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The Effects of Arm Restriction on Stabilization Step With Respect to Barrier Height

Kwon Oh-yun, Ph.D., R.P.T.
Dept. of Rehabilitation Therapy, Hanseo University
Jang Kyung-wook, Ph.D.
Dept. of Materials Science and Engineering, Hanseo University
Kim Tack-hoon, M.P.H., R.P.T
Dept. of Physical Therapy, Yeong Dong Junior College

국문요약

장애물 높이에 따른 상지 팔운동 제한이 스텝안정화 (stabilization step)에 미치는 영향

권오윤
한서대학교 재활치료학과
장경욱
한서대학교 재료공학과
김택훈
영동전문대학 물리치료과

본 연구의 목적은 장애물 높이에 따른 상지 팔운동 제한이 스텝안정화(stabilization step)에 영향을 주는지 알아보기 위하여 실시하였다. 연구대상자는 대학생 남자 14명, 여자 16명으로 총 30명이었으며, 평균 연령은 21.5세이었다. 스텝 안정화는 FASTEX (functional activity system for testing and exercise, Cybex Division of Lumex, Inc., USA)를 이용하여 측정하였다. 장애물의 조건은 1) 장애물이 없는 조건 2) 15 ㎝ 장애물 3) 25 ㎝ 장애물이었고, 팔 운동의 제한 조건은 1) 팔운동을 제한하지 않은 조건 2) 우세 팔의 운동 제한 3) 양쪽 팔을 모두 제한하는 3개의 조건에서 스텝 안정화 시간을 측정하였다. 장애물 요인과 팔운동 제한 요인간에 안정화 시간(stabilization time)의 차이가 있는지 알아보기 위하여 반복이 있는 2요인 분산분석을 실시하였고, 남녀간에 안정화 시간에 차이가 있는지 알아보기 위하여 t-검정을 실시하였다

장애물이 없는 조건에서 양팔의 운동을 제한하지 않고 측정한 안정화 시간의 평균은 0.89초이었고, 건측의 상지운동을 제한한 상태에서의 평균은 0.88초이었으며, 양쪽 팔의 운동을 모두 제한했을 때의 평균은 0.84초이었다 15 ㎝의 장애물이 있는 조건에서 양팔의 운동을 제한하지 않고 측정한 안정화 시간은 평균 0.98초이었고, 건측의 상지운동을 제한한 상태에서의 평균은 1.00초이었으며, 양쪽 팔의 운동을 모두 제한했을 때의 평균은 1.14초이었다 25 ㎝의 장애물이 있는 조건에서 양팔의 운동을 제한하지 않고 측정한 안정화 시간은 평균 1.09초이었고, 건측의 상지운동을 제한한 상태에서의 평균은 1.28초이었으며, 양쪽 팔의 운동을 모두 제한했을 때의 평균은 1.57초이었다. 남녀간

의 스텝 안정화 시간에 차이가 있는지 알아본 결과 각각의 조건에서 통계학적으로 유의한 차이가 없었다. 장애물과 팔운동 제한 조건에 따른 스텝 안정화 시간의 차이가 있는지 알아보기 위하여 반복이 있는 2요인 분산분석을 실시한 결과, 장애물의 높이에 따라 스텝 안정화 시간에는 유의한 차이가 있었고($p<0.05$), 15 ㎝, 25 ㎝ 장애물 조건에서는 팔운동 제한 조건에 따른 스텝 안정화 시간에도 유의한 차이가 있었지만($p<0.05$), 장애물이 없는 조건에서는 팔운동 제한에 따른 안정화 시간에는 유의한 차이가 없었다.

이상의 결과는 보행중 장애물을 넘고, 한발로 기립하여 안정성을 유지할 때 팔의 운동이 스텝 안정성에 영향을 미친다는 것을 알았고, 이러한 결과는 한팔 또는 두 팔을 사용할 수 없는 편마비환자나 상지 절단환자의 균형 평가나 치료시 고려되어져야 할 것이다.

핵심단어: 균형; 스텝안정화; 안정화 시간.

Introduction

Human balance is maintained through a complex process involving sensory detection of body motions, integration of sensori-motor information within the central nervous system, and execution of appropriate musculoskeletal response (Nashner, 990).

The task of maintaining in-place (ie, "static" balance during standing and sitting) is different from maintaining balance when a person is moving from point A to point B (ie, "dynamic" balance during walking) (Woollacott and Tang, 1997). Patla (1993) suggested two balance control mechanisms for maintaining equilibrium during human walking. The first mechanism, the proactive control mechanism, refers to the balance control mechanism that take place before the body encounters a potential threat to stability. This mechanism is to activate muscles or generate joint torques to reduce the inherent biomechanical threats to balance during normal walking. This proactive control involves an early detection of potential environmental hazards and the implementation of postural and locomotion adjustments prior to the actual contact with the hazards. The visual system is the key to an early detection of potential balance threats (Chen et al, 1996).

If balance threats are not detected in advance, the reactive control mechanism is needed. Then, a person has to evoke automatic postural responses to quickly regain balance. The difference between reactive control mechanism and proactive control balance mechanism is that the former primarily relies on the somato-sensory and vestibular systems to determine the extent and type of threat and to trigger appropriately scaled postural responses (Patla and Rietdyk, 1993).

Whole body postural stability is archived through the concurrent action of muscles at all segment levels (Keshner, 1990). The dynamic response of a limb is usually associated with its posture (Hogan et al, 1987). The arm movements are associated with postural adjustments while walking (Nashner, 1986). Changes in leg joint angles revealed a "hip-ankle strategy" during shoulder flexions and an "ankle strategy" during shoulder extension (Aruin and Latash, 1995). Patla and Rietdyk (1993) reported that the movement of the swing limb was modulated according to the barrier height, but not the barrier width, provided that the goal of the person was to step over, rather than around, the obstacle. The aforementioned studies suggest that the arm movements are associated with stabilization step So we hypothesized that the arm movement restrictions could have an effect on stabilization step with respect to barrier height. The purpose of our research was to study the effects of arm restriction with respect to different barrier height

Materials and Methods

Subjects

Thirty healthy subjects were used for this study: 14 men and 16 women, with an average age of 21.5 (range, 19 to 30 years). Male subjects had a mean of 21.8 years of age, 172.4 ㎝ in height, 66.4 ㎏ in weight. Female subjects had a mean of 21.2 years of age, 159.5 ㎝ in height, 57.4 ㎏ in weight. A description of the subjects is shown in Table 1. None of the subjects had a recent or remote history of significant lower extremity injury, and none had experienced muscle weakness, joint deformity or limited range of motion of the lower extremities. Also no subject had a history of vestibular or central nervous system problem.

Procedures for data collection

Stabilization step was measured by FASTEX (functional activity system for testing and exercise, Cybex Division of Lumex, Inc., USA). Measurements included stabilization time. From a standing position, the subjects were asked to step forward and land on his/her dominant leg and attempts to stabilize as quickly as possible Two platforms were used. Platform "A" was the starting platform and platform "B" was the target platform. Platform "B" was placed approximately 25 ㎝ from the edge of platform "A" Various barriers are placed between two platforms.

To test the dominant leg, the subject stood on the edge of platform "A" with both legs facing target platform. The subject focused on the target platform and not on the computer screen. After waiting for an audio cue generated from the computer, the subject stepped forward leading with the dominant leg and landing on the target platform with his/her

Table 1. Values for age, weight, and height

Gender	Age (yr)		Height (㎝)		Weight (㎏)	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Male (n_1=14)	21.8 (3.5)	19~30	172.4 (4.1)	164~177	66.4 (9.5)	57~92
Female (n_2=16)	21.2 (1.8)	19~22	159.5 (5.9)	146~168	49.5 (6.6)	40~68
Total (N=30)	21.5 (2.7)	19~30	165.5 (8.3)	146~177	57.4 (11.7)	40~92

dominant leg and stabilizes as quickly as possible. The stabilization time was calculated by the computer.

The stabilization time was calculated by measuring the time from the initial contact with the target platform until the signal was maintained within the preset voltage threshold (the vertical scale) for the entire preset period time (the horizontal scale). We adjusted the vertical and horizontal thresholds as .070 v, and .250 sec, respectively. To avoid learning effect, trials were carried out 20 times. After each set of 3 repetitions, we took the mean value as the score for that test.

We executed stabilization step test with three different barriers and with three different arm movement conditions. The barrier conditions used in the test were; no barrier, a 15 ㎝ barrier, and a 25 ㎝ barrier. The all barrier width were 10 ㎝. The arm conditions were; no restriction of the arm, restriction of the dominant arm, and restriction of both arms. A strap was used to restrict arm movement. We permitted a 2-minute rest break between each test set to avoid muscle fatigue.

Data analysis

Data were analyzed using the SPSS/PC^{+} computer package. Two-way repeated analysis of variance was used to find the effect of arm conditions (no restriction, dominant arm restriction, both arm restriction) and barrier conditions (no barrier, 15 ㎝ barrier, 25 ㎝ barrier) on stabilization time. Independent t-tests were used to compare the stabilization time with respect to gender. The significance level was set at a value of $p<.05$.

Results

All 30 subjects completed the test. Table 2 shows the mean values of stabilization time in different barrier condition with the different arm movement conditions. The mean values of stabilization time for no barrier condition were .89 sec for no arm restriction, .88 sec for dominant arm restriction and .84 sec for both arm restriction.

The mean values of stabilization time for 15 ㎝ barrier condition were .98 sec for no arm restriction, 1.00 sec for dominant arm restriction and 1.14 sec for both arm restriction. The mean values of stabilization time for 25 ㎝ barrier condition were 1.09 sec for no arm restriction, 1.28 sec for dominant arm restriction and 1.57 sec for both arm restriction (Table 2).

Table 3 shows the comparison of mean values of stabilization time at different condition, respectively. There were no significant differences.

Table 4 shows the effects of arm and barrier conditions on stabilization time. There was significant interaction ($p<.05$). We drew the interaction plots to visually clarify data from a two-factor analysis of variance. There was a significantly high difference among the three barrierconditions. Arm condition did not affect stabilization time in no barrier condition, but arm condition did affect stabilization time in the 15 ㎝ and 25 ㎝ barrier condition. In both arm restriction in the 25 ㎝ barrier condition consistently produced a longer stabilization time than other combinations of the two variables.

Table 2. Mean values of stabilization time as different conditions (unit: sec)

Barrier	Arm restriction	Mean	SD
No	No	.89	39
	Dominant side	.88	.40
	Both side	.84	36
15 cm	No	.98	32
	Dominant side	1.00	.36
	Both side	1.14	.42
25 cm	No	1.09	30
	Dominant side	1 28	.37
	Both side	1.57	.47

NS: Not significant.

Table 3. Comparison of stabilization time between males and females in different conditions

Barrier	Arm restriction	Male Mean (SD)	Female Mean (SD)	t-Value	p
No	No	.91 (.42)	.88 (.39)	.14	NS
	Dominant side	.91 (.41)	.86 (.40)	.33	NS
	Both side	.83 (.33)	.85 (39)	.16	NS
15 cm	No	1.01 (.40)	.95 (.25)	.45	NS
	Dominant side	.99 (.38)	1.01 (.36)	.09	NS
	Both side	1 17 (48)	1.11 (.36)	.37	NS
25 cm	No	1 15 (30)	1.03 (29)	1.05	NS
	Dominant side	1 36 (.30)	1.21 (.42)	1.15	NS
	Both side	1.55 (.42)	1.59 (.52)	.20	NS

NS: Not significant.

Table 4. Summary table for a two-way analysis of variance: Effect of arm conditions and barrier conditions on stabilization time

Source of variance	df	Sum of square	Mean square	F
Barrier (A)	2	8.86	4.43	30.75
Arm condition (B)	2	2.51	1.26	8.71
A×B	4	1.55	0.39	2.69

$p<.05$

Discussion

The purpose of our research was to study the effects of arm restriction with respect to different barrier height. So far, many studies have focused on ankle, hip, and trunk strategy in postural control during steady standing (Hellebrandt et al, 1962; Larson et al, 1990). Physical therapist may often meet patients with useless arm-related diseases such as hemiplegia, head trauma, and upper extremity amputee. Recently studies about the postural adjustments associated with arm movements during balancing have been increasing (Blaszczyk et al, 1997; Gantchev and Dimitrova, 1996).

Postural stability is modulated by postural control, which is exhibited in the form of postural adjustments (Cordo and Nashner, 1982). In humans, the control of balance during steady-state walking is not an easy task because of bipedal locomotor pattern which consists of a two single-limb support period. During these two periods, the vertical projection of the body's center of mass (COM) travels forward and outside the medial border of the supporting foot (Shimab, 1984). To counterbalance the mediolateral instability during single-limb support periods, a counterbalancing momentum around the hip and lower trunk is required (MacKinnon and Winter, 1993). In this study, the stabilization time had no significant difference among the three arm and no barrier conditions. MacKinnon and Winter (1993) reported that the counterbalancing momentum during steady-state walking is largely generated by the hip abductors and trunk lateral flexors, and fine tuned by the ankle evertors and invertors. This may be a possible reason why there was no significant difference among the three arm condition and no barrier condition.

A biomechanical disadvantage of human locomotion has to do with human body structure-two thirds of the total body weight is centered in the upper body (head-arm-trunk) segment. The maintenance of the upper body not only prevents a potential fall preceded by an unsteady upper-body movement, it also assist in stabilizing the head and gaze (Woollacott and Tang, 1997). As weight continues to be shifted laterally, maintaining stability requires arm movement in order to keep the trunk mass within the base of support (Shumway-Cook and Woollacott, 1995). These studies suggest that arm movement may be associated with step stabilization.

Our study found that stabilization time was significantly different among the three arm conditions in the 15 ㎝ and 25 ㎝ barrier condition, respectively. In the 25 ㎝ barrier, it was found that the three arm conditions measured a longer stabilization time than the three arm conditions measured in the 15 ㎝ barrier. Among the three arm conditions, both arm restriction measured the longest stabilization time. Dominant arm restriction was measured as the next longest stabilization time.

Patla and Rietdyk (1993) reported that the movement of the swing limb was modulated according to the obstacle height, but not the obstacle width, provided that the goal of the person was to step over, rather than around, the obstacle. This may be a possible reason why arm movement restriction may affect stabilization time in barrier conditions.

Although this study was not clearly identified, the results have important implications for balance evaluation and training in hemiplegia and upper extremity amputee in the future.

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