Advances in Research

17(5): 1-9, 2018; Article no.AIR.42870
ISSN: 2348-0394, NLM ID: 101666096

Influence of Hand Help Pressure on Body Sway and Leg Muscle Activity during One-Leg Stance

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AIR/2018/42870
Editor(s):
(1) Dr. Jaime Salvador Moysen, The Institute of Scientific Research, Universidad Juárez del Estado de Durango, Mexico.
(2) Dr. Giovanni Messina, Department of Clinical and Experimental Medicine, University of Foggia, Italy.
Reviewers:
(1) Bashir Bello, Bayero University Kano, Nigeria.
(2) Paulo Sergio Chagas Gomes, State University of Rio de Janeiro (Universidade do Estado do Rio de Janeiro – UERJ), Brasil.
(3) Recep Kurkcu, Amasya University, Turkey.
Complete Peer review History: http://www.sciencedomain.org/review-history/27741

Original Research Article

Received 22 June 2018
Accepted 30 November 2018
Published 15 December 2018

ABSTRACT

Aims: This study aimed to examine the effects of the position and pressure of the hand during hand help on body sway and leg muscle activity during OLS.
Study Design: Fifteen elderly subjects (71.5 ± 3.9 years) performed OLS with and without hand help for 30 s.
Methodology: The test with hand help was performed for six tasks with different hand positions (forward and sideward) and varying amounts of pressure (free, light, and strong). The data of the 14 elderly subjects who performed 30-s OLS were analysed.
Results: Body sway was greater in the light pressure condition than in the free and strong pressure conditions, but only in the forward hand position. It was greater in the forward position than in the sideward position in the free and light pressure conditions. The leg muscles tended to be the most active with light hand help.
Conclusion: Even if the elderly use free and light hand help pressure in sideward hand help, hand

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help pressure has little effect on postural stability because of sufficient postural stability. However, in the case of forward hand help, using light hand help pressure activates the leg muscles due to the loss of stable posture.

Keywords: One-leg stance; body sway; leg muscle activity; hand help pressure.

1. INTRODUCTION

Various physical functions decrease with age. Particularly, a decrease of balance ability is remarkable, which is a major factor of health problems such as locomotive syndrome and fracture due to a fall. As one of these prevention measures, one-leg stance (OLS) training has been used [1,2] OLS training is an extremely practical method because it only requires standing on one leg for a certain amount of time and is cost-effective and does not require a special place or a lot of time. In OLS training, use of the hands as help for safety is permissible [3]. Elderly persons with very poor balance, such as those who are frail, should use their hands. However, it has been reported that the use of hands may decrease the effectiveness of OLS training [4].

Hand help greatly affects body sway and leg muscle activity during OLS. Holden et al. [5] reported that body sway decreases only with a gentle touch on a fixed object, and the decrease is caused not only by mechanical factors but also by the physiological factor derived from the tactile fingertip, in which the fingertip touch pressure is very light (less than 1 N). Many studies have reported this phenomenon, called "light touch" [5,6,7]. In addition, Uchida et al. [4] reported that a light hand touch decreases not only body sway but also leg muscle activity. Wipple et al. [8] reported that putting one's own body weight on the legs sufficiently is a factor in effective balance training and low intensity training with a small body weight load is insufficient for effective training. As a fundamental for balance training, Mochizuki et al. [9] recommends setting movement tasks or environments of a level that is somewhat higher than the person's balance ability and to repeat movements with motor learning. Thus, if sufficient postal stability is obtained by hand help during one-leg stance training and the load on the lower legs is largely reduced due to decreased training intensity, it will be difficult for the person to achieve a desirable training effect.

Body sway and leg muscle activity during standing differ depending on the hand's pressure and position of the hand. Baccini et al. [10] examined the effect of hand help during tandem stance and reported that body sway decreased more with a forceful touch than with a gentle touch. Tateuchi et al. [11] examined the relationships between the contact force with a T-cane and body stability/lower limb muscle activity during OLS and reported that body sway decreased with an increase of the contact force until it reached 10% of the body weight. Bove et al. [12] reported that with light touch, body sway markedly decreased in the sagittal plane when anteroposterior body sway was induced, and in the coronal plane when lateral body sway was induced. Uchida et al. [13,14] reported that body sway during OLS decreased with lateral hand help more than with front hand help. Based on the literature, it can be concluded that postural stability is enhanced by increasing touch pressure and by touching in the direction of the induced body sway or in the direction of unstable posture.

Body sway and leg muscle activity differ by hand position and pressure during OLS. Safety during the OLS training in the elderly can be ensured by using hand help because of increasing postural stability. However, the decline in leg muscle activity and body sway caused in place of increasing postural stability may decrease in the training effect. Several individuals perform one-leg stance training at home [15]. It is important to provide instructions regarding the adequate help methods based on the elderly's physical fitness level to enable them to perform the training safety and effectively. This study aimed to examine the influence of various instructions regarding the hand help methods (a different position and pressure of hand help) on body sway and leg muscle activity during OLS.

2. METHODS

2.1 Subjects

Fifteen elderly adults participated in this study as subjects. Written informed consent was obtained from the all subjects. This study analysed data from 14 elderly adults (71.5 ± 3.9 years; 151.8 ± 3.8 cm; 50.8 ± 8.2 kg); one subject was unable to perform the 30-s OLS test without hand help. Sufficient power (> 0.8) was confirmed for all the tests. Based on the dominant leg and hand survey reported by Demura et al. [16,17], the dominant leg and hand in all subjects was judged to be the right one. This study was approved by the Ethics Committee on Human Experimentation of the Faculty of Human Science, Kanazawa University.

2.2 Measurement Procedure

The ankle strategy is primarily used when maintaining a stable standing position, and leg muscle groups related to plantar flexion and dorsiflexion are activated. Hence we selected the gastrocnemius, soleus, and tibialis anterior muscles as the target muscles. All subjects performed the 30-s OLS test after pasting electrodes on these muscles of a supporting leg. In addition to normal OLS, all subjects performed six kinds of OLS with hand help.

2.3 Postural Keeping Tasks

2.3.1 Normal OLS

Subjects stood on the stabilometer with hands on hips and, after being given a tester's signal, they started the 30-s OLS test by bending the left knee slightly backward.

2.3.2 OLS with hand help (6 task)

Subjects stood on the stabilometer with the left hand placed on the hip and the right hand on the table, which was set forward or sideward of their supporting leg. The table height was adjusted to the subject's hip level. After a tester's signal was given, subjects started the 30-s OLS test by bending the left knee backward (Fig. 1). The OLS test with hand help was performed under the following six tasks with different hand positions (forward and sideward) and pressure (free, light, and strong). The tests were performed in the following numerical order with one minute of rest.

<u>Task 1: OLS with forward hand help (free hand help)</u>

Subjects put their right hand on the hand pressure measuring device set in front of them and were instructed without regulating especially the hand pressure to keep their hand on the device and use the hand help as per body sway.

<u>Task 2: OLS with forward hand help (light hand help)</u>

Subjects put their right hand on the hand pressure measuring device set in front of them, and they were instructed only to keep touching the device lightly during the tests.

<u>Task 3: OLS with forward hand help (strong hand help)</u>

Subjects put their right hand on the hand pressure measuring device set in front of them, and they were instructed to keep pushing on the device strongly to stabilise their posture.

<u>Task 4: OLS with sideward hand help (free hand help)</u>

This task is the same as task 1, except that the measuring device is on the right side.

<u>Task 5: OLS with sideward hand help (light hand help)</u>

This task is the same as task 2, except that the measuring device is on the right side.

<u>Task 6: OLS with sideward hand help (strong hand help)</u>

This task is the same as task 3, except the measuring device is on the right side.

2.4 Measurement Items and Evaluation Variables

For the five patterns shown in Table 2, the total time required to step on each of the eight sheets after stimulus presentation was calculated. A mean of 10 trials (5 patterns × 2 trials) was used as a parameter. A larger value was judged inferior in the capacity to evaluate the fall-avoidance movement.

2.4.1 Body sway

For all tests, the passing of the center of pressure (COP) for 30 s (sampling frequency of 20 Hz) was measured using a stabilometer (Takei Scientific Instruments Co., Ltd), and a total pass length (TPS), which is the total distance of COP movement, was calculated. This study used %TPS as an evaluated variable for body sway, which divided TPS during OLS with hand help by that during normal OLS.

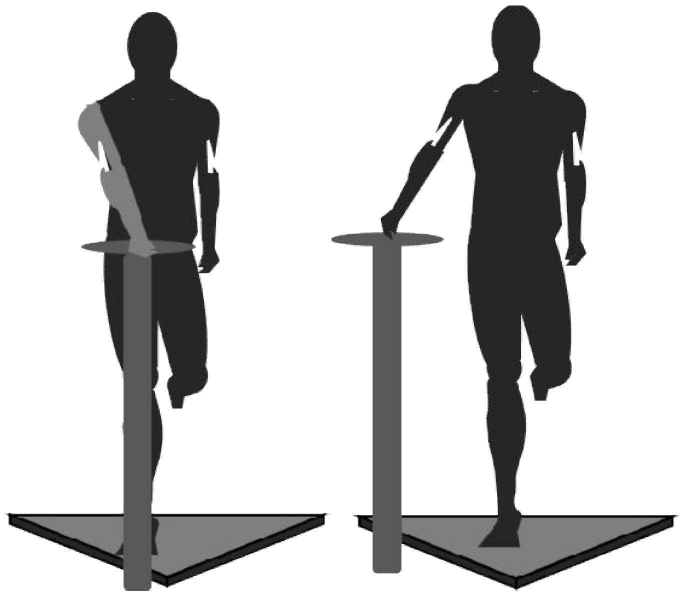

Fig. 1. OLS with hand help (right: forward help, left: sideward help)

2.4.2 Surface Electromyography (EMG)

For all tests, the surface EMG for 30 s was measured using a multichannel telemetry system (Nihon Kohden, Tokyo, Japan). This was measured with a band-pass filter of 20–500 Hz and a sampling frequency of 1,000 Hz. We used square-type active electrodes with AgCl and stick on the belly into the target muscle after rubbing the skin with alcohol. The measured EMG was translated into the root mean square (RMS) every 1 s, and we calculated the mean RMS for 30 s. This study used %RMS as an evaluated variable for EMG that divided the mean RMS during OLS with hand help by that during normal OLS.

2.4.3 Hand pressure

For all tests, hand pressure for 30 s was measured by a hand pressure measurement device (Takei scientific instruments Co., Ltd). This device can measure pressure imposed on it by 0.1 N unit. The sampling frequency was set at 20 Hz. The mean hand pressure for 30 s was used as an evaluation variable.

2.5 Statistical Analyses

Two-way analysis of variance (ANOVA) with repeated measures was used to test the differences among the means. %TPS, %RMS, and hand pressure were dependent variables, while the help position (frontal and lateral) and help methods (light touch and light support) were the independent variables. Tukey's honestly significant difference test was used for multiple comparisons if a significant interaction or main effect was found. The significance level was set at a P value of <0.05.

3. RESULTS

In this study, we used three kinds of hand help pressures (free, light, and strong). In all the subjects, the hand pressure was always kept at > 5 N for 30 s for strong hand help and at < 5 N for more than 80% of the measurement time for light hand help. In addition, the mean hand pressure in each subject was also < 5 N, and in all subjects, it was very small, at 0.454 N in forward help and 0.419 N in sideward help. In the free hand help condition, there was large variance in the subject's touch pressure: 8 persons always maintained the pressure at 5 N pressure for 30 s; however, in 4 subjects, it was < 5 N.

Table 1 shows the basic statistics of the mean hand pressure in the OLS test with hand help and the results of two-way ANOVA. The interaction was insignificant, and the main effect of hand position and pressure was significant. In the post hoc analysis, the mean hand pressure was greater in free and light pressure conditions than in strong pressure conditions in both hand positions. In addition, in strong pressure conditions only, it was greater in the forward position than in the sideward position.

Table1. Comparison of mean touch pressure (the results of repeatedmeasures two-way ANOVA)

	Free presure (Fp)		Light pressure (Lp)		Strong pressure (Sp)		F-value			Post-hoc analysis (Tukey's HSD)
	Mean	SD	Mean	SD	Mean	SD				
Forward help (Fh)	16.01	16.37	0.45	0.70	56.23	22.78	F1	6.0	*	Fp, Lp < Sp Sp : Fh > Sh
Sideward help (Sh)	12.53	16.60	0.42	1.37	41.98	21.08	F2	54.5	*	
							F3	2.7		

※ *: p<0.05
※ F1: hand help position, F2: touch pressure, F3: interaction

Table2. Comparison of total path length (the results of repeatedmeasures two-way ANOVA)

	Free presure (Fp)		Light pressure (Lp)		Strong pressure (Sp)		F-value			Post-hoc analysis (Tukey's HSD)
	Mean	SD	Mean	SD	Mean	SD				
Forward help (Fh)	0.61	0.19	0.77	0.16	0.55	0.16	F1	17.7	*	Fh: Lp < Fp, Sp Fp, Lp: Fh > Sh
Sideward help (Sh)	0.52	0.19	0.58	0.18	0.53	0.20	F2	18.7	*	
							F3	14.9	*	

※ *: p<0.05
※ F1: hand help position, F2: touch pressure, F3: interaction

Table3. Comparison of tibialis anterior muscle activity (the results of repeatedmeasures two-way ANOVA)

	Free presure (Fp)		Light pressure (Lp)		Strong pressure (Sp)		F-value			Post-hoc analysis (Tukey's HSD)
	Mean	SD	Mean	SD	Mean	SD				
Forward help (Fh)	45.35	24.55	66.18	18.63	52.63	34.12	F1	12.7	*	Fh: Lp > Fp
Sideward help (Sh)	36.65	19.01	46.71	21.29	37.52	25.04	F2	5.6	*	Lp, Sp: Fh > Sh
							F3	1.1		

※ *: p<0.05
※ F1: hand help position, F2: touch pressure, F3: interaction

Table4. Comparison of gastrocnemial muscle activity (the results of repeatedmeasures two-way ANOVA)

	Free presure (Fp)		Light pressure (Lp)		Strong pressure (Sp)		F-value			Post-hoc analysis (Tukey's HSD)
	Mean	SD	Mean	SD	Mean	SD				
Forward help (Fh)	76.60	17.45	87.39	20.13	74.75	16.43	F1	0.9		
Sideward help (Sh)	78.58	26.73	92.38	28.79	82.64	34.76	F2	14.1	*	Lp > Fp, Sp
							F3	0.6		

※ *: p<0.05

※ F1: hand help position, F2: touch pressure, F3: interaction

Table5. Comparison of solus muscle activity (the results of repeatedmeasures two-way ANOVA)

	Free presure (Fp)		Light pressure (Lp)		Strong pressure (Sp)		F-value			Post-hoc analysis (Tukey's HSD)
	Mean	SD	Mean	SD	Mean	SD				
Forward help (Fh)	73.94	24.62	90.25	17.15	77.93	25.50	F1	1.9		
Sideward help (Sh)	83.09	24.50	91.04	22.16	83.70	24.14	F2	5.9	*	Fh: Lp > Fp
							F3	1.4		

※ *: p<0.05

※ F1: hand help position, F2: touch pressure, F3: interaction

Table 2 shows the basic statistics of %TPS in the OLS test with hand help and the results of two-way ANOVA. The interaction was significant, and the post hoc analysis showed that the %TPS was longer in light pressure conditions than in the free and strong pressure conditions, but only in the forward hand positions. In addition, it is greater in the forward position than in the sideward position in the free and light pressure conditions.

Tables 3–5 show the basic statistics of %RMS in the OLS test with hand help and the results of two-way repeated ANOVA. Interactions in all muscles (gastrocnemial, soleus, and tibialis anterior muscles) were also insignificant. The %RMS of the tibialis anterior muscle was greater in the light pressure condition than in the free pressure condition, but only in the forward hand positions, and it was higher in the forward position than in the sideward position in the light and strong pressure conditions. The %RMS of the gastrocnemial muscle was greater in the light pressure condition than in the free and strong hand pressure conditions in both hand positions. The %RMS of the soleus muscle was greater in the light pressure condition than in the free hand pressure condition, but only in the forward hand position.

4. DISCUSSION

In this study we instructed subjects on three kinds of hand help pressure: with a light touch (light hand help), with strong pressure support while keeping a stable posture (strong hand help), and with no attention to hand pressure (free hand help). The touch pressure during the 30-s OLS test was almost under 5 N (over 24 s) in light hand help, and always over 5 N in the strong hand help, regardless of help direction. In addition, the mean touch pressure was larger in the free and strong hand pressure conditions than in the light hand pressure condition. Thus, help pressure differs between light touch (light hand help) and strong pressure support clearly, and the subjects could not gain mechanical support with hand help in the light touch conditions due to the very low touch pressure. A difference of mean touch pressure was not found between light and free hand help. Great variability among subjects in both test tasks affected this results. Generally, people with superior balance do not lose balance and hardly need hand help during the OLS, because they can do the OLS easily. However, people with inferior balance ability have great body sway during OLS and need the hand help to maintain stable posture. Hence, variability was great in both tasks without it being necessary to always apply strong pressure support in order to keep a stable posture.

In a strong hand help task, the mean touch pressure was smaller in sideward help than in forward help. When the elderly use hand help during OLS, their postural stability is enhanced more by sideward hand help than by forward hand help [14]. In the report by Uchida et al. [13], when using the two hand help methods of light touch (touch under 1 N) and force touch (touch of 5–10N), postural stability during OLS with forward hand help differed little between the two methods, but with the sideward hand help, force touch decreased. This suggests that even light touch has high postural stability in OLS with sideward help. Also, in this study, because subjects got enough stability by applying lighter hand pressure in sideward hand help than in forward hand help, a difference in hand pressure was found between hand help positions.

Body sway during OLS with free or light hand help was greater in forward hand help than in sideward hand help. In addition, that with forward hand help was greater in light hand help than in free and strong hand help. Postural stability gained by hand help is considered to be caused by “adding afferent information from a hand” and “mechanical support by hand help.” In this study, the touch pressure was almost under 5 N during light hand help. However, it always exceeded 5 N during strong hand help, and the mean touch pressure was also great (forward hand help 56.23 N, sideward hand help 41.98 N). It is possible that afferent information from a hand produces high postural stability in the light hand help condition and in the strong hand help condition, postural stability is enhanced more by adding mechanical support through hand help.

In sideward hand help, a difference of body sway among hand help methods was not found. When using the sideward help, the total path length is small (0.58), even in the light hand help condition, and it is almost the same value as in the strong hand help condition when using forward hand help. It is inferred that because sufficient postural stability was achieved, even in the light touch condition, body sway did not show a difference from that in the strong hand help condition. As stated previously, sideward hand help has high postural stability even in the light touch condition. When performing the OLS test, because of the elongated shape of the foot, the support base is longer in the sagittal plane and shorter in the coronal plane.

The closer the center of gravity is to an edge of the support base, the more difficult it is to maintain a stable posture [18]. Therefore, postural control to sway of the left-right direction with the shorter support base is more difficult. Bove et al. [12] reported that, in the light touch condition, touch in the direction of the sway enhanced postural stability more. Even when using light hand help, the sideward hand help with higher difficulty of postural control may produce more postural stability during the OLS.

In all targeted muscle groups, muscle activity in the light hand help condition tended to be the most active. In addition, the tibialis anterior muscle was more active in forward hand help than in sideward hand help. Generally, standing posture is kept by backward torque of the ankle joints, because the center of gravity is in front of the ankle joints. The backward joint torque was adjusted by “activity of the muscle groups related to planter flexion based on various afferent information” and “stiffness of ankle joints.” The former requires work to adjust the shift of center of gravity through activity of the muscle groups related to planter flexion based on afferent information, and the latter requires work to suppress body sway by enhancing the stiffness surrounding the ankle joints with co-contraction of the muscle groups related to them. In the more unstable light hand help condition, the gastrocnemial and soleus muscles worked to adjust to a shifted center of gravity and the tibialis anterior muscle worked to enhance the stiffness of the ankle joints.

We examined how the instability of the posture and the lower limb muscle activity that are believed to influence the balance ability differ among various hand help instructions. It may be inappropriate as balance training if the instability of posture and lower limb muscle activity decrease extremely by the hand help. We have added studies regarding the effectiveness of balance training and have shown that instability of posture and lower limb muscle activity are related to the balance ability. Furthermore, we explained to examine how they differ by hand help instructions in this study. In addition, the present subjects were elderly persons who could perform 30-s OLS and had relatively good balance. Differences in postural stability and leg muscle activity between free and strong hand pressure conditions were not found. Hence, even in the absence of special instruction regarding hand help pressure in OLS training, the elderly in this study with superior balance ability may be able to perform it safely while maintaining a stable posture. However, because to use forward hand help with a light hand can produce unstable posture and leg muscle activity, it may be an effective OLS training method. Further studies using various elderly groups with different OLS ability will be needed, because the effect of hand help depends on balance ability.

5. CONCLUSION

In conclusion, although OLS posture stabilises with the use of strong hand help pressure in the forward hand help position, postural stability may be unchanged by a difference of help pressure in the sideward hand help. Even with free and light hand help pressure conditions, the elderly can have enough postural stability in sideward hand help, but in forward hand help, light hand help pressure condition leads to a loss of postural stability and causes active work of leg muscle groups.

ACKNOWLEDGEMENT

This work was supported by JSPS KAKENHI Grant Number JP 15K12697.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/27741