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Quantitative Assessment of Postural Stability and Balance Between Persons with Lower Limb Amputation and Normal Subjects by using Dynamic Posturography

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Key words: Postural stability; computariesed dynamic posturography; lower limb amputation; AK amputation; BK amputation.

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Abstract

Background. The amputation of lower limb constitutes a major handicap which involves a functional and professional incapacity. Balance has been reported to be a better predictor of an individual's engagement in physical, daily, and social activities among persons with amputations.

Aim. To study quantitatively the postural stability between persons with amputation and normal subjects by using dynamic posturography. Also, to determine whether differences in balance confidence exist between persons with amputations due to trauma or vascular causes, as well as between below knee (BK) or above knee (AK) amputations.

Subjects and Methods. Twenty one patients with lower limb amputations who were ambulant with prostheses and 20 age-matched healthy individuals as control group were be randomly selected. The patients with BK and AK amputations due to trauma and vascular causes were included. All subjects were clinically evaluated along with brief neurological examination. The postural stability and balance were studied by using computerized dynamic posturography.

Results. A significant reduction was observed for composite equilibrium score of persons with amputation as compared with control group ($p < 0.05$). Moreover, significant reduction was observed for composite equilibrium score of vascular causes as compared with trauma causes in persons with amputation ($p < 0.05$). However, Non-significant difference was observed for composite equilibrium score in BK amputation as compared with AK amputation ($p > 0.05$).

Conclusion. Our data suggest that lower limb persons with amputation have low balance confidence compared to normal subjects and the balance is lower among individuals who had amputations due to vascular causes than trauma causes. This may be explained by impairment due to amputation as well as reduction of muscle strength and endurance in residual limb.

Introduction

The amputation of lower limb constitutes a major handicap which involves a functional and professional incapacity [1]. Falls and fear of falling are significant problems arising from impaired balancing abilities that affect people with lower limb amputation during unassisted transfer maneuvers and ambulation [2].

Balance has been reported to be a better predictor of an individual's engagement in physical, daily, and social activities than actual measures of physical performance among persons with amputations [3]. Balance confidence appears to be a persistent problem in the amputee population. Health professionals are encouraged to consider balance confidence as a potentially important variable that may influence function in this clinically unique group of individuals. The identified predictor of variables may be useful to clinicians in targeting individuals who require attention to improve balance confidence [4].

Studies of balance and postural sway consistently report variations in abilities between people with intact lower limbs and people with unilateral amputations. The continued study of balance confidence among people with lower-limb amputations is important. Measures of balance confidence were developed to provide a sensitive measure of fear of falling [3,5]. Compromised lower limb somatosensation and circulation was linked with poor balance and a history of frequent falls in the elderly dysvascular amputee population [6].

Prosthesis for both transtibial and transfemoral amputations are available for patients of every level of ambulation. Different components offer varying benefits to energy expenditure, activity level, balance, and proprioception. Less dynamic ambulators may use fixed-cadence knees and non-dynamic response feet; higher functioning walkers benefit from dynamic response feet and variable-cadence knees. In addition, specific considerations must be kept in mind when fitting a patient with peripheral vascular disease or diabetes [3]. Few studies have been conducted to establish the reliability and validity of performance scores derived from dynamic posturography.

Thus, our objectives were to study quantitatively the postural stability and balance between persons with amputation and normal subjects by using dynamic posturography. Moreover, to determine whether differences in balance confidence exist between people who have had amputations due to trauma or vascular causes, as well as between persons with BK or AK amputations.

Subjects and Methods

A total of 21 patients with lower limb amputations who were ambulating with prosthesis and 20 age-matched healthy individuals as control group were be randomly selected from the population from Artificial Limb Center and Balance Clinic, Physical Medicine and Rehabilitation Hospital, Ministry of Health, Kuwait. The patients consisted of people with unilateral transfemoral and transtibial amputations who lost their limb for vascular and nonvascular reasons. Information from medical chart reviews was linked with survey data to create the database for the analyses. Medical chart review variables included sex, date of birth, amputation date, level of amputation (AK or BK), and cause of amputation (vascular or nonvascular).

All patients & healthy individuals were evaluated clinically with brief neurological examination. Inclusion criteria for the trial were the following: (1) ability to ambulate 25 feet independently with prosthesis and mild to moderate deficits in lower extremities. Those with cognitive deficit, orthopedic or peripheral neuropathy, significant visual field or hemineglect problems cerebellar or brain stem lesions were excluded. Exclusions also were serious cardiac conditions, severe pain on weight-bearing and other serious organ system diseases. After subjects passed the screening criteria, an informed consent was taken from the subjects for this study.

All patients and healthy individuals were evaluated for postural stability and sway in altered sensory conditions, balance by using computerized dynamic posturography. The SMART Balance Master (NeuroCom International, Inc., Clackamas, OR, USA) was used for both balance function assessment [7].

Computerized dynamic posturography

The Sensory Organization Test (SOT) was performed in a clinically routine manner. The SOT included six tests conditions. The first three involved the patient standing on a fixed platform with eyes open (SOT 1), eyes closed (SOT 2), and using (sway-referenced vision) (SOT 3). The Sensory Organization Test (SOT) of the patient standing on a fixed platform is called static posturography. Another three conditions involved the patient standing on a platform moving including conditions SOT 4 (eyes open), SOT 5(eyes closed), and SOT 6 (using sway-referenced vision) are called dynamic posturography. Composite Equilibrium Score (%) was calculated that describes the overall level of performance of all six conditions. Scores range from 0 to 100, with 0 representing a fall and 100 representing perfect stability [7]. Fig. 1A represents normal dynamic posturography of control and fig. 1B represents abnormal dynamic posturography of persons with amputations.

Statistical analysis

Study data were analyzed using the SPSS (version 12) statistical package. The normality of the population was done during statistically analysis. The Student's t test indicates the magnitudes of the differences of means ± SD and therefore the magnitude of the observation. Thus, the unpaired t-test was used to assess the difference between SOT scores among people with lower-limb amputations and those of normal subjects. Prior to data analysis, the level of significance was established at $P<0.05$. A p value of < 0.05 was used as significance.

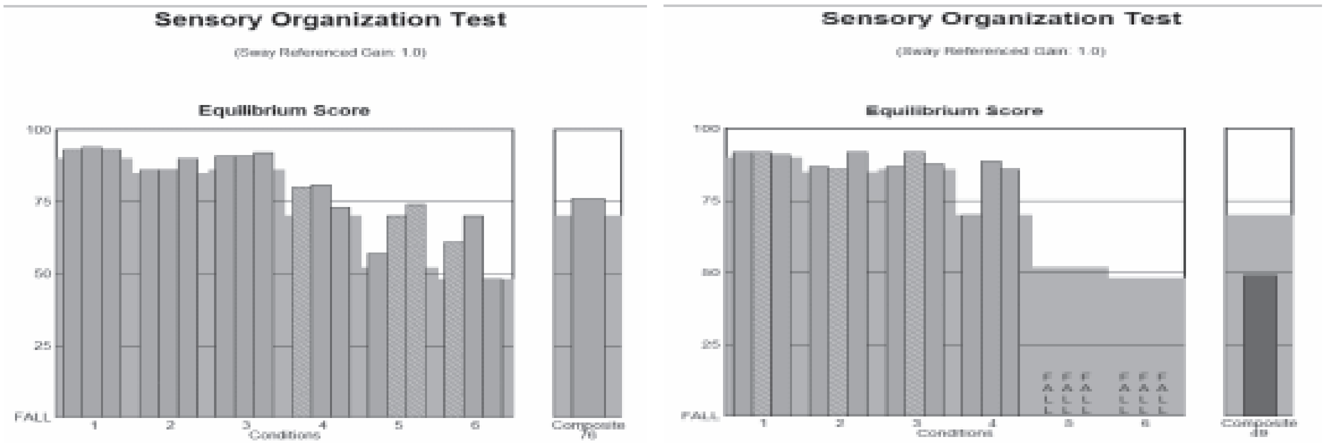

Figure 1: A, Normal dynamic posturography of control (left), B, abnormal dynamic posturography of persons with amputation (right).

Results

Baseline demographic and clinical characteristics of persons with amputation and control were showed in Table (1).

Significant reduction was observed for composite equilibrium score of amputee patients as compared with control group ($p < 0.05$). Also, in dynamic balance function (dynamic posturography), significant reduction was observed for the two conditions (SOT5, SOT6) of persons with amputations as compared with control group($p < 0.05$). However, non significant difference was observed for the first three conditions involved SOT1, SOT2, and SOT3 between persons with amputations and control group in static balance function (static posturography) ($p > 0.05$) (Table 2 and Figure 2).

Table 1: Baseline demographic and clinical characteristics of persons with amputation and control.

Characteristic	Person with Amputation n (%)= 21	Control group n = 20
Mean ± SD Age (years)	45.2 ± 1.80	41.31 ± 3.09
Sex, Male/Female	20/1	18/2
Mean time after prosthesis (months)	1.8 ± 0.7	-
Causes of amputation		
❖ Trauma	15 (71.4%)	-
❖ Vascular	6 (28.6%)	-
Level of amputation		
❖ AK = Transfemoral (TF)	7 (33.3%)	-
❖ BK = Transtibial (TF)	14 (66.6%)	-
Prosthetic details		
❖ Uniaxial SACH foot	8 (38.1%)	-
❖ Gresingher foot	10 (47.6%)	-
❖ Dynamic-response foot	2 (9.5%)	-
❖ AK prosthesis with silicone liner	7 (33.3%)	-
❖ BK prosthesis with silicone liner	14 (66.6%)	-
Trauma causes		
❖ car accidents	12 (57.1%)	-
❖ bomb blast	3 (14.3%)	-
Vascular causes		
❖ Diabetes mellitus	5 (23.8%)	-
❖ SLE (recurrent gangrene)	1 (4.7%)	-
Associated medical conditions		
❖ Hypertension	3 (14.3%)	-
❖ Smoking	3 (14.3%)	-
❖ Peripheral neuropathy	none	-

Table 2: Means ± SD of Sensory Organization Test (SOT) of persons with amputation and control.

Means ± SD	Persons with Amputation *n* = 21	Control Group *n* = 20
Composite Equilibrium Score	56.8 ± 4.9	78.8 ± 8.0*
❖ SOT1 score	90.2 ± 3.2	93.9 ± 5.4
❖ SOT2 score	76.7 ± 2.7	85.4 ± 4.9
❖ SOT3 score	68.7 ± 6.5	83.5 ± 6.0
❖ SOT4 score	66.5 ± 7.9	81.5 ± 7.2
❖ SOT5 score	41.1 ± 3.8	73.9 ± 5.8*
❖ SOT6 score	35.5 ± 5.6	73.5 ± 3.0*

Significant reduction ($p < 0.001$*); non-significant difference ($p > 0.05$).

But, significant reduction was observed for composite equilibrium score of vascular causes as compared with trauma causes in persons with amputations ($p < 0.05$). In addition, in dynamic balance function (dynamic posturography), significant reduction was

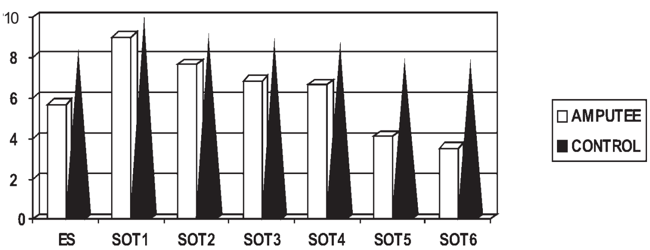

Figure 2: Represents mean (± SD) changes in composite equilibrium score (ES) and six conditions of Sensory Organization Test (SOT) of persons with amputation and control group.

Table 3: Relation between means ± SD of Sensory Organization Test (SOT) of trauma & vascular causes of persons with amputation.

Means ± SD	Trauma causes (*n* = 15)	Vascular causes (*n* = 6)
Composite Equilibrium Score	69.5 ± 7.0	42.4 ± 1.9*
❖ SOT1 score	91.1 ± 3.2	89.1 ± 5.4
❖ SOT2 score	87.7 ± 2.7	70.5 ± 4.9
❖ SOT3 score	81.4 ± 4.5	66.1 ± 6.0
❖ SOT4 score	78.6 ± 7.1	57.1 ± 7.2
❖ SOT5 score	66.2 ± 3.8	20.8 ± 2.7*
❖ SOT6 score	55.0 ± 1.6	15.4 ± 3.0*

Significant reduction ($p < 0.001$*); non-significant difference ($p > 0.05$).

observed for the two conditions (SOT5, SOT6) of vascular causes as compared with trauma causes ($p < 0.05$). In contrast, no significant difference was observed for the first three conditions involved SOT1, SOT2, and SOT3 in trauma causes as compared with vascular causes in static balance function in persons with amputation ($p > 0.05$) (Table 3 and Figure 3) .

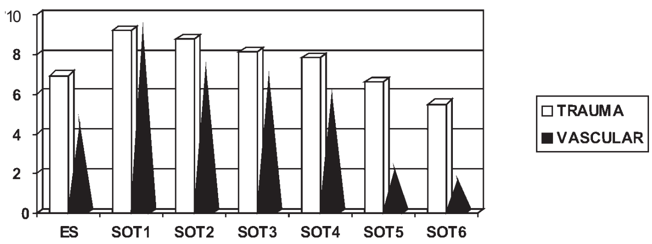

Figure 3: Represents Mean (±SD) of Sensory Organization Test (SOT) between trauma and vascular causes in persons with amputation.

However, non-significant difference was observed for composite equilibrium score (ES), SOT1, SOT2, SOT3, SOT 4, SOT5 & SOT6 of BK amputation as compared with AK amputation including both static & dynamic balance functions ($p > 0.05$) (Table 4 and Figure 4) .

Table 4: Means ± SD of Sensory Organization Test (SOT) of both BK and AK amputations.

Means ± SD	BK amputations (Transtibial) No= 14	AK amputations (Transfemoral) No=7
Composite Equilibrium Score	63.6 ± 9.7	55.3 ± 6.6 (NS)
❖ SOT1 score	90.2 ± 3.2	89.1 ± 5.4 (NS)
❖ SOT2 score	76.7 ± 2.7	85.4 ± 4.9 (NS)
❖ SOT3 score	84.8 ± 6.5	78.0 ± 6.0 (NS)
❖ SOT4 score	75.6 ± 7.9	66.0 ± 7.2 (NS)
❖ SOT5 score	59.1 ± 3.8	40.1 ± 5.8 (NS)
❖ SOT6 score	48.6 ± 5.6	32.5 ± 3.1 (NS)

Non-significant difference (NS) ($p > 0.05$).

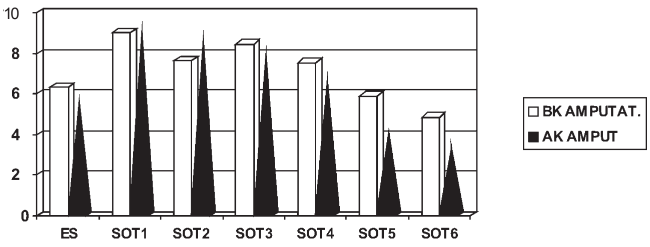

Figure 4: Represents Mean (±SD) of Sensory Organization Test (SOT) between below and above knee amputation.

Discussion

Studies of balance and postural sway consistently report variations in abilities between people with intact lower limbs and persons with amputations [5, 8]. Standing upright is a dynamic process, maintained by input from the visual, proprioceptive, and vestibular systems [3].

Falls and fear of falling are significant problems arising from impaired balancing abilities that affect people with lower limb amputation during unassisted transfer maneuvers and ambulation [2,9].Therefore, it seems important to study balance among people with amputations. Computariesed dynamic posturography (CDP) has become an important tool for understanding standing balance in clinical settings among persons with amputations.

Our data revealed a significant reduction of composite equilibrium score of persons with amputation as compared with control group ($p < 0.05$). Moreover, significant reduction was observed for composite equilibrium score of vascular causes as compared with trauma causes in persons with amputations ($p < 0.05$). There was significant correlation of the composite ES with SOT4, SOT5 ,SOT6 in AK amputation ($r = -0.710$; $p < 01$) and also in BK amputation($r= 0.761$, $p<.01$). While, there was no correlation in the composite ES with SOT4, SOT5, SOT6 in trauma & vascular causes of persons with amputations.

The findings in this study were similar to other studies. Some studies reported that balance confidence would differ between people with amputations due to vascular and nonvascular causes [10]. Quai TM et al found poor somatosensory status was associated with poor stance balance in dysvascular transtibial persons with amputation (TT). There was an association between poor vibration and circulation and increased centre of pressure excursion in quiet stance. Poor vibration sense was associated with a history of frequent falls. Compromised lower limb somatosensation and circulation was linked with poor balance and a history of frequent falls in the elderly dysvascular amputee population [5].

Moreover, fall and fear of falling are significant problems arising from impaired balancing abilities that affect people with lower limb amputation during unassisted transfer maneuvers and ambulation [2]. Other studies suggest that the balance and postural control strategy of persons with amputation relating to the gait initiation process is not a fixed motor program, but also, person with amputation will require time and training to develop alternative neuromuscular control and coordination strategies [11].

In addition, Miller WC, found that having a fall and balance deficit among people with lower-limb amputations [12].Vrieling AH, et al found Limitations in function and balance were mainly similar in transfemoral and transtibial persons with amputation [13], some studies have suggested that people with amputations due to trauma perform better than people with amputations due to vascular causes in balance and postural sway [3,8].

However, the findings in this study were not similar to some other studies. Our data found that non-significant difference of composite equilibrium score of BK amputation as compared with AK amputation ($p > 0.05$). Some studies reported that balance confidence would differ between people with amputations between people with transfemoral (TF) and transtibial (TT) amputations [10]. Moreover, other authors reported that postural sway in patients with BK amputations was found to be significantly greater than that in those with AK amputations. Amputation above the knee affects postural sway when the subject's eyes are closed because of the loss of proprioception resulting from the loss of the limb [3].

One possible explanation for balance reduction is that the differences between the groups studied are due to a proprioceptive deficit as a result of partial limb loss and this may be due to further development of impairment—such as loss of muscle strength, endurance, and balance [5]. Some authors found that amputation above the knee affects postural sway when the subject's eyes are closed indicates that the loss in proprioception resulting from the loss of the limb is compensated for by an increased dependence on visual input [3].

Transfemoral and transtibial persons with amputation with using prosthetic foot and knee, there are limitations in function of balance control due to the lack of active ankle function. Moreover, compromised lower limb somatosensation and circulation was linked with poor balance and a history of frequent falls in the elderly dysvascular amputee population. Also, poor vibration sense was associated with a history of frequent falls [13].

Miller WC et al suggest that balance confidence would differ between people with amputations due to vascular and nonvascular causes as well as between people with TF and TT amputations. Differences between groups based on the cause of amputation were expected because individuals with vascular disease tend to be older, have more comorbidity, and use more medications [12].

Some authors reported that there are sensory loss and poor static balance and dynamic ambulation performance for persons with amputation. Sub-threshold electrical stimulation and visual-auditory biofeedback rehabilitation strategies may be effective in compensating sensory loss and improving static balance and dynamic ambulation performance for persons with amputation [14].

Conclusion

We found that persons with amputation have low balance and that the balance is lower among individuals who had amputations due to vascular causes than among individuals due to trauma causes. This may be explained by impairment due to amputation as well as reduction of muscle strength and endurance, loss of somatosensory status and vibration in residual limb.

Level of amputation was not statistically related to balance disturbance. Thus, we recommend prosthetic rehabilitation for impairment that accompany inactivity, improving an individual's balance and may be method of maximizing the quality of life after amputation.

This study represents the first attempt in use of the dynamic posturography equipment as diagnostic tool in assessment of the dynamic equilibrium performance in persons with amputation in Kuwait. Further research in use of the posturography equipment is needed to study the effects of visual feedback rhythmic weight-shift training among people with lower-limb amputations.

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