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Effect of Differences in Room Brightness on Postural Control during Light Touch Contact

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Abstract. [Purpose] This study investigated the effects of differences in room brightness on standing postural control with or without light touch contact (LT). [Subjects] The subjects were of 40 healthy young people. [Methods] We tested the center of pressure (COP) oscillation during LT under illumination with fluorescent lamps, miniature bulbs, moonlight, and complete darkness. [Results] When we compared the oscillation between the conditions of LT and Non contact (NC) at various illuminations, all the parameters, except those observed in complete darkness, showed significantly lower values under the LT condition than under the NC condition. Under the LT condition, only the values of Total sway length (TSL), but not of the other two parameters, showed any significant difference; complete darkness resulted in a greater TSL than that found under the other illumination conditions. [Conclusion] These results support the idea that, 1) when a person is not touching objects, it may be necessary to adjust the surrounding illuminance to the level of fluorescent lamps (300 lux), but 2) when a person is performing LT, COP oscillation may not greatly change as long as the illuminance is moonlight or brighter, not complete darkness.
Key words: Light touch contact, Postural control, Room brightness

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INTRODUCTION

The elderly population in Japan has increased to 20.2% (2005) of the entire population and is predicted to increase further[1)]. Falls were responsible for approximately 20% of accidental deaths among the elderly (age 65 and older) in 2008[2)], a percentage which is quite large. Falls also accounted for a substantial proportion of events that resulted in medical conditions requiring nursing care. It is therefore important to develop and maintain an environment suitable for the activities as well as the safety of the elderly.

Falls occur as the result of loss of ability to perform proper postural regulation. The factors contributing to falls include internal components such as physical illness, drugs, and changes due to aging, as well as external components such as environment. These components are mutually linked to each other[3)]. To prevent falls handrails are sometimes installed as an environmental improvement. It is difficult to install handrails in the rooms of Japanese houses, because furniture and home appliances are often placed against the walls[4)]. For seniors living at home, however, falls occur most frequently in their living room; therefore it is important to maintain an environment that supports the stability of the elderly in their living rooms. Use of handrails and canes not only reduces weight bearing on the legs, it also plays a role in enhancing the stability of the user's body by expanding the base of support. In an actual living situation, many seniors acquire stability by lightly touching objects such as handrails. Also in situations in which visual information is blocked, such as in dark places, seniors compensate for the relative lack of visual information by touching surrounding objects, such as chests and walls, while walking.

Jeka validated the usefulness of touching objects lightly (light touch contact, LT) for its beneficial effects on center of pressure (COP) oscillation[5)]. However, it is not clear, whether LT is useful in dark places, e.g., when going to bathroom during the night, as opposed to during the daytime. Kawai et al. reported on the relationship between illuminance and COP oscillation[6)]. Shumway-Cook and Woollacot studied the accuracy of visual information in the context of its effect on COP oscillation[7)]. These studies together support the idea that a change in illuminance may affect the accuracy of visual information; the lower the illumination, the greater the COP oscillation may become. In complete darkness where one can see nothing at all, visual-system information is unavailable even if the eyes are open. Moreover, when the eyes are opens, a person uses visual sense dominantly and, as a result, other sensory information may be used less. Together with psychological effects due to darkness, such as fear, we speculated that, in complete darkness, COP oscillation might become greater when the eyes are open, compared to when they are closed.

No study has yet tested the effects of different levels of illuminance on postural control in the presence of LT.

By elucidating the effects of LT under different illumination conditions, we may be able to propose a daily living environment that is beneficial for the problems of postural control experienced by seniors and persons with disabilities. Accordingly, this study investigated the effects of differences in room brightness on standing postural control with or without LT. Under conditions mimicking a room during the night, we tested the COP oscillation during LT, using four levels of brightness: fluorescent lamps, miniature bulbs, moonlight, and complete darkness.

SUBJECTS AND METHODS

The participants were 40 young and healthy individuals (18 males and 22 females). Their mean age was 20.54 yr. (SD = 1.39 yr.), their mean height was 163.62 cm (SD = 6.61 cm), their mean weight was 53.13 kg (SD = 6.61 kg), and their mean foot length was 24.83 cm (SD = 1.54 cm). In accordance with the principles of the Helsinki Declaration, we thoroughly explained the purpose of this study to the subjects and obtained their informed consent in writing before conducting the experiments.

The experimental environment consisted of a special, acoustically insulated room with controllable illuminance. The brightness of each illumination was checked by an illuminometer LUX-2 (Sanwa Electric Instrument, Japan). To record the COP oscillation, we used a balance-function measurement instrument Win-Pod (Medicapteurs, France) that can also record foot-pressure distributions. We recorded the data at a sampling frequency of 100 Hz.

The measurements were conducted as follows. Each subject was asked to stand in a upright posture still with the feet together on Win-Pod. The positions of feet were marked so that the feet could be placed in the same position in each trial. LT was performed with the fingertips. During testing under LT conditions, the subjects were instructed to touch by the fingertips a paper hanging on their right side. The position of touch was left arbitrary. Mimicking daily living conditions, illuminance of the room was set to one of four conditions: fluorescent lamps (300 lux), miniature bulbs (0.5 lux), moonlight (0.1 lux), and complete darkness (0 lux). The touch condition was either LT or non contact (NC). The visuosensory condition was either open or closed eyes.

A spring-based scale (model SA-1Ng; Uchida, Japan) was used to measure the touch force of the fingertips on the paper. The location of the paper and the touch position were adjusted so that the force of LT on the paper would not exceed 100 g. Under the condition of complete darkness, we used an infrared imaging camera (Sony, Japan), so as not to influence the vision of subjects or the illuminance set-up, and to confirm that each subject was indeed performing LT. Under each test condition, subjects were instructed to gaze two meters ahead at a marker placed at their eye level. We instructed subjects that, during measurement, they should try to maintain an upright posture as much as possible, and not to change the positions of their feet or fingertips[8]. When the position of each trial was determined and the subject felt s/he was stable enough, the subject would signal it by saying "yes" and we would start recording the measurement for 30 seconds. Taking into consideration habituation effects, each trial was conducted in a random order. Between each trial, subjects were allowed to take sufficient rest.

The parameters used to analyze the COP oscillation were: total sway length (TSL) indicating the amount of COP oscillation, environmental area (EA) indicating the area of oscillation, and root mean square area (RMSA) indicating the fluctuation of oscillation.

We analyzed the data sets of two levels of illuminance with two visuosensory conditions (2×2) and also sets of four levels of illuminance with two touch conditions (4×2). We used SPSS Ver16.0 for statistical analyses and carried out a two-factor variance analysis (Bonferroni correction). The significance level was chosen as less than 5%.

Table 1.

	eyes	fluorescent lamps	complete darkness
TLS	open	299.3 ± 93.0	374.7 ± 159.6
	closed	375.5 ± 112.3	366.1 ± 128.2
EA	open	203.2 ± 101.2	257.2 ± 179.6
	closed	252.7 ± 114.6	269.4 ± 175.3
RMSA	open	1.6 ± 0.9	1.8 ± 1.8
	closed	1.7 ± 0.9	2.2 ± 2.5

RESULTS

Table 1 shows the measurements of COP oscillation under the illumination condition of fluorescent lamps or complete darkness, with eyes open or closed (2×2 conditions). When the room was illuminated by fluorescent lamps, TSL showed a significantly higher value with eyes closed than with eyes open ($p<0.01$). In complete darkness, however, there was no significant difference in TSL between the conditions of eyes closed and eyes open. When the eyes were open, TSL showed a significantly higher value in complete darkness than when illuminated by fluorescent lamps ($p<0.01$). When the eyes were closed, there was no significant difference in the sway length between the illumination conditions of fluorescent lamps and that of complete darkness. With respect to EA, when illuminated by fluorescent lamps, EA showed a significantly higher value with eyes closed than with eyes open ($p<0.05$). In complete darkness, there was no significant difference in EA between the eyes open and closed conditions. Regardless of whether the eyes were open or closed, EA did not show any significant difference in value between the illumination conditions of fluorescent lamps and that of complete darkness. As to RMSA, there was no significant difference among any of the 2 × 2 conditions tested.

Table 2 shows the measurements of COP oscillation under four different levels of illuminance, and touch conditions of either LT or NC (4×2 conditions). Under every illumination condition, TSL showed a significantly lower value under the LT condition than under the NC condition (for fluorescent lamps and complete darkness, $p<0.05$; for miniature bulbs and moon light, $p<0.01$). In the comparison of four illumination conditions in the absence of touching (NC), COP oscillation under the fluorescent lamps condi-

Table 2.

	touch	fluorescent lamps	miniature bulbs	moonlight	complete darkness
TSL	NC	328.0 ± 90.4	369.8 ± 101.8	368.8 ± 90.9	410.4 ± 118.0
	LT	299.3 ± 93.0	313.7 ± 99.2	316.7 ± 88.3	374.7 ± 159.6
EA	NC	311.4 ± 163.7	332.5 ± 168.9	327.2 ± 167.7	358.7 ± 196.7
	LT	203.2 ± 101.2	226.2 ± 122.7	231.5 ± 129.4	257.2 ± 179.6
RMSA	NC	2.6 ± 2.2	3.0 ± 2.9	2.3 ± 1.6	2.9 ± 2.9
	LT	1.6 ± 0.9	1.6 ± 1.4	1.6 ± 1.3	1.8 ± 1.8

tion was significantly lower than under to the other three illumination conditions ($p<0.01$). During LT, the condition of complete darkness resulted in significantly higher value of COP oscillation than the other three conditions ($p<0.05$). With respect to EA, the values observed with LT were significantly lower than those with NC, under all four levels of illumination ($p<0.01$). Irrespective of the touch condition (LT or NC), EA showed no significant difference in value among the four illumination conditions. RMSA showed a significantly lower value with LT than with NC, in all the illumination conditions except complete darkness (for the fluorescent-lamp condition, $p<0.05$; for the other illumination conditions, $p<0.01$). There were no significant differences in RMSA among the four illumination conditions with or without touching.

DISCUSSION

This study aimed to elucidate the effects of surrounding brightness on the COP oscillation when LT is being performed.

We first wished to test the visuosensory and psychological effects of differences in illumination on the oscillation. We compared the illumination conditions of fluorescent lamps and complete darkness, each with eyes closed and open. The results show that, when the room was illuminated by fluorescent lamps, both TSL and EA showed significantly lower values when the subjects opened their eyes than when their eyes were closed. There was no significant difference in RMSA between the two visuosensory conditions. Stability of static standing posture is defined as the "ability to confine the body's COP within a certain area while the body can be steadily maintained without changing the base of support[9]". Based on this definition, a posture could be considered more stable if TSL was shorter and if EA and RMSA were smaller. Postural regulation is achieved by collaboration among the visual, vestibular-labyrinthine, and somatosensory systems. The visual system in particular is known to have a great influence on postural regulation in humans[10]. The condition of eyes closed, compared to the eyes open condition, produced higher values in TSL and EA and similar values in RMSAs. Conceivably, shutdown of visual-system information may have brought about the increased oscillation of COP. The results indicate that, under the illumination condition of fluorescent lamps, the COP oscillation became smaller and the posture became more stable when the eyes were open than when they were closed.

In complete darkness, there was no significant difference in any oscillation parameter, suggesting that the COP oscillation under this condition does not depend on whether the eyes are open or closed. A previous study tested a condition in which visual-system information was blocked and only illumination below 6.0 lux was perceptible. Under these conditions, the visual-system information from rod cells, which can function at a low level of illumination, plays a significant role in postural regulation; Thus, the postural regulation still functions sensitively even at low illumination[6]. However, under the condition of complete darkness used in this study, irrespective of whether the eyes are open or closed, the visual-system information to perceive surroundings and also the perception of brightness is totally shut off. This probably explains why there were no significant differences in oscillation parameters between the conditions of eyes open and eyes closed. When the eyes were closed, no significant differences were observed in the oscillation parameters between the illumination conditions tested (fluorescent lamps and complete darkness). With the eyes closed, information about the position of one's body relative to the external environment, the information which is obtained from the vision, is blocked, and the effects of illumination are also removed[6]. The COP oscillation under such a condition can be considered independent of the illumination condition. This is also evident in our results showing that oscillation parameters observed in complete darkness, with the eyes both open and closed, were similar to those observed under fluorescent-lamp illumination when the eyes were open. We ask: what might the psychological effects be on COP oscillation, of having the eyes open or closed? It has been reported that people with anxiety disorders react sensitively to the fluctuation of visual information and that anxiety primarily affects processing of their visual information. Thus, visual sensitivity is observed only when the eyes are open and disappears when the eyes are closed[11]. The subjects who participated in this study consisted of young healthy individuals. In complete darkness, these subjects showed no fluctuation in visual-system information between the eyes open and closed conditions. The two visuosensory conditions can be considered equivalent at the stage of processing visual-system information. These results suggest that, among young and healthy people, the visuosensory status (eyes open or closed) probably has little psychological effect on the COP oscillation.

We then investigated the effects of differences in the brightness of surroundings on the COP oscillation. When we compared the oscillation between the conditions of LT and NC at various illuminations, all the parameters, except those observed in complete darkness, showed significantly lower values under the LT condition than under the NC condition. These results suggest that LT, combined with illumination at the level of moonlight or brighter, may stabilize posture. In complete darkness, TSL and EA showed significantly lower values with LT than with NC. These results support a view that LT increases sensory feedback from fingertips and that posture may be being adjusted through perception of the positions of various parts of the arms and trunk relative to the external environment[5, 6, 12–15]. However, standard deviations in RMSA were large and there were no significant differences among the illumination conditions. These results suggest that, in complete darkness, even with LT, there were variations in body stability and that COP can become temporarily displaced from the body center.

We compared the COP oscillation among different illumination conditions under each of the touch conditions (LT or NC). In the NC condition, only the value of TSL, but not of EA or RMSA, showed any significant difference; the illumination condition of fluorescent lamps showed a lower TSL than those found in the other illumination conditions. These results suggest that, in the NC condition, the illumination level of fluorescent lamps may reduce COP oscillation compared to other less illuminated conditions. Under the LT condition, only the values of TSL, but not of the other two parameters, showed any significant difference; complete darkness resulted in a greater TSL than those found under the other illumination conditions. These results suggest that, with LT, complete darkness may result in a greater oscillation, compared to the other illumination conditions. Taken together, these results support the idea that in daily living, 1) when a person is not touching objects, it may be necessary to adjust the surrounding illuminance to the level of fluorescent lamps (300 lux), but 2) when a person is performing LT, COP oscillation may not greatly change as long as the illuminance is moonlight or brighter, not complete darkness. That is to say, even in a place with low illuminance, such as during the night, these results suggest that performing LT would be useful.

It is known that conditions with a large influence on the ability to maintain posture, such as the condition of eyes closed as opposed to eyes open or the dynamic as opposed to the static condition, tend to be more appropriate for evaluation of falls[16]. Because the experimental procedures of this study used static conditions, the usefulness of LT found in our experiments might fall short of being directly relevant to daily life. Also, this study used young healthy individuals as the test subjects. The results for elderly subjects might possibly differ. Aging is accompanied by reductions in vestibular nerve cells, Purkinje fibers in the cerebellum, and neurons in the cerebral cortex[10]. Thus, balance-control functions other than vision deteriorate with age, resulting in decrease of balance-control functions in humans. Taking this into account, we can imagine that, in the elderly, an increase in sensory input from somatosensors may lead to reduction of COP oscillation in a static standing posture. Thus, it is possible that an increase of sensory input via LT could reduce the COP oscillation among the elderly. In the future, with the elderly as the subjects, we plan to test some methods of utilizing LT that would be practical in daily life.

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APPENDIX

TSL (mm)

$$\sum_{i=1}^{n}\sqrt{\left(X_{i+1}-X_i\right)^2+\left(Y_{i+1}-Y_i\right)^2}$$

EA (mm^2)

$$\sum_{i=1}^{120}\left\{\left(X_{i^2}+Y_{i^2}\right)\times\left(X_{i+1^2}+Y_{i+1^2}\right)\times\sin\theta/2\right\}$$

RMSA (mm^2)

$$\pi\left(\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left\{\left(X_i-\overline{X}\right)^2+\left(Y_i-\overline{Y}\right)^2\right\}}\right)^2$$

X_i, Y_i : A coordinate value of COP

θ=3°

n = 3000 (The sampling number)

$\overline{X}$, $\overline{Y}$: The mean of the oscillation of COP