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Forward Reach Distance as a Measure of Dynamic Stance Postural Control under Six Different Sensory Conditions in Neurologically Intact Adults: A Descriptive Study

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ABSTRACT

Objective: To establish the forward reach distance values in six different sensory conditions for neurologically intact adults. In addition, we intended to compare the forward reach distance value of sensory accurate condition with sensory inaccurate conditions in neurologically intact adults. **Participants:** One hundred and fifty community dwelling, healthy subjects aged between 20 and 50 years participated in the study. **Measures:** Functional Reach Test (FRT). **Results:** Descriptive statistics was used to find the forward reach distance values under six different sensory conditions. We found a decline in the forward reach distance values as the somatosensory and visual inputs were inaccurate. **Conclusion:** In neurologically intact adults, the dynamic stance postural control is dependent on the interaction of the somatosensory, visual and vestibular systems.

Key Words: Functional Reach Test; Forward reach distance; Sensory conditions; Neurologically intact adults.

INTRODUCTION

Postural control is defined as the ability to control the body's position in space for the dual purposes of stability and orientation. Postural stability is the ability to maintain the position of the body, and specifically, the centre of body mass (COM), within specific boundaries of space, referred to as stability limits. Stability limits are boundaries of an area of space in which the body can maintain its position without changing the base of support. Postural orientation is the ability to maintain an appropriate relationship between the body segments, and between the body and the environment for a task [1,2]. Postural control has two components: adaptive and anticipatory postural control. Adaptive postural control involves modifying sensory and motor systems in response to changing task and environmental demands, while anticipatory postural control involves pre-tuning sensory and motor systems for postural demands based on previous experience and learning [3,4].

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Postural control is usually maintained by interaction between sensory and motor mechanisms [5]. Somatosensory system provides information about the relationship of body segments to one another and even they report information about the body's position and motion in space with reference to supporting surfaces [6]. Vestibular system provides information about the position and movements of the head with respect to gravity and inertial forces [7]. Visual inputs report information regarding the position and motion of the head with respect to surrounding objects. In addition, it provides a reference for verticality [8-10]. Motor system includes intrinsic stiffness of muscles, background muscle tone and postural tone, i.e. activation of antigravity muscles. Furthermore, postural control depends on the generation, scaling, and coordination of muscle force with respect to the available sensory inputs [11].

Multiple measurement tools have been established to assess postural control and its various components [12,13]. Romberg's test, plumb line and postural grid system have been used to measure the postural stability. With moving platform, posturographic analysis, postural sway and centre of pressure excursion have been measured in order to find the desired postural stability under six different sensory accurate and/or inaccurate conditions. In sensory accurate or inaccurate state, sensory inputs to central nervous system (CNS) are present, absent or challenged in order to maintain the desired postural stability [14]. Similarly, Clinical Test for Sensory Interaction in Balance (CTSIB) measures the influence of sensory interaction on postural stability in standing [15]. Among the clinical tools available to measure dynamic postural control, Functional Reach Test (FRT) has been reported for its reliability and validity. It is a clinical tool that measures the forward reach distance, whilst maintaining the dynamic stance postural control. The value of forward reach distance as measured by FRT, is documented when all the sensory systems are accurate [16]. But, there are no retrievable data available to measure the forward reach distance when one or more sensory inputs of somatosensory, vestibular and visual systems are inaccurate, i.e. absent or challenged.

The aim of the study was to examine the dynamic stance postural control in six different sensory conditions for neurologically intact adults. The objective of the study was to establish the forward reach distance values under sensory accurate and inaccurate conditions for neurologically intact adults. In addition, we intended to compare the forward reach distance value of sensory accurate condition with sensory inaccurate conditions in neurologically intact adults.

METHODS

Subjects:

This descriptive study was approved by Physiotherapy Departmental Scientific Committee, Kasturba Medical College, Manipal University, Mangalore, and was conducted in community settings, i.e. homes in Mangalore. The neurologically intact adults aged between 20 and 50 years were contacted and explained about the purpose of the study. Informed consent was obtained from the interested participants, seeking their active participation in the study. The participants were excluded from the study if they had vertigo, ankle sprain and musculoskeletal dysfunction, such as low back pain and/or lower limb fracture within three months' duration. The descriptive characteristics such as age, gender, height (cm), weight (kg), hand dominance, arm length and BMI were obtained from the participants.

PROCEDURE

The participants were instructed and demonstrated about the FRT under six different sensory conditions. It is a sensory accurate or inaccurate state in which sensory inputs to CNS are present, absent or challenged in order to maintain the desired postural stability. Under sensory accurate condition, all the sensory inputs such as somatosensory, vestibular and visual systems are available to the CNS, whereas, one or more sensory inputs to CNS are absent or challenged in sensory inaccurate conditions. The six different sensory conditions were as follows. 1) standing on stable surface with eyes opened; 2) standing on stable surface with eyes closed; 3) standing on stable surface, eyes open, with visual illusionary state; 4) standing on unstable surface with eyes opened; 5) standing on unstable surface with eyes closed; and 6) standing on unstable surface, eyes open with visual illusionary state. To provide an unstable surface and a visual illusionary state, three-inch high-density foam (Figure 1) and visual conflict dome (Figure 2) were used, respectively. In order to provide a visual illusionary state to the participants, the visual conflict dome (2''×2" dome, painted black with centre white spot) was moved by the observer while asking the participants to fix their gaze on a centre white spot of the dome. Participants stood on a stable surface with eyes open under sensory accurate condition, i.e. all the somatosensory, vestibular and visual inputs were present. With sensory inaccurate conditions, any one of the sensory inputs was absent or challenged. To provide a somatosensory inaccurate state, participant stood on an unstable support, i.e. foam. Under visual inaccurate conditions, visual inputs were absent and challenged with eyes closed and visual illusionary states, respectively (Figure 3).

The participants' dominant arm was preferred to perform FRT. To measure the forward reach distance, a standard measurement tape was placed on the wall, and adjusted at the shoulder height of the participants. The participants initially stood on a stable surface, and, later on an unstable surface with feet-shoulder distance apart, and with the arm raised to 90^0 flexion so that the acromion process was at the level of zero measurement point. The arm length was calculated by measuring the distance between the acromion process and the tip of the third knuckle with the standard measurement tape. They were instructed to reach as forward as possible, without changing their base of support. The forward reach distance was computed by subtracting the arm length from the actual distance reached. Each participant performed three trials in six different sensory conditions, and average of the three trials was considered to measure the forward reach distance under each sensory conditions.

Data Analysis

The descriptive characteristics of the participants such as demographic data and forward reach distance are presented as Mean ± SD. Karl Pearson's correlation coefficient was used to compare the demographic variables under the six different sensory conditions. As a multiple level comparison, Bonferroni test was used to compare the forward reach distance values under different sensory conditions among the age groups ranging 20-29 years, 30-39 years, and 40-50 years. The statistical analysis was performed using

SPSS-13 version.

RESULTS

Among the 150 subjects who participated in the study, 77 were males and 73 were females. In the 53 participants aged between 20 and 29 years, 20 were males and 33 were females. Under the age group between 30 and 39 years, 30 were males and 20 were females. Of the 45 participants aged between 40 and 50 years, males and females were 27 and 18, respectively. All the participants were right-hand dominants except six participants. Table 1. represents the demographic data of the participants. Table 2 shows the forward reach distance values for different age groups under six different conditions.

Our study found that there was a decline in the forward reach distance values with inaccurate somatosensory and visual inputs. Table 3. shows the correlation of FRT values under six different sensory conditions. It was also found that the age group 30-39 years had significantly more reach than the age group of 20-29 under all 6 conditions. Table 4. shows the correlation of FRT values under six different sensory conditions with the demographic variables of the participants.

DISCUSSION

Interaction between sensory and motor systems helps in maintaining the static and dynamic postural stability. Sensory inputs from each of the somatosensory, vestibular and visual systems play a major role in maintaining postural control. In addition, these sensory inputs modify the motor outputs in order to attain a desired postural stability. This study provided values of forward reach distance in sensory accurate and inaccurate conditions for neurologically intact adults. Furthermore, this study

Fig 1. Three inch high density foam

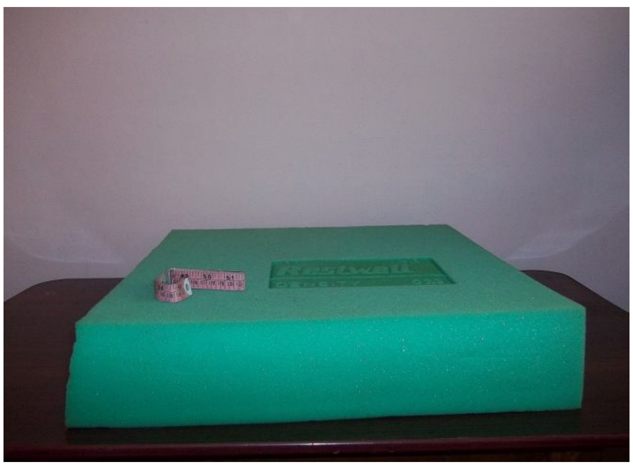
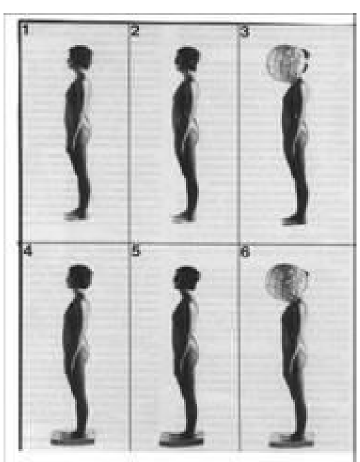


Fig 2. Visual conflict dome

Fig 3. Adapted from Insight into Otolaryngology 1988; 3: 2



also found that there was a very high correlation among the six different levels of sensory conditions. Additionally, the functional reach distance value in a sensory accurate condition was comparable to the earlier work by Duncan PW, et al [16].

When the sensory accurate state was compared to visual absent state, i.e. condition 2, there was a decline in forward reach distance value, and this value was further reduced in visual conflict sensory state, i.e. condition 3. In visual absent sensory state, the postural control was mainly dependent on somatosensory and vestibular inputs. The visual conflict dome created a visual illusionary state, resulting in a visual-vestibular mismatch, which means the dynamic postural control was wholly dependent on somatosensory inputs in condition 3. Nashner's protocol may further support this hypothesis. In Nashner's protocol, the postural sway was measured in similar sensory conditions, and found to be increased in sway velocity for visual conflict sensory condition than visual absent sensory condition [17,18].

The values of forward reach distance in somatosensory inaccurate state (conditions 4, 5 and 6) were reduced significantly when compared to the somatosensory accurate conditions (conditions 1, 2 and 3). The reason may be due to the fact that the information about the postural orientation provided by the somatosensory system was compromised, so that the visual and vestibular systems had to play a role in maintaining the postural control. The above mentioned information was supported by Dietz et al.[19] In their study, it was found that the muscle responses to vestibular signals were about ten times smaller than the somatosensory responses induced by displacement of feet. Furthermore, studies have also shown that the muscle response latencies to visual cues signalling sway are quite slow, in the order of 200 milliseconds, in contrast to the somatosensory responses that are activated in response to support surface translations which is 80-100 milliseconds. Thus, nervous system preferentially relies on somatosensory system for controlling body sway when imbalance is caused by rapid displacement of support surface [19,20]. According to Shumway-Cook and Horak, the body sway was least in somatosensory accurate condition where support surface orientation inputs are accurately reporting the body's position in space, regardless of the availability and accuracy of visual inputs. But the sway was more when support surface orientation is no longer available as an accurate source of orientation information [21].

Table 1: FRT values for the demographic variables in different age groups

Demographics	Age Group	Number	Mean (SD)	Confidence Interval
Height (cm)	20-29	53	166.17 (7.94)	163.98-168.36
	30-39	52	162.77 (7.74)	160.61-164.92
	40-50	45	163.47 (7.53)	161.20-165.73
	20-50	150	164.18 (7.85)	162.91-165.45
Weight (kg)	20-29	53	60.91 (10.07)	58.13-63.68
	30-39	52	61.52 (9.44)	58.89-64.15
	40-50	45	63.42 (9.37)	60.61-66.24
	20-50	150	61.87 (9.64)	60.32-63.43
Body Mass Index	20-29	53	21.97 (2.55)	21.26-22.67
	30-39	52	23.22 (3.25)	22.31-24.13
	40-50	45	23.82 (3.24)	22.85-24.79
	20-50	150	22.96 (3.10)	22.46-23.46
Arm length (cm)	20-29	53	60.38 (3.84)	59.32-61.44
	30-39	52	60.75 (3.53)	59.77-61.73
	40-50	45	59.96 (3.64)	58.86-61.05
	20-50	150	59.79 (3.66)	59.79-60.97

The results of our study also stated that the postural control was mainly dependent on vestibular inputs in sensory conditions 5 and 6. Similarly, the Clinical Test for Sensory Interaction in Balance (CTSIB) also supports the above mentioned statement [22]. When the sensory conditions 5 and 6 were compared, the value was less in condition 6, suggesting that postural control was solely dependent on the inputs from semicircular canals. In sensory condition 5 where the somatosensory system was inaccurate and the visual system was absent, subjects relied upon vestibular system to maintain the postural orientation. In sensory condition 6, the vestibular system was alone accurate and rest of the sensory systems were inaccurate, but, the movement of visual conflict dome would have created a mismatch between visual and vestibular systems, thus the decreased forward reach distance value in sensory condition 6 [15]. Literature on Vestibulo-Ocular Reflex (VOR) also suggests that the gaze stability and postural stability are mainly dependent on the interaction between the visual and vestibular systems. When these systems are in a state of mismatch, poor postural control may be anticipated [23].

We also attempted to examine the correlation between forward reach distance values and the demographic variables, and found no high correlation except the height of the subjects. We may hypothesis that the anthropometry of the human body, particularly the spinal leverage, would have helped the taller individuals to reach at the far distance. The study by Chaffin DB, et al [24] may further favor for this hypothesis. In their study, it

Table 2. Participants in different age groups, and their FRT values under six different sensory conditions

Sensory Conditions	Age Group	Number	Mean (SD)	95% Confidence Interval
SSEO	20-29	33[a]	36.92 (3.61)	35.64-38.20
		20[b]	38.44 (4.69)	36.25-40.64
		53[c]	37.49 (4.09)	36.37-38.62
	30-39	22[a]	35.37 (5.88)	32.76-37.98
		30[b]	39.03 (5.28)	37.05-41.00
		52[c]	37.48 (5.78)	35.87-39.09
	40-50	18[a]	34.10 (4.80)	31.71-36.49
		27[b]	36.51 (5.91)	34.17-38.85
		45[c]	35.55 (5.56)	33.87-37.22
SSEC	20-29	33[a]	35.02 (4.22)	33.53-36.52
		20[b]	36.19 (3.90)	34.36-38.02
		53[c]	35.46 (4.10)	34.33-36.60
	30-39	22[a]	33.61 (5.48)	31.18-36.04
		30[b]	36.91 (4.98)	35.05-38.78
		52[c]	35.52 (5.40)	34.01-37.02
	40-50	18[a]	32.62 (4.63)	30.32-34.93
		27[b]	34.50 (5.63)	32.27-36.73
		45[c]	33.75 (5.28)	32.16-35.34
SSEOVC	20-29	33[a]	33.08 (4.33)	31.55-34.62
		20[b]	34.92 (4.23)	32.93-36.90
		53[c]	33.78 (4.35)	32.58-34.97
	30-39	22[a]	32.49 (5.49)	30.05-34.93
		30[b]	36.01 (4.12)	34.47-37.56
		52[c]	34.52 (5.02)	33.12-35.92
	40-50	18[a]	30.47 (4.07)	28.45-32.50
		27[b]	32.39 (5.82)	30.08-34.69
		45[c]	31.62 (5.22)	30.05-33.19
SUSEO	20-29	33[a]	31.29 (5.06)	29.46-33.12
		20[b]	33.43 (4.3)	31.37-35.49
		53[c]	32.11 (4.88)	30.75-33.47
	30-39	22[a]	30.83 (5.29)	28.48-33.18
		30[b]	34.68 (4.90)	32.85-36.52
		52[c]	33.05 (5.38)	31.56-34.55
	40-50	18[a]	28.59 (4.24)	26.48-30.70
		27[b]	30.98 (6.03)	28.60-33.37
		45[c]	30.03 (5.46)	28.38-31.67
SEC	20-29	33[a]	29.74 (4.83)	28.02-31.45
		20[b]	32.71 (4.46)	30.62-34.80
		53[c]	30.86 (4.87)	29.51-32.20
	30-39	22[a]	29.61 (5.41)	27.21-32.02
		30[b]	33.60 (4.98)	31.74-35.46
		52[c]	31.91 (5.49)	30.38-33.44
	40-50	18[a]	27.01 (4.65)	24.69-29.33
		27[b]	29.28 (6.45)	26.72-31.83
		45[c]	28.37 (5.85)	26.61-30.13
SUSEOVC	20-29	33[a]	27.83 (5.27)	25.96-29.70
		20[b]	31.26 (4.46)	29.17-33.35
		53[c]	29.12 (5.21)	27.69-30.56
	30-39	22[a]	28.10 (5.49)	25.66-30.53
		30[b]	32.41 (5.37)	30.41-34.42
		52[c]	30.59 (5.78)	28.98-32.20
	40-50	18[a]	25.23 (4.16)	23.16-27.30
		27[b]	27.23 (6.92)	24.49-29.97
		45[c]	26.43 (6.00)	24.63-28.23

[a]-Female,[b]-Male,[c]-Total

was stated that the reach motion posture was affected by the anthropometric characteristics of the human body. Thus, short stature subjects may have less reach motion than tall stature subjects.

We found a decreased reach distance value in the age group between 30 and 39 compared to the age group between 20 and 29. The reason for the same remains unclear. The probable reasons may be due to the followings: Firstly, there were a slightly higher percentage of males (20%) than females (15%) in the age group 30-39, but females (22%) were more compared to males (13%) in age group 20-29. This was supported by an earlier study addressing that females tend to reach less distance than males due to the limb muscular contractility and narrower shoulder width[24]. Secondly, despite the fact age

Table 3. Correlation of FRT values among six different sensory conditions.[a]

	SSEO[b]	SSEC	SSEOVC	SUSEO	SUSEC
SSEC[c]	.949(<.0001)	-	-	-	-
SSEOVC[d]	.876(<.0001)	.899(<.0001)	-	-	-
SUSEO[e]	.813(<.0001)	.841(<.0001)	.957(<.0001)	-	-
SUSEC[f]	.759(<.0001)	.789(<.0001)	.925(<.0001)	.972(<.0001)	-
SUSEOVC[g]	.707(<.0001)	.743(<.0001)	.895(<.0001)	.977(<.0001)	.947(<.0001)

[a]-Karl Pearsons correlation values expressed as R(P), [b]-Standing on stable surface with eyes open, [c]-Standing on stable surface with eyes closed. [d]-Standing on stable surface with eyes opened using visual conflict dome, [e]- Standing on unstable surface with eyes open, [f]-Standing on unstable surface with eyes closed. [g]-Standing on unstable surface with eyes opened using visual conflict dome.

Table 4. Correlation of FRT values in six different sensory conditions with the demographic variables of the participants.[a]

	SSEO	SSEC	SSEOVC	SUSEO	SUSEC	SUSEOVC
Height	.311(<.0001	.265 (<.001)	.307 (<.0001)	.276 (<.001)	.245(<.002)	.268(<.001)
Weight	.101(<0.220)	.108(<.190)	.216(<.008)	.233(<.006)	.222(<.006)	.257(<.001)
BMI[b]	-.102(<.215)	-.063(<.441)	.037(<0.649)	.081(<.325)	.090(<.276)	.117(<.154)
Arm length	.146(<.075)	.134(<.103)	.181(<.026)	.161(<.050)	.140(<.088)	.121(<.139)

[a]- Karl Pearsons correlation values expressed as R(P), [b]-Body mass index.

group that 20 and 29 were the student population, 90 % of them scored less on activity index, whereas the age group between 30 and 39 scored better on similar ratings. The age group of 40-49 showed a decline in mean reach distance despite more number of male participants. This may be due to the fact that there is not much difference in reach distance obtained between male and female participants above 40 years of age. We warrant caution with above mentioned reasons since the number of participants were less in each groups.

Limitations

The limitations of the study are as follows: Firstly, the participants aged above 50 years were not included in this study since age-related sensory, neuromuscular and musculoskeletal degenerative changes may affect their postural control and stability, thus increasing the risk of falling. Future studies should recruit the subjects who are aged above 50 years. In addition, their postural stability may be compared with subjects who are aged below 50 years in order to obtain the role of aging on dynamic stance postural stability. Secondly, the participants were asked to stand with feet shoulder width apart. In order to measure the desired dynamic stance postural stability, the stance with feet close together condition may be applied in the future study. Thirdly, the limited number of participants was recruited from the single geographical location. In further studies, multi-centre trials should be conducted with large sample size in order to confirm our study findings.

Implication

The forward reach distance under six different sensory accurate and inaccurate conditions may provide reference values for neurological patients with postural dysfunction due to impaired sensory integration. Furthermore, these values may be used as prognostic indicator for the patients who are undergoing sensory-motor training aimed at improving postural control.

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