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Effect of Japanese Sitting Style (Seiza) on the Center of Foot Pressure after Standing

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Abstract Seiza is one of the most commonly used sitting postures in various enrichment lessons of Japanese origin. It is reported that Seiza with large knee flexion produces harmful effects on the cartilage of knee joints and hemodynamics of the lower legs. This study aimed at examining the influence of Seiza on tissue oxygenation kinetics of the lower limbs, plantar somatic and cutaneous sensation, and the center of foot pressure (COP) sway using 10 young adults. COP sway was measured for 1 min just after sitting on a chair for 10 min (pre-test), after 30-min Seiza (post-test 1), and 5 min after Seiza (post-test 2). To evaluate the COP sway, we used 4 body sway factors; unit time sway factor (F1), front-back sway factor (F2), left-right sway factor (F3) and high frequency band power spectrum factor (F4). Physiological parameters (i.e., tissue oxygenation kinetics in the lower legs and sensation on the sole) were measured during 30-min Seiza (continuously on tissue oxygenation, and at 1 min intervals on sensation), and for 1 min just before each COP test (pre-test, post-test 1 and 2).

Oxygenated hemoglobin/myoglobin (Hb/Mb) concentration decreased markedly and deoxygenated Hb/Mb concentration increased markedly, resulting in reaching a plateau state at around 7 min. Tissue Hb/Mb index changed little during Seiza. Proprioceptive perception thresholds increased rapidly about 17 min after Starting Seiza. Means of 3 COP sway factors of F1, F2 and F4 were significantly higher in post-test 1 than in pre-test and post-test 2. In conclusion, a marked decrease in tissue oxygen concentration of the lower legs within 4–5 min, and an increase of proprioceptive perception thresholds in the sole at about 17 min are induced by Seiza. Although wiggle and quick body sway in the antero-posterior axis increases markedly in an upright posture just after maintaining Seiza for 30 min, sway recovers after sitting on a chair for 5 min. *J Physiol Anthropol Appl Human Sci 24 (2): 167–173, 2005*
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Introduction

Japanese people have a lifestyle habit of sitting directly on the floor like Seiza (sitting straight) and Agura (sitting cross-legged) as endemic sitting styles. The former is a sitting style in which both legs set at about a 180 degree angle (Mori, 1982) and lay both femurs on both lower legs. The “Seiza” sitting style is frequently used in daily life and enrichment lessons of Japanese origin (like Kendo, Judo, and flower arrangement, etc.). Namely, it is one of the main Japanese-style activities of daily living (ADL) (Iwakura et al., 1982; Imai et al., 2001). Because a sit to stand movement from Seiza and a chair (Ikeda et al., 1991; Jibodh et al., 2004) or supine position (Jibodh et al., 2004) is often repeated in daily life, kinesiological analyses and electromyography measurement are conducted in the domain of physiotherapy (Iwaoka et al., 1999; Imai et al., 2001).

Femoral arteries delivering oxygen to cells of lower limbs tissue reach the anterior and posterior tibial recurrent arteries through the inside of knee joints (popliteal artery). It is reported that due to large knee flexion, Seiza has harmful effects on not only the skeletal system but also the hemodynamics of lower limbs. For example, Mori (1982) reported that Seiza occludes blood flows of lower limbs because of compression by the weight of the upper body. Nagasue (1994) also reported that repeated Seiza in daily life could be a cause of popliteal arterial constriction or obstruction.

Furthermore, Seiza induces blood flow occlusion of the lower legs from the start, reduction of skin temperature, and 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). Sensory receptors existing in superficial and deep tissues of the lower limbs perform many important roles in postural control (Fransson et al., 2000). Thus, the dysesthesia induced by sitting in Seiza may become a disturbance factor toward a sit to stand movement from Seiza and the following standing posture.

However, there are few studies on the effect of Seiza on postural control and plantar sensation after standing. The purpose of this study was to examine the influence of Seiza on the tissue oxygenation kinetics of lower limbs, plantar somatic and cutaneous sensation, and center of foot pressure (COP) sway.

Methods

Subjects

Ten healthy male adults with no extremity disorder (age: 21.2±3.54 yrs, height: 171.9±4.64 cm, body weight: 71.43±15.4 kg) participated in this study. The subject's physical characteristics were almost the same as the age-matched national standard value (Lab Physical Edu in Tokyo Met Univ, 2000), and they did not have a special habit of sitting in Japanese style (Seiza) in daily life. Before the measurements, the purpose and procedure of this study were explained in detail to all subjects and informed consent was obtained from them.

Experimental protocol

To examine the influence of Seiza on COP, COP sway was measured just after resting in a chair for 10 min (pre-test), after 30-min of Seiza (post-test 1), and 5 min after Seiza (post-test 2) (See Fig. 1-1). Each subject was asked to stand at the same place by marking the feet position in each test.

Physiological variables (tissue oxygenation kinetics, deep and superficial plantar sensations) were measured during 30-min of Seiza and for 1 min just before each test. Duration of Seiza and sitting-on-chair position in post-test 1 and 2 were decided through some pilot studies that were conducted to confirm the kinematics of each physiological variable.

During Seiza, all subjects 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. Subjects sat bolt upright with the upper body weight on the heels through the ischial tuberosity. Both heels were slid closer 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 (See Fig. 1-2).

Subjects were instructed to avoid sleeping, intensive exercising, drinking and eating within 2 hours before this experiment in consideration of their effects on the nervous and circulatory systems. All subjects entered the measurement room 30 min before the experiment started. Temperature and humidity of the measurement room were kept constant (22.0 degrees and 50%).

Measurement device and procedure

Tissue oxygenation kinetics

A NIRS instrument manufactured by Hamamatsu Photonics, Japan (NIRO-300TM) was used in this study. It uses 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 (Van Beekvelt et al.,

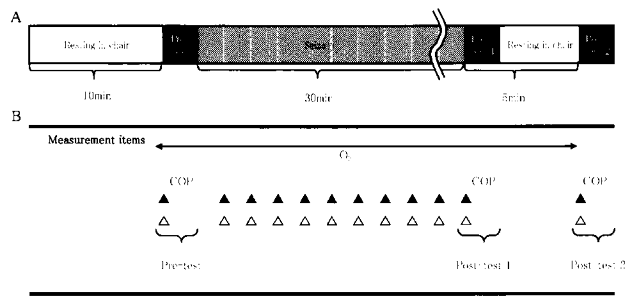

Fig. 1-1 Experimental protocol (A) and measurement items (B).
Note 1) COP: center of foot pressure, O2: tissue oxygenation kinetics, ▲: proprioceptive perception thresholds, △: two-point discrimination thresholds
Note 2) Thresholds of ▲ and △ were measured every 1 min during Seiza.

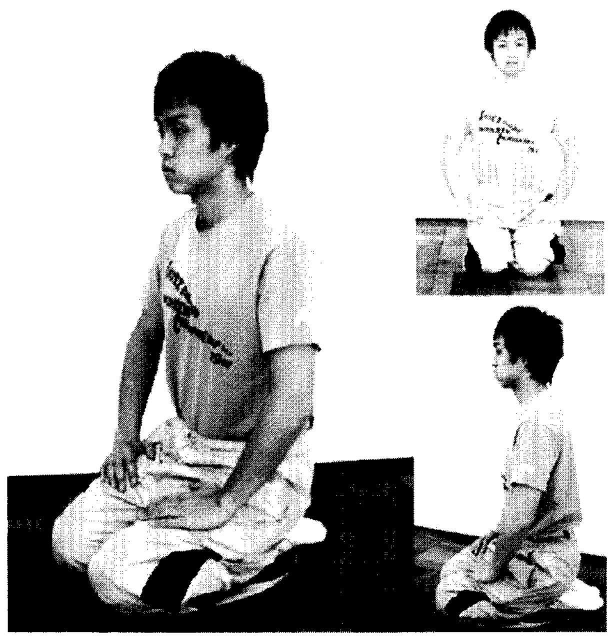

Fig. 1-2 Japanese sitting style (Seiza).

2001; Delpy et al., 1988), and separately measures changes in oxygenated Mb and Hb concentrations and changes in deoxygenated Mb and Hb 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 the experimenter confirmed steady values during sitting on a chair. 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 tape. 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 half of the separation distance between each optode, or 2.5 cm into the tissue.

Proprioceptive perception thresholds

To evaluate the alteration of the proprioceptor threshold in deep plantar during Seiza, an electrical stimulation with a low frequency therapy device (Chiba and Chichibu, 1993; Jelasic, 1983; Gibson, 1968) was used. In this study, we measured the perception thresholds to muscle movements of proprioceptors in deep plantar based on the method of limits technique (Helme et al., 2004) by inducing continuous contraction/relaxation of the plantar muscles (i.e., flexor digitorum longus muscle and flexor hallucis longus muscle) with pulse waves of the device. A medical use low frequency therapy device HV-F125 (OMRON, Japan) was used to provide electrical stimulus to induce muscle contractions intermittently (Chiba and Chichibu, 1993).

An experimenter attached two electrodes of the HV-F125 with a 20 mm center-to-center distance to a subject's right foot sole. Voltage intensity of the stimulation was increased slowly, and the voltage where the subject could perceive the movements of muscle contractions by electrical stimulation was recorded. These thresholds were measured every 1 min during Seiza.

Two-point discrimination thresholds

A two-point discrimination threshold in the right foot sole for all subjects was measured to examine the perceived level of superficial sensation. The two-point threshold value (cm) at rest was used as a reference, and two points of the discrimination status of a subject were recorded every 1 min during Seiza.

Center of foot pressure (COP)

A stabilometer G5500 (ANIMA, Tokyo, Japan) was used for COP measurement. This instrument can calculate the COP of vertical loads from the values of three vertical load sensors that are 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 subjects were instructed to maintain the stable posture for 1 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. All subjects were measured for COP sway twice at pre-test (the rest time between each trial was 5 min), and once at post-test 1 and 2, respectively.

Parameters

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 (μmol/l)), and an index of tissue Hb/Mb (relative value of the total Hb/Mb concentration to resting value (%)).

The perception threshold of proprioceptors in plantar muscles was evaluated by the perception threshold for electrical stimulation. For the cutaneous sensation, percentages were calculated for subjects who could not discriminate between two points.

The influence of Seiza on COP sway was examined by the following 4 body sway factors (Kitabayashi et al., 2003) extracted from 32 parameters (Demura et al., 2001; Kitabayahsi et al., 2002) (See table 1). The factors were unit time sway factor (F1), front-back sway factor (F2), left-right 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).

Statistical analysis

The similarity between the curves of tissue oxygenation kinetics of both legs was evaluated by the cross-correlation coefficient. Inflection points were calculated for the time series of Oxy-Hb/Mb, Deoxy-Hb/Mb, and the perception threshold of proprioceptors in plantar muscles during Seiza. Each time series data was divided into two groups at all combinations and respective regression lines were calculated. Both regression lines were fitted to have the highest determination coefficient. The inflection points were defined as the time corresponding to the boundary point between the former and latter regression lines.

One-way ANOVA was used to test the mean difference of 4 sway factors between pre- and post-Seiza. The level of statistical significance (α) was set at $p<0.05$. According to Bonferroni's method, α was adjusted by the factor number. Tukey's HSD test was used for a multiple comparison test if ANOVA indicated a significant difference.

Results

1. The effect of Seiza on tissue oxygenation kinetics of lower limbs, plantar somatic and cutaneous sensation

Fig. 2-1 shows a mean graph of tissue oxygenation and cross correlation coefficients of the mean data between both legs. Oxygenated hemoglobin/myoglobin concentration (Oxy-Hb/Mb) obviously decreased at 1 min after starting Seiza, and reached a steady state (plateau) about 5 min later (left leg: 4.41±2.67 min, right leg: 4.83±1.90 min) (See table 2). Deoxygenated Hb/Mb concentration (Deoxy-Hb/Mb) markedly increased at 2 min after starting Seiza, and reached a plateau (left leg: 6.74±2.67 min elapsed, right leg: 4.83±1.90 min elapsed) (Table 2). The cross-correlation coefficients

Table 1 Four COP factors

	Factors	COP parameters
F1	Unit time sway factor	No.16, 36, 1, 9, 14, 34, 10, 15, 33, 35
F2	Front-back sway factor	No.8, 4, 29, 13, 31, 2, 21, 12, 11
F3	Left-Right sway factor	No.17, 3, 7, 23, 32, 30
F4	High frequency band power spectrum factor	No.28, 24, 26, 18, 27, 22, 20

Note 1) COP parameters represent each factor (F1–F4).

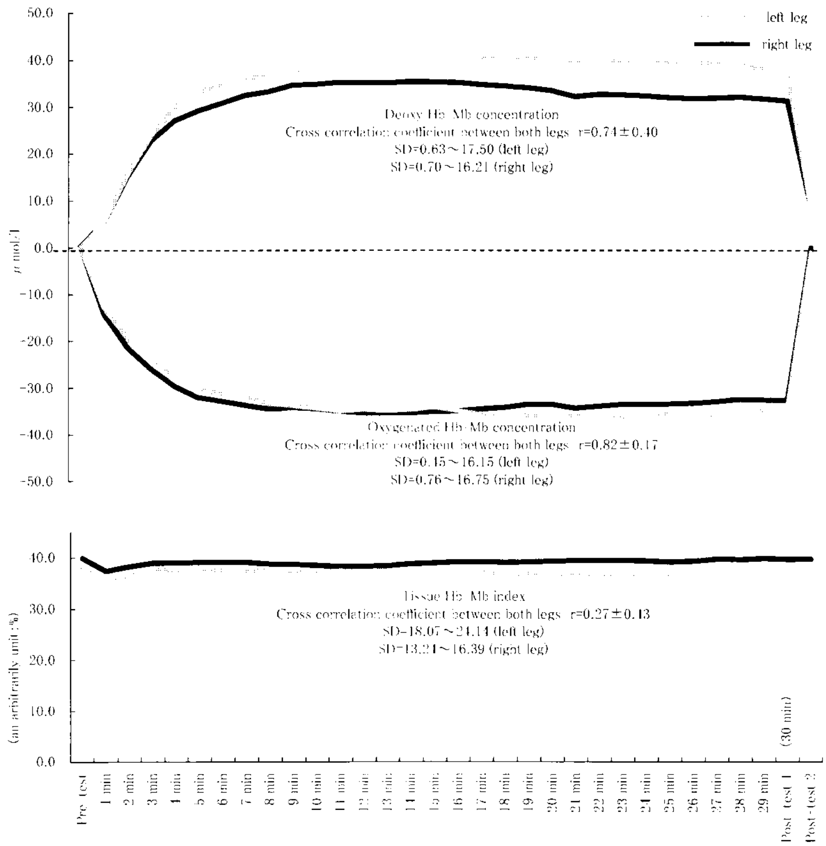

Fig. 2-1 Tissue oxygenation kinetics in both legs before (pre-test) during, and after Seiza (post-test1, 2).

Table 2 Inflection points in each physiological parameter (n=10)

		Time	Value
		Mean SD	Mean SD
Oxygenated Hb/Mb concentration	(left leg)	4.41±2.67	−35.72±14.40
	(right leg)	4.83±1.90	−33.25±10.93
Deoxygenated Hb/Mb concentration	(left leg)	6.45±2.74	36.85±12.85
	(right leg)	5.10±1.66	38.65±9.78
Proprioceptive perception thresholds	(Right sole)	16.33±5.19	6.97±1.48

Note 1) Unit: Time (minute: minutes elapsed from starting Seiza start), oxygenated and deoxygenated Hb/Mb concentration (μmol/l), proprioceptive perception thresholds (V)

Note 2) Inflection points of proprioceptive perception thresholds are culculated except data of upper limit of a measurement device.

between both legs were very high for both parameters (0.82 in the Oxy-Hb/Mb, and 0.74 in the Deoxy-Hb/Mb). No effect of Seiza was found on the tissue Hb/Mb index, with a low coefficient of 0.27.

Fig. 2-2 shows changes of percentages of subjects who could not discriminate between two points and the proprioceptive perception thresholds. The former maintained 0% for the first 12 min, and then rapidly increased around 13 min and reached 100% at about 20 min. The latter rapidly increased around 17 min (Table 2) after the former rapidly increased.

2. The effect of Seiza on COP sway

Table 3 shows the test results of one-way ANOVA and Tukey's HSD test for body sway factors. All factors increased markedly just after 30-min Seiza (post-test 1) and returned to the resting level 5 min after Seiza (post-test 2). Significant differences between pre- and post-Seiza were found in the unit

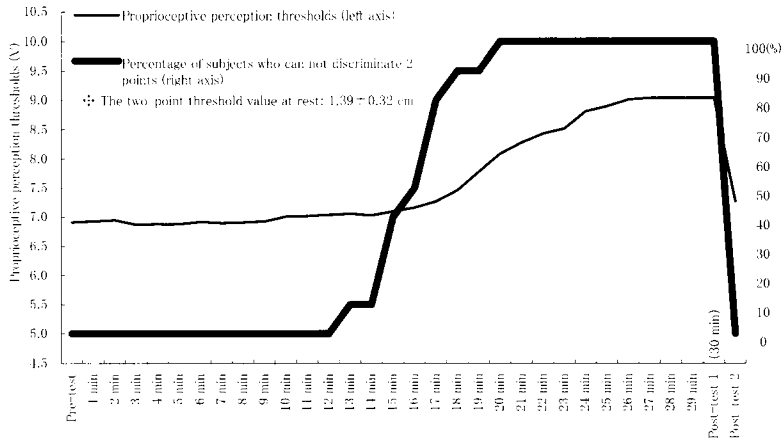

Fig. 2-2 Proprioceptive perception thresholds and percentages of subjects who can not discriminate 2 points in right leg before Seiza (pre-test), during and after Seiza (post-test 1 and 2).
Note1) Proprioceptive perception thresholds (V): vales in table 2×8.0=true measured value (V)

Table 3 Changes in each COP sway factor before and after Seiza (n=10)

	Pre-test		Post-test 1		Post-test 2		One way ANOVA			Post-Hoc, HSD
	Mean	SD	Mean	SD	Mean	SD	MS_b	MS_w	F-value	
F1	−7.89	3.59	12.71	14.87	−4.81	5.98	1234.41	75.81	16.28†	Pre, Post-test 2<Post-test 1
F2	−4.74	4.36	7.31	8.80	−2.57	5.54	413.11	30.63	13.49†	Pre, Post-test 2<Post-test 1
F3	−1.52	2.72	2.06	4.22	−0.54	3.06	34.22	10.97	3.12	
F4	−0.99	0.77	1.09	1.39	−0.10	0.81	10.87	1.09	9.95†	Pre, Post-test 2<Post-test 1

Note 1) †: $p<\alpha'$ (=0.05/4), Pre-test: a measurement just before Seiza, Post-test 1: 30 min after starting Seiza, Post-test 2: 5 min after 30-min Seiza
Note 2) Factor names from F1 to F4 are the same as table 1.

time sway factor (F1), front-back sway factor (F2), and high frequency band power spectrum factor (F4). They were lower in pre-tests and post-test 2 than in post-test 1.

Discussion

1. The effect of Seiza on tissue oxygenation kinetics of lower limbs

As shown in Fig. 2-1, tissue oxygenation kinetics of antigravity muscles (lateral soleus) of both lower legs shows the effect of Seiza with marked changes in the kinetics from starting Seiza. Oxygenated (Oxy-Hb/Mb) and deoxygenated (Deoxy-Hb/Mb) hemoglobin/myoglobin concentrations reached a plateau around 7 min from starting Seiza and kept steady until 30 min. In contrast, the tissue Hb/Mb index changed little (Fig. 2-1 below). Although the total blood volume in both lower legs changed little, the blood supply for metabolic demands might be disturbed. It is inferred that the arteriovenous blood flows of lower legs were occluded just after starting Seiza and the blood stasis was maintained during Seiza. The plateau state of tissue oxygenation kinetics occurred during Seiza is considered as an equilibrium state between reduced blood supply of arterial and metabolic demands.

When occluding an 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 cuff pressure higher 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) (Lab Physical Edu in Tokyo Met Univ, 2000) may be imposed on both of the subjects' legs by Seiza.

However, large individual differences were found in the oxygenation kinetics during Seiza. The blocked blood flow by Seiza occurs from compression of the upper body weight and large knee flexion. Although we strictly controlled the Seiza posture, there are plural factors such as upper body weight (Chiba and Chichibu, 1993), the lower limb skeleton and anatomical characteristics of blood vessel system related to the large individual differences of the oxygenation kinetics.

Moreover, it is inferred that the Seiza position distributes the occluding effects evenly on both lower legs from the high relationships (r=0.74–0.82) of tissue oxygenation kinetics.

2. The effect of Seiza on plantar somatic and cutaneous sensation

Changes in two-point discrimination and proprioceptive perception thresholds in deep plantar induced by Seiza occurred later than those in tissue oxygenation kinetics (Fig. 2-1, 2). Because an inflection point of proprioceptive perception thresholds occurred at about 10 min after reaching a plateau of Oxy- and Deoxy-Hb/Mb, an oxygen deficiency for 10 min may affect proprioceptive perception in deep plantar.

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 the main cause 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 when sitting in 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 posture for a long time (e.g., over 17 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, affect also the postural control system.

3. The effect of Seiza on COP sway

Body sway factors of unit time sway (F1), front-back sway (F2), and high frequency band power spectrum (F4) changed more significantly after 30-min Seiza than after the resting period, and they all returned to a resting level after sitting on a chair 5 min after Seiza (table 3). These sway factors may be largely influenced by Seiza.

The present results showed that oxygen concentration (Oxy-Hb/Mb) decreases in the lateral soleus by Seiza, and paresthesia occurs in the sole situated distal to that muscle. The temporal compression of the lower legs by Seiza extensively influences the lower limbs. The large changes of COP sway factors (F1, F2 and F4) may result from disturbed postural control around the ankle (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 sway in the antero-posterior axis increases similarly to that in the present study.

We cannot definitely state from the present results to what extent duration of Seiza influences postural control. A further study needs to be conducted to examine the corresponding relationships between sensory paralysis by Seiza and changing timing of sway factors. The elderly are inferior in equilibrium because of decreased leg strength (Demura and Sato, 2000). Locomotion and maintenance of upright posture are indispensable movements in activities of daily living. If some sensory systems related to those movements are disturbed by Seiza, it will lead to fall accidents.

Conclusion

Seiza blocks arterial inflow to lower legs and venous return, and results in an oxygen deficiency in antigravity muscles of the lower legs. After sitting in Seiza for over 17 min, proprioceptive perception thresholds begin to increase, and 30-min Seiza position influences COP sway, such as unit time sway, antero-posterior sway and the high frequency band power spectrum after standing. However, the above large sway induced by Seiza returns to a resting level after sitting on a chair for 5 min.

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