).

Tissue oxygenation kinetics in the soleus muscle and plantar somatosensory thresholds (ST) were measured just before each COP test and during Seiza. From starting Seiza, oxygenated hemoglobin/myoglobin decreased markedly and reached a plateau within about 6 min. ST abruptly increased at about 19 min from starting Seiza. VTF decreased to less than 30% MVC in 33% of the participants after 10 min from the acute increase in ST, and in 100% after 20 min. When sustaining Seiza for 19 min, ST rose and sway velocity and antero-posterior sway increased. With continued Seiza, VTF decreased to below 30% MVC at 10 - 20 min, and the above stated body sway further markedly increase.

Key words: traditional floor sitting (Seiza), posture, sway factors, tissue oxygenation kinetics, toe flexion strength

INTRODUCTION

In Japan, the traditional floor sitting (Seiza) is frequently used in daily life and keeping the posture is one of enrichment lessons of Japanese origin (like Kendo, Judo, and flower arrangement, etc.). Seiza is a style in which we sit down with both legs set at about a 180 degree angle (Mori, 1982) and lay both femurs on both lower legs, and is one of the main Japanese-style activities of daily living (ADL) (Iwakura et al., 1982; Imai et al., 2001).

A sit-to-stand movement from Seiza and from chair sitting (Ikeda et al., 1991; Jibodh et al., 2004) is often performed in daily life, particularly among the elderly. Their fall accidents after standing up from Seiza are a serious problem. Therefore, kinesiological analyses and electromyographic measurements for the elderly to evaluate knee joint functions during Seiza and a sit-to-stand movement have been conducted in the domain of physiotherapy (Iwaoka et al., 1999; Imai et al., 2001).

Demura et al. (2005) examined the influence of Seiza on balance after standing, and reported that wiggle and quick body sway in the antero-posterior axis increased when standing just after keeping Seiza for 30 min. Femoral arteries delivering oxygen to cells of lower limb tissues reach the anterior and posterior tibial recurrent arteries through the inside of knee joints (popliteal artery). Due to large knee flexion, Seiza has harmful effects not only on the skeletal system but also on the hemodynamics of the lower limbs.

Mori (1982) reported that Seiza occludes blood flow of lower limbs because of compression by the weight of the upper body. Seiza induces blood flow occlusion of the lower legs from starting the posture, reduction of skin temperature, and a rise of the cutaneous perception threshold, i.e. dysesthesia. These physiological changes finally lead to temporal ataxia in the lower limbs (Chiba and Chichibu, 1993).

Sensory receptors existing in deep tissues of the lower limbs perform many important roles in postural control (Fransson et al., 2000). The dysesthesia induced by Seiza may become a significant disturbance factor toward a sit-to-stand movement from Seiza and the following standing posture. Sustaining Seiza makes it impossible to voluntarily contract lower leg muscles (temporal ataxia) (Chiba and Chichibu, 1993) in addition to creating dysesthesia in the lower legs. In this case, the ataxia may be a greater critical disturbance factor than the dysesthesia. This phenomenon is considered to occur in a clinical situation such as arteriosclerotic obliteration as well as in the case of Seiza (Gaskell et al., 1978; Pollak et al., 1976). However, there are few studies on the influence of Seiza on postural control after standing from both the viewpoints of dysesthesia and temporal ataxia. To clarify the timing when the dysesthesia and temporal ataxia by Seiza occur is important for preventing fall accidents after standing.

The purpose of this study was to examine the influence of somatic dysesthesia and decrease in voluntary contraction strength of plantar muscles induced by Seiza on the center of foot pressure (COP) sway.

METHODS

Participants

Fifteen healthy male adults with no extremity disorders (age: 22.0 ± 3.1 yrs, height: 172.4 ± 4.8 cm, body weight: 67.4 ± 5.1 kg) participated in this study. The participants' physical characteristics were almost the same as the age-matched national standard values (Laboratory of Physical Education at Tokyo Metropolitan University, 2000), and they did not have a habit of Japanese traditional floor sitting (Seiza) in daily life. Before the measurements, the purpose and procedures of this study were explained in detail to all participants and informed consent was obtained from them.

Experimental protocol

When continuing a Seiza posture, firstly dysesthesia and secondly ataxia occur in the lower legs with time (Chiba and Chichibu, 1993). Thus, we cannot examine the influence of dysesthesia or ataxia by Seiza on the upright postural control within a period of keeping Seiza. We set two kinds of experimental conditions and measured COP sway; one condition just after occurrence of dysesthesia (condition A) and the other condition just after a decrease of toe flexion strength to less than a specific level (condition B) (Fig. 1-1).

During Seiza (Fig. 1-2), all participants sat with both lower legs under both thighs, and then contacted the floor with the anterior surface of the lower legs and dorsum of both feet, arbitrarily lapping the great toes. Participants sat bolt upright with the upper body weight on the heels through the ischial tuberosity. Both heels were slid close to each other under the buttocks, with the knees spaced about 10 cm apart. Both arms were put on the thighs with the elbow joints loosely bent (Demura et al., 2005).

Participants were instructed to avoid sleeping, intensive exercising, drinking and eating within two hours before this experiment in consideration of their effects on the nervous and circulatory systems. All participants entered the measurement room 30 min before starting the experiment. Temperature and humidity of the measurement room were kept constant (22.0°C and 50%).

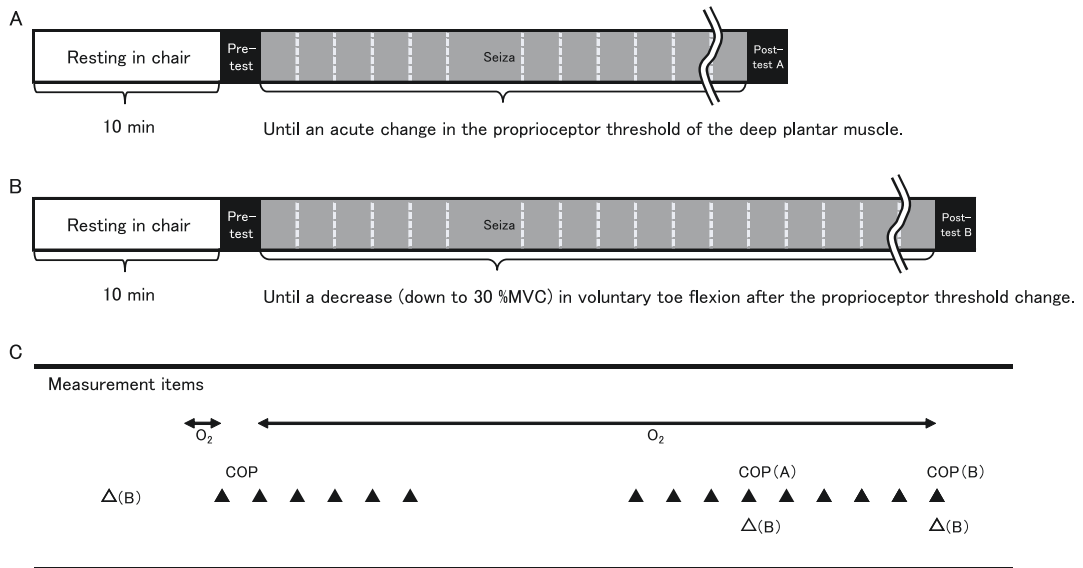


Fig. 1-1. Experimental conditions (A and B) and measurements (C) of each participant

Note 1 COP: center of foot pressure (COP) sway measurements, O_2 : tissue oxygenation kinetics, Δ : the proprioceptor threshold of the deep plantar muscle, \blacktriangle : toe flexion strength

Note 2 The proprioceptor threshold was measured intermittently per 1 min during Seiza.

Note 3 The toe flexion strength was measured at 5 min intervals after an acute change of the proprioceptor threshold during Seiza.



Fig. 1-2. Seiza posture

Measurement device and procedure

(1) Tissue oxygenation kinetics

A near-infrared spectroscopy (NIRS) instrument (NIRO-300TM, Hamamatsu Photonics, Japan) was used. It utilized four wavelengths (775, 813, 850 and 913 nm) with an algorithm based on Lambert-Beer theory to measure the tissue oxygenation change in the lateral soleus. Probes were set on the soleus for tissue oxygenation measurements during Seiza. It is reported that the soleus muscle plays an important role during upright standing postural control (Caron, 2003). NIRS separately measured changes in oxygenated Hb and Mb concentrations and changes in deoxygenated Hb and Mb concentrations (Van Beekvelt et al., 2001; Delpy et al., 1988). The values were quantified with respect to initial control values set equal to zero when a tester confirmed steady values during chair

sitting rest.

The probe unit consists of a photodiode as the light detector (3-point detection) and a laser diode as the light source (the above-stated 4 wavelengths). The probe was attached to the skin with adhesive tapes. The sampling frequency of the NIRS was 1 Hz. The distance between each diode was set at 5 cm. It is hypothesized in NIRO-300TM that the mean light passing length is one half the separation distance between each optode, or 2.5 cm into the tissue.

(2) Proprioceptive perception thresholds

To evaluate the alteration of the proprioceptive threshold in the deep plantar during Seiza, an electrical stimulation with a low frequency therapy device (Demura et al., 2005; Chiba and Chichibu, 1993; Jelasic, 1983; Gibson, 1968) was used. We measured the perception thresholds to muscle movements of proprioceptors in the deep plantar based on the method of limits technique (Helme et al., 2004) by inducing continuous contraction/relaxation of the plantar muscles with pulse waves from the device. A low frequency therapy device (HV-F125, OMRON, Japan) was used to provide electrical stimuli to induce muscle contractions intermittently (Chiba and Chichibu, 1993).

The thresholds were measured just before the pre-test, post-tests A and B, and during Seiza intermittently (at 1 min intervals). Two electrodes of the HV-F125 with a 20 mm center-to-center distance were attached to a participant's right foot sole. Voltage intensity of the stimulation was increased slowly, and the voltage where the participant could perceive the movements of muscle contractions by electrical stimulation was recorded.

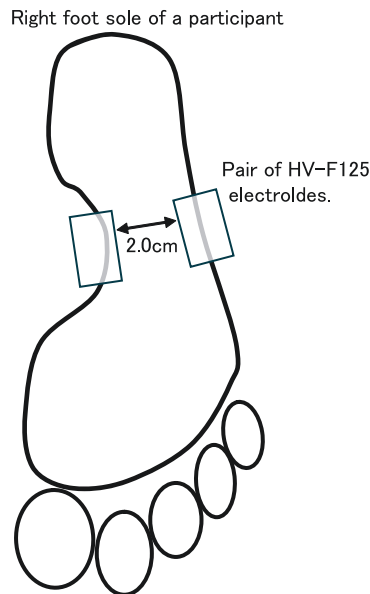


Fig. 1-3. The position of a pair of electrodes for measurements of the proprioceptive threshold

(3) Toe flexion strength

Voluntary toe flexion strength was measured with a digital hand dynamometer with a load-cell sensor (EG-100, SAKAI, Japan) during the resting period and just after an acute change in the proprioceptive threshold in the deep plantar muscle in post-test B at 5 min intervals. A handle of the dynamometer was attached to the toe of each participant's right leg. The participants were told to fix the ankle and maximally flex their toe (Fig. 1-4). We measured the flexion strength three times in the pre-test and used the maximal value of the three measurements for further analysis. In post-test B, we measured it once at each measurement time point until the strength went down to 30% MVC and used all the values obtained.

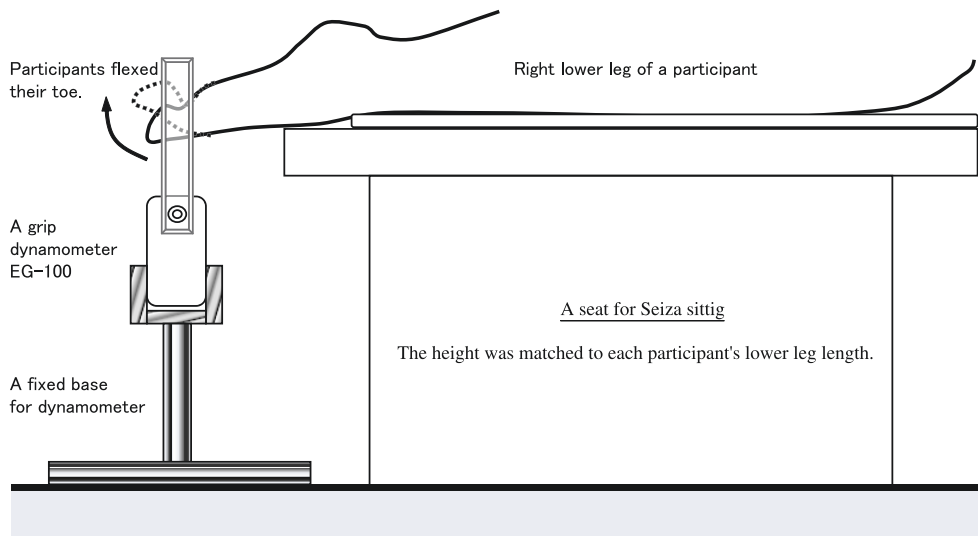


Fig. 1-4. Schematic view of the toe flexion strength measurements

(4) Center of foot pressure (COP)

A stabilometer (G5500, ANIMA, Tokyo, Japan) was used for center of foot pressure (COP) measurements. This instrument could calculate the COP of vertical loads from the values of three vertical load sensors put on the peak of an isosceles triangle on a level surface. COP data was sampled at 20 Hz and recorded in a personal computer. The participants were instructed to maintain the stable posture for one min after standing on a footprint on the stabilometer in Romberg's posture with their eyes gazing at a fixed view point in front of them. For all participants, COP sway was measured twice, at pre-test (the rest time between each trial was 5 min), and once during post-tests A and B.

Parameters

Time when an acute change of deep somatic sensation of plantar muscles (the proprioceptive perception thresholds measured by electrical stimulations) occurred was calculated to quantify changes of proprioceptive sensation of plantar muscles. We defined the acute change time of somatic sensation as the time when the value of the proprioceptive perception threshold measured from the start of Seiza at one min intervals exceeded +2 SD of the threshold values until one min before the latest measurement value. Mean values and standard deviations (SD) of strength of toe flexion measured at 5 min intervals in post-test B were calculated.

To evaluate tissue oxygenation kinetics of antigravity muscles (the soleus muscle) of both lower legs during Seiza, we used the concentration of oxygenated, deoxygenated hemoglobin/myoglobin (Oxy-Hb/Mb, Deoxy-Hb/Mb ($\mu\text{mol/l}$)), and an index of tissue Hb/Mb (relative value of the total Hb/Mb concentration to resting value (%)).

For Oxy-Hb/Mb and Deoxy-Hb/Mb time series, to confirm that the occluding effect of Seiza occurred evenly on both lower legs, inflection points (time at inflection point: min and value at the inflection point: $\mu\text{mol/l}$) were calculated. The influence of Seiza on the center of foot pressure (COP) sway was examined by the following four body sway factors (Kitabayashi et al., 2003); sway velocity factor (F1), antero-posterior sway factor (F2), lateral sway factor (F3), and high frequency band power spectrum factor (F4). Each factor score was calculated using factor score coefficients reported by Kitabayashi et al. (2003). We evaluated the factor scores as follows; the higher each factor score was, the more clearly participants were characterized by the factor.

Statistical analysis

Reliability of the time of acute changes in the perception threshold of proprioceptors and values of voluntary toe flexion strength were examined with the intra-class correlation coefficient (ICC).

To confirm there was no lateral difference in the influence of Seiza on tissue oxygenation kinetics, the similarity between the curves of tissue oxygenation kinetics of both legs was evaluated by the cross-correlation coefficient. Tukey's t-test was conducted to test the mean difference of inflection time and concentration (at the inflection point) of Oxy- and Deoxy-Hb/Mb between both legs.

The inflection points were calculated based on Yamaji et al.'s method (Yamaji et al., 2004; Nakada et al., 2004). Both data were divided into two groups at all combinations and respective regression lines were fitted. Both regression lines were fitted to have the highest determination coefficient. The inflection points were defined as the intersecting point between the former and latter regression lines. We calculated the time and values of tissue oxygenation kinetics at each inflection point.

One-way analysis of variance (ANOVA) was conducted to test the mean difference of 4 sway factors between resting period (pre-test) and both post-tests (A and B). The level of statistical significance was set at $p < 0.05$. According to Bonferroni's method, adjustments were made by the factor number. Tukey's HSD test was used for a multiple comparison if ANOVA indicated a significant main effect.

RESULTS

Table 1 shows reliability (intra-class correlation coefficients: ICC) and results of ANOVA for the time at an acute change of proprioceptive perception thresholds and toe flexion strength during sitting on a chair. Both ICCs were high (0.73, 0.80) and there was no significant difference between conditions or trials.

Fig. 3 shows examples of tissue oxygenation kinetics of both legs measured in both conditions (oxygenated hemoglobin/myoglobin concentration: Oxy-Hb/Mb). It can visually be confirmed that the tissue oxygenation kinetics changed evenly on both lower legs. Cross correlation coefficients of Oxy- and Deoxy-Hb/Mb between both legs were high (0.92 and 0.94 in the condition A, 0.82 and 0.93 in the condition B).

Table 1. Reliability of measurements of the proprioceptor threshold of the deep plantar muscle and toe flexion strength (n=15).

	Mean		SD		ICC	ANOVA	
	F-value	significance					
Time of acute threshold change of the deep plantar muscle (min) in both conditions	19.20	2.64	18.40	2.47	0.73	2.78	ns
Toe flexion strength (kg)	13.40	1.85	13.74	2.08	0.80	1.02	ns

Note 1 ns: $p > 0.05$; SD: standard deviation

Note 2 ICC was calculated between both experimental conditions for the time of acute threshold change of the deep plantar muscle and between trials for toe flexion strength.

Effect of Seiza on the tissue oxygenation kinetics of the lower legs and voluntary toe flexion strength

Table 2 shows the inflection points (inflection time: min, value at the inflection point: $\mu\text{mol/l}$) of tissue oxygenation kinetics in both conditions (A and B). Oxy-Hb/Mb obviously decreased from one min after starting Seiza, and reached a steady state (plateau) about 5 min (4.4 - 5.6 min) later. Inflection times of the left and right legs were 4.4 min and 5.6 min in condition A, and 4.7 min and 5.3 min in condition B. Values in each inflection point were $-48.9\mu\text{mol/l}$ and $-47.6\mu\text{mol/l}$ in condition A, and $-47.7\mu\text{mol/l}$ and $-51.0\mu\text{mol/l}$ in condition B.

Deoxy-Hb/Mb markedly increased from 2 min after starting Seiza, and reached a plateau about

Table 2. Inflection points (time and value) of tissue oxygenation kinetics in the both experimental conditions (A and B) (n=15).

			Left leg		Right leg		t-value
			Mean	SD	Mean	SD	
Condition A	Oxy-Hb/Mb	Inflection time(min)	4.4	1.29	5.6	1.34	-2.09 ns
	Deoxy-Hb/Mb	Inflection time(min)	5.4	1.54	6.0	1.14	-1.36 ns
Condition B	Oxy-Hb/Mb	Inflection time(min)	4.7	1.59	5.3	1.00	-1.50 ns
	Deoxy-Hb/Mb	Inflection time(min)	5.4	1.30	5.8	1.09	-1.54 ns
Condition A	Oxy-Hb/Mb	Value at inflection point($\mu\text{mol/l}$)	-48.9	10.46	-47.6	9.01	-1.17 ns
	Deoxy-Hb/Mb	Value at inflection point($\mu\text{mol/l}$)	39.1	12.17	38.1	13.55	0.14 ns
Condition B	Oxy-Hb/Mb	Value at inflection point($\mu\text{mol/l}$)	-47.7	11.74	-51.0	15.09	0.63 ns
	Deoxy-Hb/Mb	Value at inflection point($\mu\text{mol/l}$)	40.2	13.20	36.5	13.83	0.69 ns

Note 1 ns: $p>0.05$; SD: standard deviation

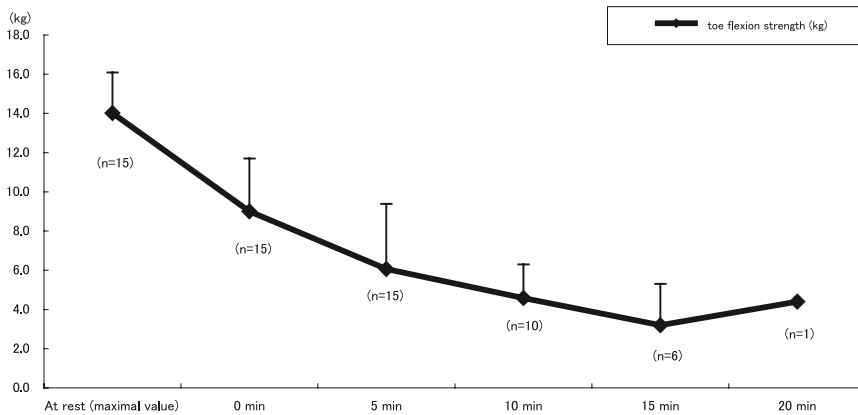


Fig. 2. Time-series change of toe flexion strength (kg) of right leg in the experimental condition B

Note 1 At rest (maximal value): maximal toe flexion strength measured before the pre-test, 0 min: toe flexion strength just after an acute increase in the proprioceptor threshold of the deep plantar muscle, 5 - 20 min: toe flexion strength after 5 to 20 min from the acute change in the proprioceptor threshold of the deep plantar muscle.

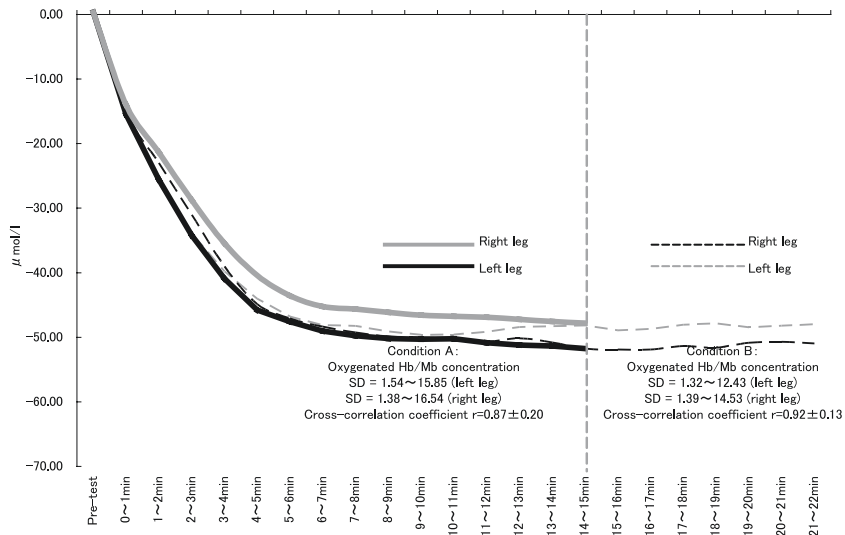


Fig. 3 A sample of tissue oxygenation kinetics (Oxy-Hb/Mb of both legs in the both experimental conditions) (n=15)

Note1 This line was plotted for both conditions according to participants who have the shortest time in producing an acute change of (condition A) or a decrease of toe flexion strength (condition B).

6 min (5.4 - 6.0 min) later. Inflection times of the left and right legs were 5.4 min and 6.1 min in protocol A, and 5.4 min and 5.8 min in protocol B. Values at each inflection point were 39.1 μ mol/l and 38.1 μ mol/l in protocol A, and 40.2 μ mol/l and 36.5 μ mol/l in protocol B. There was no lateral difference between both legs in any parameter.

Fig. 2 shows time-series changes of toe flexion strength (kg) of the right leg in experimental condition B. The maximal strength (14 kg) exerted at the pre-test (resting period) decreases 9 kg (64% MVC) at post-test A, and 6.1 kg (43.2% MVC) at 5min later after post-test A.

Effect of Seiza on the center of foot pressure (COP) sway

Table 3 shows the test results of one-way ANOVA and Tukey's HSD test for body sway factors and effect size (ES) between each test. F1 (sway velocity factor) and F2 (antero-posterior sway factor) showed a significant main effect of Seiza, being higher in the order of the post-tests A and B and the pre-test. A large ES was found in F1 and F2. The largest difference was found between the pre-test and post-test B in F1.

Table 3. Changes in each COP sway factor before (pre-test) and after Seiza (post-tests A and B) (n=10).

	Pre-test		Post-test A		Post-test B		One way ANOVA			Post-Hoc (HSD)		Effect size		
	Mean	SD	Mean	SD	Mean	SD	MS _b	MS _w	F-value			Pre-test	Post-test A	Post-test B
F1	-10.49	4.17	-0.99	7.37	11.49	13.49	1822.9	41.8	43.6 [†]	Pre-test < Post-test A < Post-test B		2.28	5.28	1.15
F2	-6.23	3.65	-0.20	5.13	6.43	10.31	600.8	26.8	22.5 [†]	Pre-test < Post-test A < Post-test B		1.65	3.47	0.81
F3	0.56	3.90	-0.89	4.26	0.33	4.29	9.1	4.2	2.2			0.37	0.06	0.29
F4	-0.18	1.08	-0.19	1.32	0.37	1.64	1.6	1.0	1.6			0.01	0.52	0.38

Note1 [†]: <math>p < \alpha' (=0.05/4)</math>

Note2 F1: sway velocity factor, F2: antero-posterior sway factor, F3: lateral sway factor, F4: high frequency band power spectrum factor

Note3 Pre-test : COP sway measurements after standing from resting on a chair

Post-test A: COP sway measurements just after an acute increase in the proprioceptor threshold of the deep plantar muscle by Seiza.

Post-test B: COP sway measurements just after a decrease (down to 30% of maximal voluntary contraction in the resting period) in voluntary toe flexion.

DISCUSSION

It has been reported that occlusion of blood flow to the lower legs induced by the traditional floor sitting (Seiza) markedly affects postural control after standing (Demura et al., 2005). It induces a rise of the cutaneous perception threshold, i.e. dysesthesia, and these physiological changes finally lead to temporal ataxia in lower limbs (Chiba and Chichibu, 1993). However, it has not been revealed when the dysesthesia and temporal ataxia occur, and their effects on postural control after standing from Seiza remain unclarified. In this study, we measured both of the factors (dysesthesia and decrease in voluntary toe flexion strength) that were considered to markedly affect postural control and the center of foot pressure (COP) sway during standing just after their occurrences.

Reliability of the time of acute changes in the perception threshold of proprioceptors and values of voluntary toe flexion strength were high (ICC = 0.73, 0.80) and there was no significant difference between conditions or trials (Table 1). There was no lateral difference in the inflection points of the tissue oxygenation kinetics (time: min and value: μ mol/l) between both legs (Table 2). The cross correlation coefficients of oxygenated and deoxygenated hemoglobin/myoglobin concentration (Oxy- and Deoxy-Hb/Mb) were very high ($r = 0.87 - 0.94$).

Therefore, it is inferred that Seiza affected both legs evenly. In addition, Fig. 3 suggests that condition B was measured on the extension of condition A.

Effect of Seiza on the tissue oxygenation kinetics of lower legs and voluntary toe flexion strength

Tissue oxygenation kinetics of antigravity muscles (lateral soleus) of both lower legs showed marked changes in the kinetics just after starting Seiza. This indicates a definite effect of Seiza on hemodynamics in lower limbs (Fig. 3). A decrease in oxygenated (Oxy-Hb/Mb) and an increase in deoxygenated (Deoxy-Hb/Mb) hemoglobin/myoglobin concentrations reached a plateau within about 6 min after starting Seiza (Oxy-Hb/Mb: 4.4 - 5.6 min, Deoxy-Hb/Mb: 5.4 - 6.0 min) (Table 2), and a

steady state was kept until the end of the Seiza.

In contrast, the tissue Hb/Mb index changed little. Although the total blood volume in both lower legs changed little, the blood supply to metabolic demand might be disturbed. It is inferred that the arteriovenous blood flow of lower legs was occluded just after starting Seiza and the blood stasis was maintained during Seiza. Considering that the tissue Hb/Mb index changed little as stated above, the plateau state of tissue oxygenation kinetics that occurred during Seiza is considered to have been an equilibrium state between reduced oxygen supply by pressing the lower legs and metabolic demands.

When occluding the upper arm with a cuff, venous return can be occluded with a cuff pressure equal to the diastolic blood pressure, and arterial blood flow can be occluded with a higher cuff pressure than the systolic blood pressure (Iwanaga et al., 1993). In this study, a pressure higher than the systolic blood pressure (age-matched national standard value: 124.7 mmHg) (Laboratory of Physical Education at Tokyo Metropolitan University, 2000) might be imposed on the participants' legs by Seiza.

The acute changes of the perception threshold of proprioceptors induced by Seiza occurred at about 19 min (condition A: 19.2 min, condition B: 18.4 min) after starting Seiza, following the changes of tissue oxygenation kinetics (Table 2). Because their perception changes occurred after 14 min from reaching plateaus of Oxy- and Deoxy-Hb/Mb, an oxygen deficiency for 14 min may have affected proprioceptive perception of plantar muscles.

According to Kopell and Thompson (1963), the same symptom as entrapment neuropathy occurs with temporal compression of the body. There are the compression theory (Castaldo and Ochoa, 1984) and the occlusion theory (Sunderland, 1990) as indicating the main causes of entrapment neuropathy. Although we cannot assert the causes because the blood flow and the effect of mechanical stimulus to the peripheral nervous system were not measured in this study, the temporal compression of both lower legs by Seiza may produce the nerve pressure in addition to the above-stated occlusion effect.

Important sensory receptors for maintaining an upright posture such as muscle or neurotendinous spindles of the sole may not work normally when maintaining Seiza for a long time (e.g. over about 19 min). There are receptors for important postural reflexes such as positive supporting reactions in the phalanges of the feet and the plantar. Seiza is considered to affect them and, as a result, the postural control system as well.

The voluntary toe flexion strength decreased to 9 kg (equal to 64.3%MVC) at the time of acute changes in the perception threshold of proprioceptors (post-test A), and the strength in 5 of 15 participants decreased to below 30% MVC after 10 min of the acute changes. The strength in 9 participants decreased after 15 min (Fig. 2). It is inferred that the decrease in voluntary toe flexion strength has resulted from physical pressure against the lower limbs and the blocked blood flow induced by Seiza. However, it is inferred that selective type II recruitment was mainly used and anaerobic energy was supplied because all participants exerted strength maximally during Seiza in this study. The decrease of toe flexing strength may depend on causes different from those related to the energy metabolism systems.

Effect of Seiza on the center of foot pressure (COP) sway

Sway factors F1 (sway velocity factor) and F2 (antero-posterior sway factor) were higher when an acute change of proprioceptive perception threshold occurred as compared with the level before Seiza, and they became higher when the toe flexion strength decreased (Table 3). In our previous report (Demura et al., 2005), they significantly increased after keeping Seiza for 30 min. Sway factors (F1 and F2) are considered to be largely influenced by Seiza.

The present results showed that oxygen concentration (Oxy-Hb/Mb) in the lateral soleus decreased by Seiza, and paresthesia occurred in the sole situated distal to that muscle, with voluntary toe flexion strength decreased. The temporal compression of the lower legs by Seiza extensively influences the lower limbs. The large changes of sway velocity and antero-posterior sway may result

from disturbed postural control around the ankles (ankle strategy) (Horak et al., 1989). Fransson et al. (2003) conducted an experiment to disturb the lower leg proprioceptors (muscle, neurotendinous spindles) by giving a vibratory stimulus to the calves. They confirmed that body sway in the antero-posterior axis increased similarly to that in the present study.

The elderly have inferior equilibrium because of decreased leg strength (Demura and Sato, 2000). Locomotion and maintenance of an upright posture are indispensable in activities of daily living. If some sensory system of the lower limbs is disturbed by Seiza, it may lead to fall accidents due to body instability when standing from a prolonged period of Seiza.

Mori (1982) reported that customary Seiza induces bone deformity (Mori, 1982). Frequently repeating Seiza is considered to have a large influence on physical anatomical structures. This study used participants without a Seiza habit, but different results may be obtained when using participants with a Seiza habit because they can sustain Seiza for long periods. Further study will be needed.

CONCLUSION

In conclusion, the traditional floor sitting (Seiza) blocks arterial inflow to the lower legs and venous return, and results in an oxygen deficiency in antigravity muscles of the lower legs. Following Seiza for 19 min or longer, proprioceptive perception thresholds begin to increase and influence the center of foot pressure (COP) sway such as sway velocity (F1) and antero-posterior sway (F2) after standing. When a participant further maintains Seiza, a decrease of voluntary toe flexion strength progresses. If it reaches a level below 30% MVC, sway velocity and antero-posterior sway increase further.

REFERENCES

- Caron, O (2003) Effects of local fatigue of the lower limbs on postural control and postural stability in standing posture. *Neurosci. Lett.*, **340**: 83-86.
- Castaldo, JE, and Ochoa, JL (1984) Mechanical injury of peripheral nerves. Fine structure and dysfunction. *Clin. Plast. Surg.*, **11**: 9-16.
- Chandhok, PS, and Bagust, J (2002) Differences between the cutaneous two-point discrimination thresholds of chiropractic students at different stages in a 5-year course. *J. Manipulative Physiol. Ther.*, **25**: 521-525.
- Chiba, A, and Chichibu, S (1993) The relation between cutaneous paresthesia and skin temperature due to sitting Japanese style. *Acta. Med. Kinki Univ.*, **18**: 123-127.
- Delpy, DT, Cope, M, van, der, Zee, P, Arridge, S, Wray, S, and Wyatt, J (1988) Estimation of optical pathlength through tissue from direct time of flight measurement. *Phys. Med. Biol.*, **33**: 1433-1442.
- Demura, S, and Uchiyama, M (2005) Effect of Japanese sitting style (Seiza) on the center of foot pressure after standing. *J. Physiol. Anthropol. Appl. Human Sci.*, **24**: 167-173.
- Demura, S, Yamaji, S, Noda, M, Kitabayashi, T, and Nagasawa, Y (2001) Examination of parameters evaluating the center of foot pressure in static standing posture from the viewpoints of trial-to-trial reliability and interrelationships among parameters. *Equilibrium Res.*, **60**: 44-55.
- Demura, S, and Sato, S (2000) Characteristics of muscular function in older people. *Japanese Journal of Physiological Anthropology*, **5**(2): 5-10.
- Fransson, PA, Johansson, R, Hafström, A, and Magnusson, M (2000) Methods for evaluation of postural control adaptation. *Gait Posture*, **12**:14-24.
- Gaskell, P, and Parrott, JC (1978) The effect of a mechanical venous pump on the circulation of the feet in the presence of arterial obstruction. *Surg. Gynecol Obstet.*, **146**: 583-592.
- Gibson, RH (1968) Electrical stimulation of pain and touch. In: Kenshalo DR., ed. *The Skin Senses*, Springfield: CC Thomas IU: 223-261.
- Helme, RD, Meliala, A, and Gibson, SJ (2004) Methodologic factors which contribute to variations in experimental pain. *Neuroscience Letters*, **361**: 144-146.
- Horak, FB, Shupert, CL, and Mirka, A (1989) Components of postural dyscontrol in the elderly: a review. *Neurobiology of Aging*, **10**: 727-738.
- Ikedo, ER, Schenkman, ML, Riley, PO, and Hodge, WA (1991) Influence of age on dynamics of rising from chair. *Phys. Ther.*, **71**: 473-481.

- Imai, K, Yanami, M, Shouji, J, Ohya, T, Takeda, T, Uesako, M, and Endou, T (2001) Effect of home exercise on the gonarthrosis patients. *J. Phys. therapy*, **15**: 30-34. (in Japanese)
- Iwakura, H, Yoshida, K, Itoh, H, Iwasaki, T, Tanaka, S, and Yamada, M (1982) The role of knee joint muscles in Japanese sitting activity. *Orthop. surg. Traumatol.*, **25**: 1917-1923. (in Japanese)
- Iwanaga, K, Sakurai, M, Minami, T, and Kikuchi, Y (1993) Effect of restricted blood flow on intracellular pH threshold of working muscle. *Ann. Physiol. Anthropol.*, **12**: 181-188.
- Iwaoka, K, Hattori, N, Yasue, T, and Nakamura K (1999) Characteristics of rising from a chair in fit elderly women. *Rep. Res. Cent. Phys. Ed.*, **28**: 71-76.
- Jelasic, F (1983) Quantitative assessment of skin sensitivity. *Dtsch. Med. Wochenschr.*, **108**: 419-421.
- Jibodh, SR, Gurkan, I, and Wenz, JF (2004) In-hospital outcome and resource use in hip arthroplasty: influence of body mass. *Orthopedics*, **27**: 594-601.
- Kitabayashi, T, Demura, S, Yamaji, S, Nakada, M, Noda, M, and Imaoka K (2002) Gender differences and relationships between physic and parameters evaluating the body center of pressure in static standing posture. *Equilibrium Res.*, **61**: 56-62.
- Kitabayashi, T, Demura, S, and Noda, M (2003) Examination of the factor structure of center of foot pressure movement and cross-validity. *J. Physiol. Anthropol. Appl. Human Sci.*, **22**: 265-272.
- Kopell, HP, Thompson, WA, Postel, AH (1962) Entrapment neuropathy of the ilioinguinal nerve. *N. Engl. J. Med.*, **266**: 16-19.
- Korotkov, A, Radovanovic, S, Ljubisavljevic, M, Lyskov, E, Kataeva, G, Roudas, M, Pakhomov, S, Thunberg, J, Medvedev, S, and Johansson H (2005) Comparison of brain activation after sustained non-fatiguing and fatiguing muscle contraction: a positron emission tomography study. *Exp. Brain Res.*, **163**: 65-74. Epub. 2005 Jan 12
- Laboratory of Physical Education, Tokyo Metropolitan University (2000) *New Physical fitness standards of Japanese people*, 5th edition. Fumaido, Tokyo: pp. 98-101.
- Mori, Y (1982) Upright setting and knee joint. *Orthop. surg. Traumatol.* **25**: 1912-1916 (in Japanese)
- Nakada, M, Demura, S, Yamaji, S, Minami, M, Kitabayashi, T, and Nagasawa Y (2004) Relationships between force curves and muscle oxygenation kinetics during repeated handgrip. *J. Physiol. Anthropol. Appl. Human Sci.*, **23**: 191-196.
- Pollak, EW, Chavis, P, and Wolfman, EF (1976) The effect of postural changes upon the ankle arterial perfusion pressure.
- Sunderland, S. (1990) The anatomy and physiology of nerve injury. *Muscle Nerve*, **13**: 771-784.
- Weist, R, Eils, E, and Rosenbaum, D (2004) The influence of muscle fatigue on electromyogram and plantar pressure patterns as an explanation for the incidence of metatarsal stress fractures. *Am. J. Sports Med.*, **32**: 1893-1898.
- Yamaji, S, Demura, S, Nagasawa, Y, and Nakada, M (2004) Relationships between decreasing force and muscle oxygenation kinetics during sustained static gripping. *J. Physiol. Anthropol. Appl. Human Sci.*, **23**: 41-74.
- Van, Beekvelt, MC, Collier, WN, Wevers, RA, and Van Engelen, BG (2001) Performance of near-infrared spectroscopy in measuring local O₂ consumption and blood flow in skeletal muscle. *J. Appl. Physiol.*, **90**: 511-519.