

Original Article

EFFECTS OF VIEWING DISTANCE AND HEAD FLEXION ON POSTURAL CONTROL DURING ONE AND TWO-LEGGED STANCE

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ABSTRACT

Background: Short viewing distances and head flexion decrease and increase postural sway, respectively. Few studies have examined the effects of these factors during one-legged stance or voluntary body leaning within the base of support, both of which often occur in daily life. The purpose of this study was to examine the effect of viewing distance and head flexion in several postural control conditions.

Materials and Methods: Fifteen healthy young subjects participated in this study, and center of pressure (CoP) displacement was measured in five conditions (gazing 600 cm forward, 150 cm forward, downward, forward with eyes closed, and downward with eyes closed) during two- and one-legged stances and voluntary body leaning. Measurements included that the root mean square (RMS) of the anteroposterior (A-P) and mediolateral (M-L) directions during two- and one-legged stance, and maximum A-P and M-L distances during voluntary body leaning.

Results: Our results showed that the M-L RMS of 150 cm was less than that of 600 cm during one-legged stance ($p = 0.01$). Moreover, the A-P and M-L RMS values of downward gazing were lower than those of 600 cm (A-P RMS: $p = 0.003$ and M-L RMS: $p = 0.002$). The M-L distances of 150 cm and downward were larger than that of 600 cm ($p = 0.002$ and $p < 0.001$, respectively).

Conclusions: Our findings suggest that the effect of viewing distance was more evident during one-legged stance and voluntary body leaning.

KEY WORDS: Balance, Vision, Stance, Head flexion, Postural sway.

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INTRODUCTION

The integration or interaction of visual, vestibular, and proprioceptive information is necessary for successful balance control in a standing position [1]. In particular, visual information is critical for balance control, and a number of studies have demonstrated that

viewing distance can alter postural sway during upright standing [2-7]. For example, postural sway in near-viewing conditions was smaller in far-viewing conditions [2, 4, 5, 7]. It has been suggested that this effect of viewing distance can be observed up to approximately 5 m [2]. However, the viewing distances for which postural sway has been examined are relatively

short considering the distances typically encountered in daily living. Tested viewing distances have ranged from 10 to 100 cm [7] or 40 to 200 cm [4, 5]. In fact, only Bles et al. [2] assessed long viewing distances (from 0.5 to 200 m), but they only included six subjects. In this study, we tested whether relatively long viewing distances (from 150 to 600 cm, which we often encountered inside rooms or buildings) affect postural sway.

The effect of head extension/flexion on postural sway has also been evaluated and was shown to influence visual and vestibular information [2, 8-11]. In healthy elderly subjects, head flexion increased postural sway when their eyes were opened [8, 10] and closed [10]. It has been hypothesized that the vestibular information disruption during head flexion led to postural instability in elderly subjects. That is, head flexion changed the utricular otolith position beyond their working range [9]. We were interested in examining the effect of head flexion on postural sway because head flexion commonly occurs during standing and walking. The effect of head extension/flexion and viewing distance on postural sway are more obvious when subjects stand on a foam rubber than on a firm platform [2, 10]. In daily activities, we often adopt a one-legged stance, such as when we put on socks. One-legged stance is a more unstable condition than two-legged stance. Moreover, this condition is reproducible and more sensitive for visual information needed to maintain balance [12]. We therefore postulated that the effects of viewing distance and head flexion on postural sway would also become more obvious during one-legged stance.

Functionally, balance is divided into three levels: posture maintenance during standing, control of the center of mass (CoM) during activities such as turning and reaching, and the maintenance of CoM within the area over the base of support in response to a destabilizing force [13]. With regard to the second aspect of postural control, it is a more challenging condition than one-legged stance, and it has been reported that dynamic posturography can predict the likelihood of falling in elderly people [14]. Although this study assessed a young population, knowledge of the effects of viewing distance

and head position on a dynamic balance to control the CoM within the base of support during leaning could be useful for preventing falls.

The purposes of this study were to examine the effects of viewing distance and head position on postural sway and to determine whether these effects were more pronounced during one-legged stance by healthy young subjects. We also examined the effect of viewing distance and head position while the subjects leaned within their base of support.

MATERIALS AND METHODS

Subjects: Fifteen healthy young subjects participated in this study (age [mean \pm SD]: 26.3 \pm 4.0 years, BMI: 20.2 \pm 1.6 kg/m², visual acuity: 1.1 \pm 0.4, male [n]: 7). All subjects worked at the hospital where this study was conducted. The exclusion criteria were a history of vertigo or dizziness, vestibular neuritis, or neurological disorders and orthopedic diseases of the neck, trunk, or lower limbs.

Ethics: This study was approved by the ethics committee of the hospital. All subjects provided written informed consent prior to participation.

2.3 Procedure

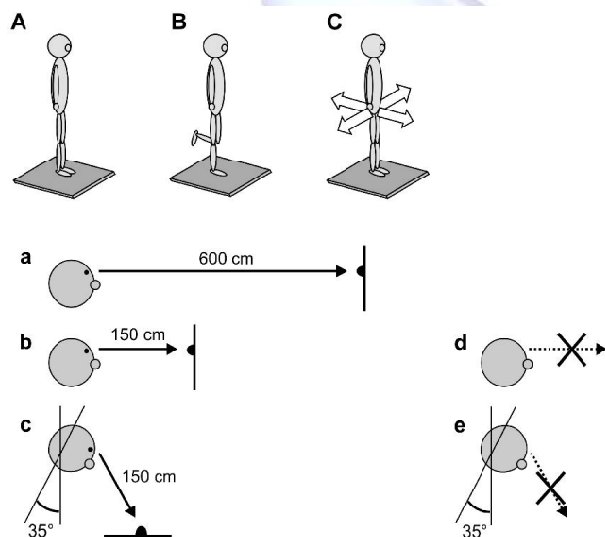
A force plate equipped with a data processor (Anima Co. Ltd., Tokyo, Japan) was used for measuring center of pressure (CoP) displacement, and the sampling rate was set at 50 Hz. Measurements were made in a large rehabilitation room with moderate light and low noise levels. The cumulative CoP displacement was measured in five conditions (Fig. 1a–e) during two- and one-legged stance (Fig. 1A– B). The maximum CoP displacement distance was measured in the same five conditions (Fig. 1a–e) during two-legged stance (Fig. 1C).

The five conditions were as follows [8]: (i) eyes fixed forward on a marker attached to a wall 600 cm straight ahead (600-cm condition); (ii) eyes fixed forward on a marker 150 cm ahead (150-cm condition); (iii) eyes fixed downward on a point 50 cm in front of their toes, with the head flexed at an angle of 35° to the trunk (downward condition); (iv) facing straight ahead with eyes closed (the closed-forward condition); and (v) facing downward in the same scenario as the downward condition but with the eyes closed

(closed-downward condition). The two- and one-legged stances were as follows during cumulative CoP displacement measurement: in two-legged stance, the subjects stood barefoot on the force plate with their arms alongside their trunk and with their feet together. In the one-legged stance, the subjects stood only on their right leg because they reported no effect for leg preference [12, 15]. In both stances, subjects were instructed to stand as still as possible, and their cumulative CoP displacements were recorded for 30 seconds. To measure the maximum CoP displacement distance, subjects were required to maximally lean their body forward, backward, rightward, and then leftward without any part of their feet off the floor during two-legged stance [13, 16]. Subjects were required to maintain for 10 seconds each leaning position.

Stances were performed in the following order: two-legged, one-legged, and two-legged with leaning. Two trials in each of the five conditions were performed randomly, and the subjects were allowed to rest for 30 s between conditions. The mean of two trials was used for data analysis.

Fig. 1: Schematic representation of the measurement conditions.



Measurements were conducted in five conditions (a to e) during three stances (A to C).

A: Two-legged stance. B: One-legged stance.

C: Voluntary body leaning in the a: 600-cm, b: 150-cm, c: downward, d: closed-forward, and e: closed-downward conditions.

Measurements: During two- and one-legged stances anteroposterior (A-P) and mediolateral (M-L) directions of root mean square (RMS) were

used as parameters to capture the CoP fluctuation characteristics (A-P RMS and M-L RMS, respectively) [2, 8, 16]. The maximum CoP displacement distances in the A-P and M-L directions were calculated from the center of 10-s CoP data at each leaning position (between forward and backward, A-P distance and rightward and leftward, M-L distance).

Statistical Analysis: To evaluate the effect of viewing distance, the A-P and M-L RMS values were compared between the 600- and 150-cm conditions for two- and one-legged stances. To evaluate the effect of downward gazing, the A-P and M-L RMS values were compared between the 150-cm and downward conditions in each stance. To assess the combined effect of viewing distance and downward gazing, the A-P and M-L RMS values were compared between the 600-cm and downward conditions in each stance. Finally, to evaluate the effect of head flexion without vision, the A-P and M-L RMS values were compared between the closed-forward and closed-downward conditions.

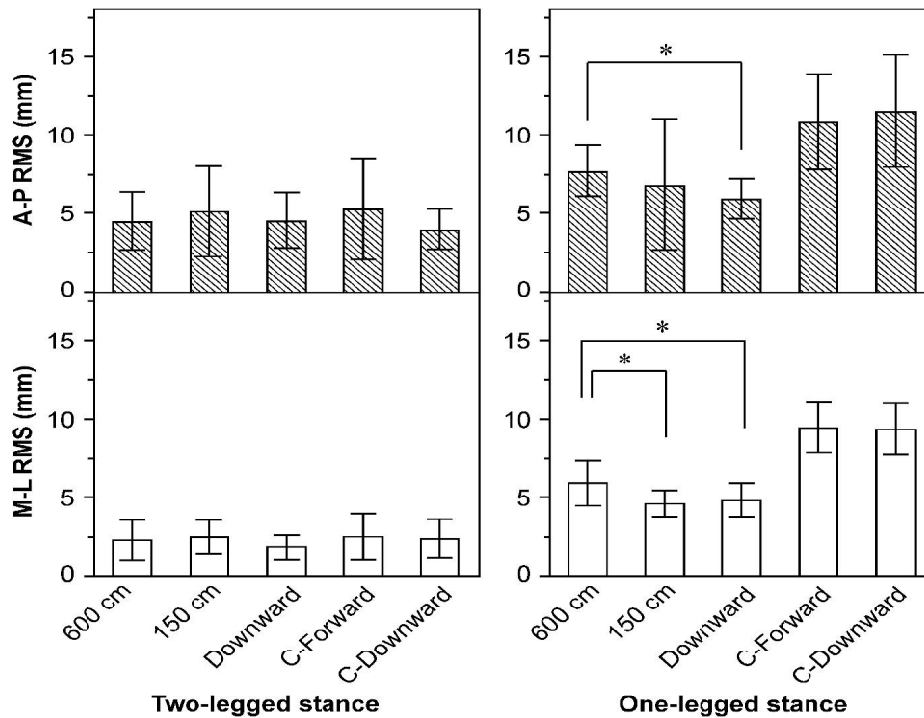
The evaluation of A-P and M-L distances had the same aim as those of A-P and M-L RMS values, the comparisons were conducted between the same conditions as described for the comparisons of A-P and M-L RMS above.

Paired t-tests were used for comparisons. Statistical significance was set to 0.05, and Holm's method [14] was used to adjust the p values to control the family wise error rate. All statistical procedures were conducted using JMP 10.0.2 software (SAS Institute, Cary, NC, USA).

RESULTS

A-P and M-L RMS: In evaluating the effect of viewing distance, the M-L RMS value for the 150-cm condition was lower than that of 600-cm condition during one-legged but not two-legged stance (4.6 ± 0.8 mm and 5.9 ± 1.4 mm for one-legged stance, $p = 0.01$, $t = -2.96$; 2.5 ± 1.1 mm and 2.3 ± 1.3 mm for two-legged stance, $p = 0.64$, $t = 0.47$). In evaluating the combined effect of viewing distance and downward gazing, the A-P and M-L RMS values of the downward condition were lower than those of the 600-cm condition during one-legged stance (A-P RMS: 5.9 ± 1.3 mm and 7.7 ± 1.6 mm,

Fig. 2: Anteroposterior and mediolateral RMS values for each condition during two- and one-legged stance.



Bars and whiskers represent the mean values and standard deviations, respectively. An asterisk (*) denotes statistical significance between conditions (significance in the paired t-test was accepted at a corrected P value of 0.05 with Holm's method).

p = 0.003, t = -3.62; M-L RMS: 4.8 ± 1.1 mm and 5.9 ± 1.4 mm, p = 0.002, t = -3.69). No significant differences were observed for two- and one-legged stances for the effect of head flexion without vision (Fig. 2).

A-P and M-L distances: The M-L distance of the 150-cm condition was higher than that of the 600-cm condition (p = 0.002). In evaluating the combined effect of viewing distance and downward gazing, the M-L distance for the downward condition was higher than that of the 600-cm condition (p < 0.001). For head flexion without vision, the A-P distance for the closed-downward condition was greater than that of the closed-forward condition, but this difference did not reach the statistical significance (p = 0.051, Table 1).

Table 1: Anteroposterior and mediolateral distances between conditions.

	A-P distance (mm)		p value	t value	M-L distance (mm)		p value	t value
	Mean	SD			Mean	SD		
600 cm vs. 150 cm	127.4 ± 26.3	133.4 ± 23.0	0.105	-1.73	192.4 ± 39.6	211.1 ± 41.8	0.002*	-3.75
150 cm vs. downward	133.4 ± 23.0	131.2 ± 27.1	0.574	0.58	211.1 ± 41.8	205.4 ± 38.5	0.262	1.17
600 cm vs. downward	127.4 ± 26.3	131.2 ± 27.1	0.181	-1.41	192.4 ± 39.6	205.4 ± 38.5	<0.001*	-6.07
c-forward vs. c-downward	118.5 ± 32.6	122.1 ± 29.7	0.051	-2.13	188.4 ± 48.2	192.5 ± 49.9	0.251	-1.2

Values are the mean ± SD of A-P and M-L distance of each condition.

An asterisk (*) denotes statistical significance between conditions (significance in the paired t-test was accepted at a corrected p value of 0.05 with Holm's method).

DISCUSSION

A-P and M-L RMS: We observed differences for viewing distances only when subjects adopted a one-legged stance. This is presumably because two-legged stance was not a challenging condition for healthy young subjects, so the effects of viewing distance were not emphasized in the two-legged stance [2, 10]. Indeed, the mean A-P and M-L RMS values in

the two-legged stance were increased by approximately 130 to 170% and 190 to 260% from those in the one-legged stance with vision, and by approximately 200 to 290% and 380 to 400% from those without vision, respectively (Fig. 2).

For one-legged stance, we found that the M-L RMS for the 150-cm condition was lower than that for the 600-cm condition. This result is

consistent with findings reported in a previous study in which the effect of viewing distance was only observed in the M-L direction of CoP sway [17]. Our results also showed that the A-P and M-L RMS values of the downward condition were lower than those of the 600-cm condition, but no difference was observed between the downward and 150-cm conditions. These results indicate that the low postural sway in the downward condition might be attributed to the viewing distance effect. Because the downward and 150-cm conditions had similar viewing distances when consider to the subjects' heights (150–175 cm), there seemed to be differences between conditions due to head flexion. Our finding of a difference in A-P RMS values between the downward and 600-cm conditions might support our assumption of a predominant viewing distance effect. The decreased A-P RMS in the downward condition seemed to be explained by the finding that the detection threshold during A-P sway was lower than that in the forward condition (i.e., up-down eye movement during downward gazing could more easily detect subtle sway than vergence during forward gazing) [7, 8].

Most studies that have examined the effects of head flexion on postural sway reported that the postural sway was increased [2, 8, 10], which is in contrast with our results. It was hypothesized that this balance loss occurred because disrupted vestibular information was used. Although the vestibular system is considered to work predominantly under conflicting sensory conditions [9, 18, 19], Kogler et al. [20] reported that the balance score for young subjects was not significantly altered for several neck positions (i.e., neutral, forward, right, and left). We found that the RMS values for the closed-forward and closed-downward conditions were not different. We postulated that the conditions in this study did not create a sensory-conflicting situation for our young subjects; therefore, they did not use the disrupted vestibular information for postural control.

A-P and M-L distances: The M-L distances of the 150-cm and downward conditions were significantly lower than that of the 600-cm condition, although the A-P distances did not differ. However, the M-L distance of the 150-cm

condition was significantly lower than that of the 600-cm condition, which is consistent with our findings from the RMS comparison. Le and Kapoula [5] reported that the effect of viewing distance was more evident in A-P than M-L body sway because A-P body sway caused angular size variation on the retina. In contrast, Guerraz et al. [3] reported that the effect of viewing distance was more evident in the M-L direction, and they postulated that this was due to extra-ocular muscle proprioception [21] and a sense of motion parallax. Furthermore, others have reported that this effect can be observed in both the A-P and M-L directions [2, 4, 21]. We found that when subjects voluntarily moved in A-P and M-L directions, the sense of motion parallax was more obvious during M-L movement (i.e., M-L movement yielded retinal slip but A-P movement only generated vergence). We postulated that motion parallax was more evident for detecting M-L movement; therefore, the increment in the M-L distance was observed for the viewing distance effect.

The M-L distance of the downward condition was larger than that of the 600-cm condition. Moreover, the M-L distance was not significantly different between the downward and 150-cm conditions. These results might be due to the viewing distance effect as described above. However, the A-P distance was not different between the 600-cm and downward conditions. Buckley et al. [10] reported that the A-P direction of CoP would be moved forward by head flexion. We postulated that this change in CoP location inhibited voluntary movement in the A-P direction (especially backward movement), and that this resulted in no change in A-P distance, even if there was a viewing distance effect.

Our results indicate that viewing distance improved both postural controls during one-legged stance and voluntary body leaning within the subjects' bases of support. These findings suggest that optimizing viewing distance could help prevent falls. The downward gazing condition also improved postural control ability compared to the far-forward gazing condition, which indicates that this improvement was solely due to the viewing distance effect. Moreover, this improvement during downward gazing might only be observed in young people

because they tend to have minimal degeneration of sensory modalities such as vision, proprioception, and the vestibular system. Further studies of frail elderly or physically impaired populations were needed to clarify these effects.

CONCLUSION

In conclusion, the results of the present study indicate that there is an effect of viewing distance on postural control during one-legged stance and voluntary body leaning in young subjects, but this effect was not observed during two-legged stance. We did not note any effect of head flexion, which deteriorates postural control ability, in this study.

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Conflicts of interest: None

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