The Influence of Time of Day on Static and Dynamic Postural Control in Normal Adults

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Abstract. [Purpose] We attempted to determine whether static and dynamic postural control ability fluctuated depending on the influence of the time of day (9 am, 1 pm, and 5 pm), and at which time point postural balance performance was best in healthy individuals. [Subjects and Methods] Twenty-four healthy subjects participated in this study. The static and dynamic postural balance test was conducted during three sessions (i.e., at 9 am, 1 pm, and 5 pm) with a counterbalanced order for prevention of learning effects. As outcome measurements, AP distance, ML distance, and velocity moment were adopted in the static balance test, and the performance time and total distance were measured in the dynamic balance test. [Results] For the static postural balance test, COP distance was shorter and COP velocity was slower at 9 am compared with those at 1 and 5 pm. In particular, the COP distance at 9 am was statistically different from that at 13 pm. During the dynamic postural balance test, performance time and total distance were influenced by the time of day, as the best performance was observed in the morning. [Conclusion] This study found that static and dynamic postural balance abilities were greatest in the morning and worst at 1 pm. Understanding of the mechanism of the time-of-day effect on postural balance will be helpful for assessment and treatment of postural balance by physical therapists and in making desirable clinical decisions.
Key words: Time of day, Static postural balance, Dynamic postural balance

INTRODUCTION

Optimal postural balance (PB) is an important foundation for the individual's ability to perform movement, and constitutes a central element in ensuring adequate movement capabilities. It is no longer considered simply as summation of static reflexes but rather is considered a complex skill based on the interaction of dynamic sensorimotor processes[1)]. Poor postural control increases the risk of falls. Falls are a major problem and cause not only various physical injuries but are also associated with high medical-related costs[2)]. Therefore, precise and reliable measures of PB in scientific and clinical settings are essential to prevention of problems caused by falls.

The time-of-day effect is recognized as a physiologic and neurologic function, which is influenced by diurnal patterns to follow a proposed circadian rhythm in humans[3–5)]. The circadian rhythm is influenced by external environmental factors such as daylight, temperature, and social interactions[6)]. In addition, previous studies have reported that cognitive and physical activities fluctuated throughout a 24-hour period in terms of cognitive abilities, reaction time, strength, body temperature, and heart rate[3, 7, 8)]. Some of these factors may contribute to postural control and could create daily fluctuations in this aspect of neuromuscular control[9, 10)]. However, little is known about the influence of time of day on motor ability such as postural control.

Therefore, the purpose of this study was to investigate the time of day effect on postural balance and to provide results that can be used by researchers and clinicians in consideration of this factor in assessment of postural control or development of rehabilitation exercise programs.

SUBJECTS AND METHODS

Twenty-four healthy students (10 male, mean ages 22.17±1.61) volunteered to participate in the study. Participants were excluded according to the following criteria: 1) history of musculoskeletal problems in the body and limbs within three years, 2) previous orthopedic surgery on the spine or limbs, 3) severe dizziness or vestibular problems, 4) history of any neurologic disease, and 5) taking balance-affecting medication (psychotropic, hypnotic, or antide-

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Table 1. Static and dynamic postural control abilities at three different times of the day

			Time of day		
			9:00 AM	1:00 PM	5:00 PM
Static postural control	AP distance (mm)	Raw	131.3±65.1	157.7±46.0	151.4±64.7
		Normalized	0.8±0.2	0.9±0.1*	0.9±0.2
	ML distance (mm)	Raw	8.1±7.0	15.00±10.6*	10.7±5.9
		Normalized	0.5±0.3	0.8±0.3*	0.7±0.3†
	COP Velocity (mm/s)	Raw	7.1±2.8	10.4±8.9	9.3±8.3
		Normalized	0.7±0.2	0.8±0.2	0.7±0.3
Dynamic postural control	Perform time (sec)	Raw	19.6±10.4	27.1±14.0	27.4±19.1
		Normalized	0.7±0.2	0.9±0.2*	0.8±0.2†
	Total distance (mm)	Raw	2167.0±943.0	3142.9±1704.8	2896.8±1582.5
		Normalized	0.7±0.2	0.8±0.3*	0.7±.02

The results of post hoc analysis are indicated by superscripts. An asterisk (*) indicates significance at the $p<0.05$ level in comparison between 9:00 AM and at1:00 PM, and an obelisk (†) indicates comparison between 9:00 AM and 5:00 PM.

pressive). Participants were asked to abstain from alcohol for 48 hours and to sleep for least 8 hours before the test. All participants received an explanation of about this study and signed a written informed consent form before being included in the experiment. The study was approved by the Institutional Review Board of the local ethics committee, in accordance with the ethical standards of the Declaration of Helsinki.

The static and dynamic balance tests were assessed using the a Good Balance system (Metitur, Finland) with an equilateral triangular force platform (800 × 800 × 800 mm) connected to a computer. The analogue signals of the strain gauge transducer were converted into digital signals by three 24-bit, 2-channel A/D converters and transformed into digital data at a frequency of 50 Hz. Digital data were transmitted to a computer through a serial port using a Bluetooth adapter. The signal was then digitally filtered in the Good Balance software (Metitur, Finland), first using a three-point median filter and then using an IIR filter (cut-off frequency 20 Hz) for removal of any high-frequency noise content in the signal. After the digital signal data were collected, center of pressure was calculated based on the vertical force signals. The balance outcome variables were calculated for movement of the center of pressure.

The balance ability of participants according to the different time of day was evaluated by a static balance test and dynamic balance test. The balance tests were performed during three sessions that took place in the morning (9:00 am), noon (1:00 pm), and evening (6:00 pm). This study was counterbalanced across the start time in order to exclude the learning effect. In order to guarantee sample homogeneity, the participants were randomly divided into by three groups depending on the starting time of the balance test (Table 1).

The static balance test was performed with participants standing on the force platform. They were asked to remain calm in a standing position for 30 s with their eyes open, hands hanging down loosely, and feet comfortably apart and to gaze directly at a mark placed at eye level. In the dynamic balance test, the participants were asked to move their center of pressure along a track shown on a computer monitor placed at eye level. The monitor for visual feedback located was on a table directly in front of the participants.

The target arrangements of the test were showed nine boxes consisting of eight peripheral target boxes and one central COP box. If the COP reached the target box, the next target box was displayed on the computer monitor. After demonstrating the test, the subjects were allowed to perform several preliminary trials for practice before the measurements were taken. At the beginning of each trial, the tester made sure that participants stood symmetrically on both legs. The participants were instructed to reach targets as quickly and accurately as possible, and to avoid unnecessary and inefficient movement.

In the static balance test, the outcome variables were AP distance (the space, within which a given part of the anteroposterio coordinates of the COP was contained in mm), ML distance (the space within which a given part of the mediolateral- coordinates of the COP was contained in mm), and velocity moment (moment of velocity from the path of the COP in mm^2/s). In the dynamic balance test, the performance time (time used to complete the test) and total distance (the length of the path traveled by the COP during the test) were measured. To eliminate the effect factor according to the difference in balance ability between subjects, all measurement variables were converted to normalized values with a mean of 1 and standard deviation (SD) of 0 based on the highest value in each variable.

The statistical package SPSW 18.0 for Windows was used for the statistical analysis. Demographic data, including sex, age, height, and weight, were analyzed using descriptive statistics. The data were

for AP distance, ML distance, velocity moment, performance time, and total distance were analyzed using ANOVA with a post hoc test. Values of $p < 0.05$ were considered statistically significant.

RESULTS

Variables of static and dynamic postural control assessment, that is, AP distance, ML distance COP velocity, performance time, and total distance, were ultimately acquired from the 24 participants. The participants' heights and weights were 165.75±10.15 and 59.00±10.05, respectively. In assessment of static postural control, the AP and ML dis-

tances were shorter and the COP velocity was faster at 9 am than 1 and 5 pm. Significant differences in the normalized values of the AP and ML distances were observed among the three time points (i.e., 9 am, 1 pm, and 5 pm). Post hoc analysis using the Bonferroni method indicated significant differences only between 9 AM and 1 PM. However, no statistical differences in raw data for AP distance and COP velocity were observed among the three time points. In assessment of dynamic postural control, the performance time and total distance were shorter at 9 am than at 1 pm and 5 pm. Statistical significance was observed in normalized values of performance time and total distance. The results of post-hoc analysis indicated differences between 9 am and 1 pm in terms of performance time and total distance and between 9 am and 5 pm in terms of performance time. However, no statistical differences in raw data for any dynamic postural control variables were observed among the three time points.

DISCUSSION

In the current study, we investigated the effect of the time of day on postural balance ability in healthy adults. These findings would have implications with regard to how researchers and clinicians schedule and interpret postural control testing when making comparisons across days and groups of subjects. Therefore, we measured the ability of static and dynamic postural control abilities at 9 am, 1 pm, and 5 pm to compare three meaningful times with respect to when physical therapy 5 pm is generally performed. In, addition, we used the normalized value of dependent variables for AP distance, ML distance, COP velocity, performance time, and total distance. It was reasoned that the normalized value could be used to correct and offset interindividual variability in postural performance at each time point. For the static postural balance measures, the COP distance was shorter and COP velocity was slower at 9 am than at 1 pm and 5 pm. In particular, the COP distance at 9 am differed statistically from that at 1 pm, indicating that static postural balance was best in the morning. During performance of the dynamic postural balance task, performance time and total distance were influenced by the time of day, as the best performances occurred in the morning. In addition, we found that the static and dynamic postural balance abilities were worst at 1 pm. In fact, as mentioned above, the effect of time of day on postural control ability has been reported by several previous studies[9–11]. However, these studies did not consider a learning effect resulting from repetitive assessments with a balance test. So, we designed an experimental paradigm to consider the procedural schedule of performed tasks.

Convergent evidence from investigation of the effects of time of day on postural control in younger subjects and older adults supports our results[9–11]. Forsman et al.[11] reported that postural stability changed during the day (8:30 am, 10:30 am, and 1:30 pm) in younger subjects, and that the worst postural stability was observed in the afternoon. According to the study of Gribble et al.[9], the effect of time of day was evident in static and dynamic postural control,

which were best in the morning. However, on the second day of measurement, no effect of time of day on static postural control was found, and it was suggested that this could be the result of a learning effect. The cause of the fluctuation in postural control ability could be described as a factor of cognitive variation during the day, which is known to peak early in human circadian rhythms[12, 13]. Perhaps elevated cognitive ability in the morning could allow for more efficient maintenance of the center of mass during performance of balance tasks. In addition, the reason for better performance in the evening than at the afternoon has been assumed to be a circadian rhythm that is close to that of body temperature or vigilance[14]. However, previous findings concerning the effect of time of day on physical performance were not in accordance with those concerning the effect of time of day onpostural balance ability[15, 16]. Dynamic postural balance peaked in the morning, whereas most physical performance peaked in the afternoon[8, 16]. Physical performance such as muscle torque generation and energy intake may not be directly related to postural control ability, and was influenced by the same diurnal pattern[7, 15, 16]. The conflict between physical performance and postural control with respect to the effect of time of day may be attributed to the fact that dynamic postural balance requires integration of sensory inputs from the visual and somatosensory systems, as well as appropriate motor responses, in order to maintain the body over the base of support.

Physical therapists and researchers have been using postural balance testing to provide information on neuromuscular control or proper communication between the central nervous system and muscles of subjects. However, cognitive and metabolic processes that affect physical activity fluctuate throughout the day. The findings of our study indicated that static and dynamic postural control abilities were influenced by the time of day, as morning produced the best performance and the noon produced the worst performance. Based on these findings, considering the effect of time of day for assessment and training of postural balance will be helpful to physical therapists in making desirable clinical decisions. In addition, we expect that effects of the time of day on various functional abilities related to rehabilitation intervention such as sensory, cognitive, and emotional modules will be considered in future studies.

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