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The Effect of Weight Bearing Symmetry on Dynamic Postural Control During Bending and Reaching in Chronic Stroke Patients

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Abstract

Background: The majority of hemi-paretic stroke patients showed weight bearing asymmetry effects on postural control during bending and reaching tasks. The purSpose of this study was to investigate the effect improving weight bearing asymmetry using 5˚ and 7.5˚ lateral shoe wedges on dynamic postural control of chronic stroke patients during bending and reaching.

Methods: Seventeen hemi-paretic patients (10 female and 7 male, 11 left hemiparesis and 6 right hemiparesis), and weight bearing asymmetry more than 10% during standing participated in this study. Postural sway parameters were computed for six targets (2 distances and three directions) in four conditions of wedges: non- wedge, wedge 5˚, wedge 7.5˚ and last non wedge during bending and reaching tasks.

Results: There were no statistical differences between the effects of two types of lateral shoe wedges (5˚ and 7.5˚) on symmetry index and postural sway parameters. The main effects of target were significant for all body sway parameters but the main effects of wedges were only significant for sway path and velocity. Interaction effects of target by wedge were not significant for any of sway parameters.

Conclusion: Lateral shoe wedges have a positive effect on dynamic postural control of stroke patients. This method may be used to treat postural control deficits during bending and reaching tasks in stroke rehabilitation.

Keywords: Weight-Bearing, Balance, Stroke

Conflicts of Interest: *The authors have no conflict of interest in this study.*
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Introduction

Balance is the maintenance of the center of body mass in the limit of stability [1]. Balance impairments are frequently seen in hemiparesis stroke patients which is caused by changes in muscle strength, joint range of motion, muscle tone, sensory inputs and sensory motor integration. This issue associates with functional dependence in this population [2].

The majority of stroke patients have many problems in doing daily tasks which require postural control during standing, walking, sitting up , bending and reaching [3-5]. Bending and reaching are voluntary tasks that require active transfer of center of body mass in order to control dynamic balance [3, 6, 7]. Since these dynamic tasks have more postural control demands, hemi-paretic stroke patients are more likely to fall while doing them.

Another problem for many hemiparesis patients is weight bearing asymmetry during bending and reaching tasks, with

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↑What is "already known" in this topic:
Using lateral shoe wedges can improve weight bearing asymmetry in hemiparesis stroke patients.

→What this article adds:
Improvement of weight bearing asymmetry can improve dynamic postural control during bending and reaching in hemiparesis stroke patients.

more weight on the sound limb [3, 4, 6]. Postural asymmetry in these people may be caused by learned non-use theory, meaning that the affected limb cannot bear body weight because of sensory and motor impairments. Hence, the person do not use his/her paretic limb [8]. Weight bearing asymmetry exacerbates balance deficits [9-11] and may disturb ones' bending and reaching function. As previous studies reported that hemiparesis patients usually show larger center of pressure excursion and average velocity during bending and reaching [12, 13].

Many studies have reported the use lateral shoe wedges for treatment of weight bearing asymmetry and balance improvement in stroke patients [9, 10, 14]. However, there is no evidence available yet on the use of this technique for improving balance control during bending and reaching in stroke patients. The aim of this study was to evaluate the effects lateral shoe wedges (5˚ and 7.5˚ wedges) on postural sway parameters during bending and reaching in hemi-paretic patients.

Methods

Participants

Participants were those with chronic unilateral hemiparesis selected by non- random sampling method. The inclusion criteria were: (a) no cognitive impairment according to Mini Mental Status Examination (MMSE); [15] (b) no visual-spatial neglect by Star Cancellation Test (>44); [16] (c) weight bearing asymmetry more than 10% during standing [14], according to measures of two standard analog weight scales; (d) the ability to perform bending and reaching independently in different distances and directions; (e) no history of other neurological diseases or orthopedic problems. The spasticity of plantar flexor muscle group of the lower extremity was assessed according to Modified Ashworth Scale by using procedure described in the literature [17]SS .

The exclusion criteria were inability to perform all the tests and falling during bending and reaching. The subjects were informed of the examination protocol and gave their written consent in accordance with Tehran University of Medical Sciences ethics committee (Ethic Number: 91.S.260.2008).

Procedure

COP coordinates were recorded using a strain gauge Bertec 9090-15 and Bertec AM-6701 amplifier (Bertec corporations, Columbus, Ohio, USA) force platform at a frequency of 100 Hz with 12 second recording time for each trial. The postural sway parameters were the COP Total Path Excursion (TPE), the Average COP Velocity (AV), the Maximum COP displacement in Medial- Lateral direction (MML) and the Maximum COP displacement in Anterior-posterior direction (MAP)[3, 6] and were computed for six targets individually. Previous studies have shown the reliability for COP parameters [18, 19].

The subjects were instructed to stand relaxed, look straight ahead while both feet were shoulder width apart and their arms at their sides. The anterior border of each shoe was aligned with the transverse force platform line. The subjects were asked to perform bending and reaching in different targets. A total of 6 targets (two distances and three directions) were selected for doing bending and reaching tasks. The near and far distances were ten and thirty percent of the body height away from the middle of the tips of the two big toes, respectively [3, 6]. The three directions were middle (M), left (L) and right (R) with 45 degrees angle between lines [6].

Nine sizes of closed toe shoes with a rigid counter, two types of full- shoe wedged insoles (5˚ and 7.5˚) with the length of the corresponding shoes made of Ethylene Vinyl-Acetate were used. The highest part of the wedge was placed under the lateral part of the sound limb [14, 20].

The bending and reaching task was performed in four conditions of wedge: non wedge, wedge 5˚, wedge 7.5˚ and last non wedge. The order of the distances and directions changed randomly for each subject but all subjects performed bending and reaching tasks with the order of non-wedge, wedge 5˚, wedge 7.5˚ and last non wedge.

Weigh bearing of patients was assessed by two standard analog weight scales for determining the symmetry index. These scales are good and useful instruments to assess symmetry in weigh bearing [4, 21] and were used in previous studies [22, 23]. This instrument reports a quantitative data (Kilogram) for the amount of weigh bearing during standing. Both scales were located on the floor between parallel lines (two lines in medial-lateral direction and two other lines in anterior-posterior direction). The symmetry index between paretic and non-paretic limbs was calculated during standing in three conditions (non-wedge, wedge 5˚and wedge 7.5˚).

Data and Statistical Analysis

Measures determined from COP data were TPE, AV, MML and MAP. The COP parameters during bending and reaching were calculated according to the formula given by Chern J-S and et.al. [3, 6]. The average of two trials for all parameters in each target was used for statistical analysis. The symmetry index (SI) between two limbs during standing was determined according to the formula proposed by Chen CH et al. The range of SI changed between -200% to +200%, which a SI of 0% shows that weigh bearing symmetry is maximum [14].

The comparison of symmetry index between three conditions (non- wedge, wedge 5˚and wedge 7.5˚) was done by repeated measures ANOVA. Postural actions were analyzed using separate 4 (wedge) × 6 (target) two way analyses of variance for repeated measures to determine possible significant main effects and interactions of the two within- subject factors for each one of the COP parameters in the presence of significant effects. Multiple comparison of post hoc analysis was considered using Bonferroni adjustment method.

Kolmogorov-Smirnov tests for normality were used to determine the presence of a normal distribution and results indicated that the data were normally distributed in all postural sway parameters and symmetry index. 5 percent level of confidence was considered for statistical analyses.

Results

Table 1. Mean (Standard Deviation) of all parameters of COP measures

Target	Left-Near	Left- Far	Right- near	Right-Far	Middle- Near	Middle- Far
TPE(1/cm^2)						
Non-Wedge	0.0078(0.0029)	0.0028(0.0007)	0.0072(0.0022)	0.0029(0.0009)	0.0070(0.0020)	0.0030(0.0011)
Wedge 5°	0.0068(0.0018)	0.0028(0.0006)	0.0068(0.0019)	0.0028(0.0009)	0.0070(0.0024)	0.0026(0.0007)
Wedge 7.5°	0.0067(0.0017)	0.0028(0.0008)	0.0064(0.0018)	0.0027(0.0008)	0.0073(0.0024)	0.0025(0.0006)
Last Non- Wedge	0.0067(0.0021)	0.0026(0.0007)	0.0068(0.0020)	0.0025(0.0007)	0.0066(0.0017)	0.0025(0.0006)
AV(cm/s)						
Non-Wedge	5.5767(1.4667)	6.4672(1.2173)	5.3420(1.5313)	6.4681(1.8888)	5.2977(1.3619)	6.3000(1.6746)
Wedge 5°	5.1412(0.8426)	5.7920(0.8719)	5.2224(1.0265)	6.1342(1.5412)	5.2976(1.3619)	5.9865(1.2641)
Wedge 7.5°	5.0772(1.0403)	6.0909(0.8537)	4.9752(1.0523)	5.8706(1.2132)	5.3078(1.1623)	6.0012(1.0612)
Last Non- Wedge	4.9482(1.1090)	5.8728(0.7866)	4.8873(0.9806)	5.6498(1.1514)	5.0170(1.1213)	5.7083(0.9838)
MML([ ])						
Non-Wedge	0.3750(0.1266)	0.4250(0.1061)	0.3157(0.1243)	0.4123(0.1738)	0.3162(0.1039)	0.4346(0.1959)
Wedge 5°	0.3748(0.8709)	0.3999(0.0904)	0.3239(0.1287)	0.4365(0.1673)	0.3287(0.0984)	0.3601(0.0944)
Wedge 7.5°	0.3444(0.8915)	0.4061(0.1038)	0.3153(0.1077)	0.4091(0.1335)	0.3694(0.1286)	0.4007(0.1303)
Last Non- Wedge	0.3448(0.9173)	0.4058(0.1160)	0.3358(0.1213)	0.4223(0.1729)	0.3358(0.0874)	0.3601(0.0944)
MAP(1/cm)						
Non-Wedge	0.0167(0.0027)	0.0065(0.0014)	0.0163(0.0033)	0.0068(0.0011)	0.0165(0.0031)	0.0072(0.0012)
Wedge5°	0.0168(0.0041)	0.0065(0.0012)	0.0162(0.0050)	0.0073(0.0017)	0.0164(0.0043)	0.0073(0.0013)
Wedge 7.5°	0.0166(0.0027)	0.0067(0.0014)	0.0159(0.0030)	0.0066(0.0012)	0.0159(0.0022)	0.0070(0.0013)
Last Non- Wedge	0.0153(0.0038)	0.0063(0.0013)	0.0158(0.0025)	0.0066(0.0016)	0.0161(0.0036)	0.0069(0.0013)

TPE, Total Path Excursion; AV, Average COP Velocity; MML, Maximum COP Displacement in Medial- Lateral Direction; MAP, Maximum COP Displacement in Anterior-posterior Direction

Seventeen chronic unilateral hemiparesis patients (10 female, and 7 male, 11 left hemiparesis and 6 right hemiparesis), with mean age of 53.18±9.88 years, mean post stroke time of 66.18±77.03 months, average height 165± 8.43 cm and mean weight 76.03±17.09 Kg with first stroke participated in this study. Results of descriptive data analysis for all parameters of postural sway were shown in Table 1.

Results of two- way repeated measures ANOVA for the main and interaction effects of wedges and targets for all measures of postural sway were indicated in Table 2. The main effects of target were significant in all parameters of COP measures and the main effects of wedges were only significant in TPE and AV parameters. The interaction effects of target by wedge were not significant for any of sway parameters.

The results of post hoc analysis in different conditions of wedges and targets for all COP measures are presented in Tables 3 to 5.

Table 2. Results of Mixed ANOVA summary for the wedges and targets interaction effects of postural sway parameters

	DF	MS	F	p
TPE				
Targets	5	0.01	145.168	0.000*
Wedges	3	7.545E-6	5.997	0.008*
Targets× Wedges	15	3.318E-6	1.751	0.147
AV				
Targets	5	15.016	13.799	0.000*
Wedges	3	9.168	7.401	0.003*
Targets× Wedges	15	0.722	1.306	0.259
MML				
Targets	5	0.292	5.88	0.008*
Wedges	3	0.007	0.631	0.512
Targets× Wedges	15	0.018	1.746	0.118
MAP				
Targets	5	0.004	200.749	0.000*
Wedges	3	1.033E-5	1.703	0.198
Targets× Wedges	15	3.630E-6	0.430	0.847

*P<0.05

DF, Degree of Freedom; MS, Mean Square; TPE, Total Path Excursion; AV, Average COP Velocity; MML, Maximum COP Displacement in Medial- Lateral Direction; MAP, Maximum COP Displacement in Anterior-posterior Direction

Table 3. The results of post hoc analysis in multiple comparison between different types of wedges

	TPE(1/cm^2)	AV(cm/s)	MML([ ])	MAP(1/cm)
NW with W5°	0.004*	0.000*	0.208	0.709
NW with W7.5°	0.004*	0.000*	0.625	0.386
NW with LNW	0.000*	0.000*	0.256	0.051
W5° with w7.5°	0.484	0.564	0.346	0.293
W5° with LNW	0.054	0.001*	0.846	0.032
W7.5° with LNW	0.249	0.002*	0.437	0.153

*P<0.0083

NW, Non- Wedge; W5°, Wedge 5°; W7.5°, Wedge 7.5°; LWN, Last Non- Wedge; TPE, Total Path Excursion; AV, Average COP Velocity; MML, Maximum COP Displacement in Medial- Lateral Direction; MAP, Maximum COP Displacement in Anterior-posterior Direction

Table 4. The results of post hoc analysis in multiple comparison between different types of targets

	TPE(1/cm^2)	AV(cm/s)	MML([ ])	MAP(1/cm)
LN with LF	0.000*	0.000*	0.000*	0.000*
LN with RN	0.230	0.334	0.019	0.498
LN with RF	0.000*	0.000*	0.001*	0.000*
LN with MN	0.931	0.650	0.212	0.759
LN with MF	0.000*	0.000*	0.011	0.000*
LF with RN	0.000*	0.000*	0.000*	0.000*
LF with RF	0.782	0.867	0.618	0.119
LF with MN	0.000*	0.000*	0.000*	0.000*
LF with MF	0.449	0.611	0.252	0.000*
RN with RF	0.000*	0.000*	0.000*	0.000*
RN with MN	0.272	0.104	0.151	0.688
RN with MF	0.000*	0.000*	0.000*	0.000*
RF with MN	0.000*	0.000*	0.000*	0.000*
RF with MF	0.514	0.741	0.034	0.070
MN with MF	0.000*	0.000*	0.001*	0.000*

*P< 0.0033
LN, Left- Near; LF, Left Far; RN, Right- Near; RF, Right Far; MN, Middle Near; MF, Middle Far; TPE, Total Path Excursion; AV, Average COP Velocity; MML, Maximum COP Displacement in Medial- Lateral Direction; MAP, Maximum COP Displacement in Anterior-posterior Direction

Table 5. Results of post hoc analysis in multiple comparison of different types of wedges and targets for all postural sway parameters

	Wedges					
Targets	**NW with W5°**	**NW with W7.5°**	**NW with LNW**	**W5° with W7.5°**	**W5° with LNW**	**W7.5° with LNW**
Left- Near						
TPE(1/cm^2)	0.034	0.048	0.047	0.734	0.694	0.916
AV(cm/s)	0.100	0.052	0.014	0.625	0.175	0.374
MML([ ])	0.355	0.399	0.373	0.848	0.841	0.983
MAP(1/cm)	0.912	0.903	0.160	0.822	0.027	0.094
Left- Far						
TPE(1/cm^2)	0.046	0.444	0.051	0.305	0.976	0.257
AV(cm/s)	0.001*	0.049	0.001	0.127	0.599	0.138
MML([ ])	0.339	0.381	0.460	0.769	0.768	0.983
MAP(1/cm)	0.986	0.458	0.599	0.337	0.374	0.075
Right- Near						
TPE(1/cm^2)	0.252	0.036	0.239	0.048	0.778	0.102
AV(cm/s)	0.556	0.078	0.023	0.062	0.039	0.480
MML([ ])	0.732	0.985	0.215	0.718	0.536	0.363
MAP(1/cm)	0.933	0.658	0.505	0.756	0.719	0.930
Right- Far						
TPE(1/cm^2)	0.434	0.035	0.011	0.228	0.002	0.126
AV(cm/s)	0.244	0.015	0.016	0.136	0.033	0.166
MML([ ])	0.266	0.885	0.542	0.161	0.479	0.518
MAP(1/cm)	0.124	0.617	0.601	0.059	0.013	0.817
Middle- Near						
TPE(1/cm^2)	0.814	0.384	0.186	0.517	0.187	0.132
AV(cm/s)	---	0.958	0.055	0.958	0.055	0.195
MML([ ])	0.380	0.006*	0.365	0.063	0.629	0.228
MAP(1/cm)	0.863	0.318	0.566	0.666	0.786	0.825
Middle-Far						
TPE(1/cm^2)	0.052	0.046	0.046	0.356	0.356	---
AV(cm/s)	0.089	0.253	0.070	0.947	0.300	0.094
MML([ ])	0.058	0.420	0.058	0.071	---	0.071
MAP(1/cm)	0.481	0.380	0.188	0.135	0.051	0.759

T*P<0.0083
NW, Non- Wedge; W5°, Wedge 5°; W7.5°, Wedge 7.5°; LWN, Last Non- Wedge; TPE, Total Path Excursion; AV, Average COP Velocity; MML, Maximum COP Displacement in Medial- Lateral Direction; MAP, Maximum COP Displacement in Anterior-posterior Direction

Single- factor repeated measure ANOVA demonstrated the effect of lateral shoe wedges on SI which was significant and SI decreased strongly with lateral shoe wedges. The results of post hoc analysis in multiple comparisons for different types of wedges of SI are presented in Table 6.

Table 6. The results of post hoc analysis in multiple comparisons between different types of wedges for symmetry index

	Symmetry Index
NW with W5°	0.010*
NW with W7.5°	0.011*
W5° with w7.5°	0.577

*P<0.017
NW, Non- Wedge; W5°, Wedge 5°; W7.5°, Wedge 7.5°

Discussion

The rationale for this research was to provide the useful management for postural control during bending and reaching in stroke patients by lateral shoe wedges. This program was based on providing of weight bearing symmetry between paretic and non-paretic lower limbs. The results of this study indicated that the use of shoe wedges caused significant decrease of TPE and AV in bending and reaching task. Although the results did not show significant differences after use of shoe wedge for MML and MAP of COP measures, there was a tendency for a decrease in these parameters of COP.

Previous studies indicated that COP displacement and mean velocity of postural sway in quiet standing [24], moving of body segments [7, 24], and even bending and reaching [6] conditions were greater in stroke patients than normal subjects which may indicate difficulty in stability and postural control [6, 24, 25]. They reported that larger COP displacement and average velocity may be due to changed postural adjustment in the control of balance during moving of body segments and bending and reaching that causes irregular COP trajectory with greater safety margin or might be because of impaired sensory inputs, improper sensory integration and neuromuscular control and changed muscular group synergies in stroke patients [6, 7, 24].

Former studies suggested that asymmetric condition also restricts stability limits of balance and produces an unstable postural control in stroke patients [10]. The results of this study have shown that the use of shoe wedge increases the tendency to bear more weight on the affected side and decreases symmetry index [14, 20], that may increase stability and this result may lead to decreased TPE and AV. Also previous studies showed that increase in weight bearing on the affected side in stroke patients increases sensory inputs to the central nervous system and may improve standing and gait symmetry after the use of shoe wedges [14, 20]. Thus, decreased postural sway displacement and velocity in this study may indicate increased sensory feedback and sensory motor integration. Also according to previous findings [6, 24], increasing of weight bearing on the affected limb decreased postural sway due to increased neuromuscular activation and improved muscular activation pattern of postural muscles in the lower extremity in stroke patients.

Previous studies demonstrated that latency in balance response was greater and strength of the muscle response was weaker on the affected side in stroke patients and by increasing weight bearing symmetry, latency of postural response decreased and strength of the muscle responses increased in the affected side in stroke patients [10] So using wedges for providing weight bearing symmetry may improve postural stability. The current study showed that weight bearing symmetry increased after using both 5˚ and 7.5˚ shoe wedges. These results supported the results of previous researches that said applying 5˚ and 7.5˚ lateral shoe wedges increases weight bearing symmetry [14, 20]. Some researchers reported that these results may be caused by movement of the center of gravity from the unaffected limb toward the midline and subsequently improvement of the stability [9, 20]. Previous studies reported that using a lateral wedge insole could increase hip, knee and ankle control [14, 26, 27] and decreases the affected knee abductor moment during ambulation [14]. Thus beneficial effects of lateral shoe wedge is to transfer more weight to the affected side and improvement of balance action during bending and reaching.

In addition, many stroke patients have varus foot in the affected limb and using lateral shoe wedge might increases foot pronation and subsequently increases ankle joint stability and shock absorption [14, 26, 27]. This condition may improve balance action during bending and reaching in the current study. Also these results might be caused by increased brain awareness of position of body and of the affected limb [14].

Our results indicate that after removing the lateral shoe wedges, their effects on TPE and AV remained. This result may be interpreted as the short term effect of lateral shoe wedges, but its long term effect should be further investigated.

There were no statistical differences between the effects of two types of lateral shoe wedges (5˚ and 7.5˚) on SI, TPE and AV, indicating that 5˚ lateral shoe wedge was probably sufficient for production of weight bearing symmetry and improvement of balance performance. Also the results of this study showed that there were significant differences between different target distance and direction, but the interaction effect of wedge and target were not significant for any of postural sway parameters, illustrating that the wedge differences on TPE and AV were not affected by the target location.

Increasing of weight bearing symmetry may decrease falling of stroke patients which is assossiated with weight bearing asymmetry [20], but this hypothesis needs more investigation in future.

Study limitations: The limitation of our study was the short-term usage of lateral shoe wedge during bending and reaching. So, additional studies are needed to indicate that whether lateral shoe wedge has consistent effect on balance performance of hemi-paretic stroke patients.

Conclusion

A lateral shoe wedge has a positive effect on postural actions in stroke patients. Also this technique can be used to improve weight bearing symmetry in these patients. This method might be used to treat the "learned nonuse syndrome" in rehabilitation during bending and reaching in stroke patients. Also, these results confirmed that this technique may be beneficial during all daily activities.

Conflict of Interests

The authors declare that they have no competing interests.

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تاثیر تقارن در تحمل وزن بر ویژگی های کینتیک کنترل وضعیتی در خم شدن و رساندن دست به شیء در بیماران مبتلا به سکته مغزی مزمن

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چکیده

مقدمه: بیشتر بیماران همی پارزی عدم تقارن در تحمل وزن را نشان می‌دهند که روی کنترل وضعیتی در تکلیف خم شدن و رساندن دست به شیء تاثیرگذار است. هدف از این مطالعه بررسی تاثیر تقارن در تحمل وزن با استفاده از کفی با گوه خارجی 5 و 7/5 درجه بر ویژگی‌های کینتیک کنترل وضعیتی بیماران سکته مغزی مزمن در حین خم شدن و رساندن دست به شیء می‌باشد.

روش‌ها: در این مطالعه 17 بیمار همی پارزی (10 زن و 7 مرد، 11 همی پارزی چپ و 6 همی پارزی راست) با بیش از 10 درصد اختلاف تحمل وزن میان اندام‌های تحتانی در حالت ایستاده، شرکت کردند. پارامترهای نوسان وضعیتی در حین خم شدن و رساندن دست به شیء در 6 موقعیت هدف (در دو فاصله و سه جهت) و در چهار وضعیت قبل از استفاده از کفی با گوه خارجی، حین استفاده از کفی با گوه خارجی 5 درجه، حین استفاده از کفی با گوه خارجی 7/5 درجه و پس از استفاده از کفی با گوه خارجی توسط صفحه نیرو محاسبه شد.

یافته‌ها: تفاوتی میان تاثیر دو نوع کفی با گوه خارجی 5 و 7/5 درجه بر شاخص تقارن و پارامترهای نوسان وضعیتی وجود نداشت. تاثیر اصلی موقعیت هدف در تمامی پارامترهای نوسان وضعیتی معنادار بود، اما تاثیر اصلی کفی با گوه خارجی فقط در کل مسیر طی شده و میانگین سرعت نوسانات وضعیتی معنادار بود. تاثیر متقابل موقعیت هدف و کفی با گوه خارجی در هیچ یک از پارامترهای نوسان وضعیتی معنادار نبود.

نتیجه‌گیری: تقارن در تحمل وزن تاثیر مثبتی بر کنترل وضعیتی پویای بیماران همی پارزی دارد. این روش می‌تواند برای کاهش مشکلات کنترل وضعیتی در توانبخشی بیماران سکته مغزی حین تکلیف خم شدن و رساندن دست به شیء مورد استفاده قرار گیرد.

کلیدواژه‌ها: تحمل وزن، تعادل، سکته مغزی

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