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Reference Values of Functional and Lateral Reach Test Among the Young Saudi Population: Their Psychometric Properties and Correlation with Anthropometric Parameters

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Background: Due to lack of normal reference values of forward and lateral reach tests for Saudi young adults, this study aimed to formulate normative values of the forward reach test and lateral reach test and to assess the correlation between the demographic variables and the reach test results.





Material/Methods: We randomly assigned 240 normal young Saudi adults ages 20–23 years to assess reach test scores in forward and lateral directions. All the subjects had been measured for distance reached in forward and lateral direction on graph paper fixed to a white board.

Results: The mean and standard deviation of forward and lateral reach distances were 25 ± 8.14 cm and 19.78 ± 5.70 cm, respectively. Significant differences were found between males and females for forward reach and lateral reach scores ($p < 0.001$). Forward reach and lateral reach values showed a moderate correlation with height, lower limb length, and upper limb length. The intra-rater reliability assessed by intra-class correlation coefficient was 0.91 and 0.92 for the forward and lateral reach test scores, respectively.

Conclusions: This study established reference values of forward and lateral reach scores for Saudi young adults ages 20–23 years. Height, upper limb length, and lower limb length were moderately correlated with the reach distances in forward and lateral directions. Males performed longer reach distances than females.

MeSH Keywords: **Nervous System Diseases • Postural Balance • Young Adult**

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Background

Balance assessment is one of the most common neurological examinations conducted by health professionals [1]. Balance describes the static and dynamic stability of a person [2]. The incidences of traumatic brain injuries [3], traumatic spinal cord injuries [4], stroke [5], and substance use disorders [6] are high among young adults in Saudi Arabia. All these disorders affect the nervous system and create problems with balance, muscle strength, and function. There are many outcome measures for assessing balance, including the Berg balance test, Romberg's test, the timed up and go test, the forward reach test (FRT), and the lateral reach test (LRT) [7]. Among the available balance measurement options, reach tests are simple and reliable and produce valid outcomes for measuring balance objectively in terms of the limits of stability [8–10].

Duncan et al. published an initial study on the FRT in 1990, introducing the FRT as a method for evaluating the margin of stability in the forward direction. They compared the FRT with a standardized examination (center of pressure excursion) and found that FRT is a very simple, easy, reliable, precise, and valid method to test balance [8].

Separately, Brauer et al. developed the LRT, a clinical test for measuring balance performance, in 1999. This test evaluates a person's control over their body in a sideward direction while maintaining a fixed base of support. Concurrent validity of the test has been proven with center of pressure excursion on a force plate. It has high test–retest repeatability [9].

There are many articles that provide normative data for balance as measured by the FRT and LRT [8,10–15]. Perceptible variations were noted among different age groups range, 20–89 years) for FRT and LRT. The studies conducted by Duncan and Silveria et al. used broad age groups: 20–40, 41–69, 70–89 years [8,13], their sample sizes in each age group were less than 50, and the generalizability of normative data for FRT and LRT values obtained, due to small sample size and wide age group, was debatable. Here, we assessed whether including larger samples with narrower age groups (4 years) would delineate standardized values for young adults ages 20–23 years.

The lack of normative reference values for reach tests among young people can make the assessment weaker and lacking in objectivity. Having adequate reference values for young adults undergoing a balance reach test will increase the confidence and provide objectivity in the balance assessment. The primary aims of this study were thus to establish the normative reference values for FRT and LRT among young adults in Saudi Arabia and to elucidate any correlations that exist between demographic variables and functional reach test outcomes.

Material and Methods

The Research Ethics Committee of King Khalid University approved this study (approval no. REC # 2016-08-29) on December 8, 2016. In this cross-sectional study, we included 240 normal young adults ages 20–23 years. Out of 240 subjects, 120 were males and 120 were females. The participant sample was randomly selected from the university medical colleges by using the random number table method. Subjects with any health issues affecting the neuromusculoskeletal system were excluded. Individuals with common conditions that affect physical performance, such as rhinitis, flu, and fever, were also excluded. The investigators were well-qualified, with a master's degree and doctoral degree, respectively, in the field of physical therapy, and had more than 10 years of experience in the same field.

After obtaining written informed consent from the participants, a brief explanation of the procedure was provided. Participant name (optional), age, occupation, mobile number, and address for communication were collected on a data entry sheet. Height was obtained using a stadiometer in centimeters and weight was obtained on a weighing scale in kilograms. Upper limb length was recorded from the anterior part of the acromion to the tip of the styloid process of the radius bone [16], while lower limb length was recorded from the anterior superior iliac spine to the medial malleolus of the tibia [17]. Trunk length was measured between the acromion process and the anterior superior iliac spine [18]. All of these measurements were obtained in centimeters using a tape measure.

The forward reach and lateral reach distances were obtained in centimeters on a graph paper affixed to a white, movable board [19]. After the subject was directed to stand in a relaxed position with legs apart to shoulder width without shoes, the whiteboard was arranged parallel to the forward centerline next to them. The participant's right arm was raised until located 90 degrees in the forward direction and parallel with the graph paper on the whiteboard. The starting position and end position were recorded by a pen mark on the graph paper; the reference point of the marking was the tip of the third metacarpal.

While reaching, the subjects were directed to reach as far as possible without taking a step, touching the board, lifting their heels, or bending their knees. After reaching the maximal distance, the subjects were asked to keep their hand along the graph paper for 2–3 s for measurement. The distance between the 2 points was measured in centimeters.

The details of the FRT procedure are illustrated in Figure 1. Initially, all the subjects were taken through a practice trial, followed by 3 actual trials. The average result of the 3 trials

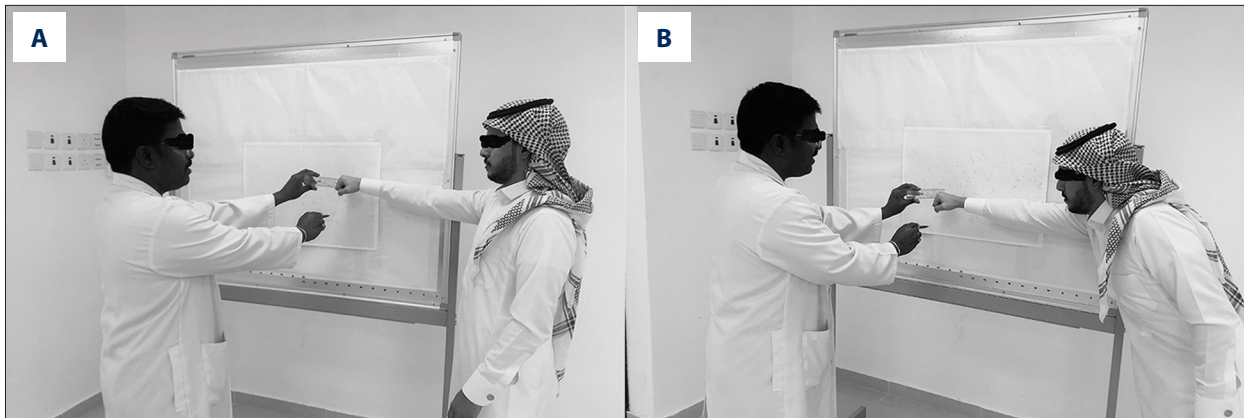


Figure 1. Procedure of forward reach test. (A) Before reach; (B) after reach.

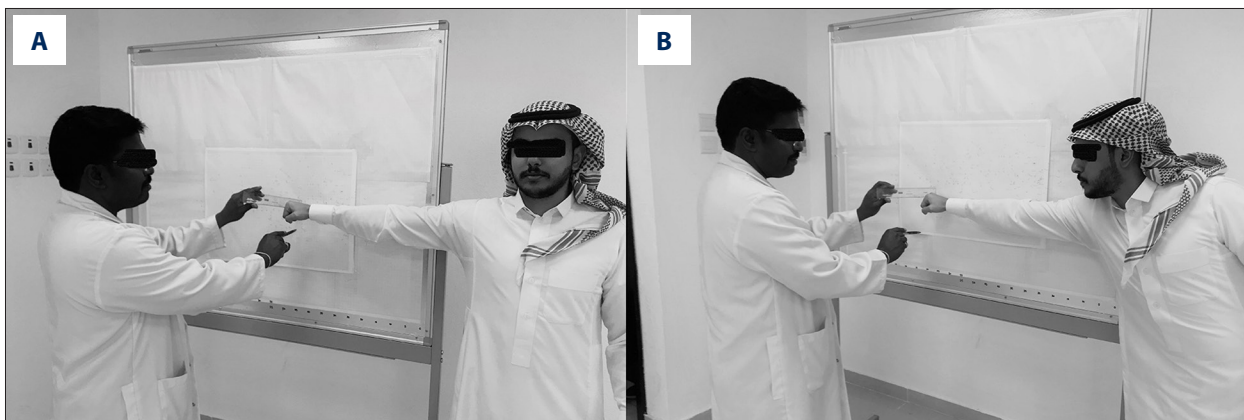


Figure 2. Procedure of lateral reach test. (A) Before reach; (B) after reach.

was then recorded for data analysis purpose. The lateral reach procedure was done in a similar fashion, with the board position positioned in a lateral fashion to suit the reach direction, the arm abducted to 90 degrees, and the person directed to reach laterally without lifting or bending their legs. The details of the LRT procedure can be seen in Figure 2. Both the FRT and LRT measurements were repeated after 15 min by the same evaluator to obtain intra-rater reliability data.

Data analysis

Univariate analysis of all the variables regarding means and standard deviations (SDs) was done by descriptive statistics. Correlations between demographic variables and FRT and LRT were identified by using Pearson correlation analysis. The gender and test differences for all variables were calculated by independent-samples *t* test. The intra-rater reliability was measured by intraclass correlation coefficient (ICC). SPSS version 21.0 (IBM Corp., Armonk, NY, USA) was used for analysis, and a *p*-value of less than 0.05 at a 95% confidence interval was considered to be significant.

Results

The aim of this study was to determine normative results for FRT and LRT for young Saudi adults ages 20–23 years. We assessed 240 medical students, of whom 120 were males and 120 were females. Descriptive statistics were used for analyzing age, height, weight, body mass index (BMI), upper limb length, lower limb length, trunk length, and FRT and LRT values. The mean \pm SD values of FRT and LRT for the total sample were 25 ± 8.14 cm and 19.78 ± 5.70 cm, respectively. The mean \pm SD values of the individual age groups and sexes are presented in Table 1.

The mean \pm SD for age for the whole sample was 21.4 ± 1.09 years. The mean \pm SD values for age for the males and females, respectively, were 21.55 ± 1.08 years and 21.25 ± 1.09 years. The comparison of anthropometric parameters (height, weight, BMI, upper limb length, lower limb length, and trunk length) was performed between males and females by using an independent-samples *t* test, and the results revealed that there was a significant difference in anthropometric measurements between males and females, with a *p*-value of less than 0.001. The comparison of FRT and LRT values was also

Table 1. Mean and standard deviations of demographic characteristics and FRT and LRT values of the whole sample (n=240).

Age	Gender	No.	Parameter	Height (m)	Weight (Kg)	BMI (Kg/m ²)	ULL (cm)	TL (cm)	LLL (cm)	FRT (cm)	LRT (cm)
20 years	Male	26	Mean	1.69	69.12	24.04	58.79	48.46	92.52	29.17	22.76
			SD	0.07	15.39	5.04	8.53	3.00	4.05	7.05	6.19
	Female	40	Mean	1.57	55.50	21.98	52.60	47.39	83.93	19.95	16.48
			SD	0.06	10.96	4.02	3.18	8.64	7.17	4.53	3.83
	Total	66	Mean	1.62	60.86	22.79	55.03	47.81	87.31	23.58	18.95
			SD	0.09	14.43	4.52	6.59	6.97	7.42	7.22	5.76
21 years	Male	31	Mean	1.71	73.19	25.09	57.19	48.61	91.90	30.47	22.02
			SD	0.05	16.21	5.08	2.26	3.39	4.86	6.32	5.99
	Female	30	Mean	1.56	55.42	22.30	52.80	45.63	84.75	19.09	16.16
			SD	0.05	13.00	4.21	2.52	3.76	4.51	4.80	3.55
	Total	61	Mean	1.64	64.45	23.72	55.03	47.15	88.39	24.87	19.14
			SD	0.09	17.13	4.84	3.25	3.86	5.89	8.00	5.72
22 years	Male	34	Mean	1.69	72.34	24.84	57.06	48.79	91.09	31.09	23.59
			SD	0.06	16.53	6.33	3.02	3.48	4.15	6.53	4.45
	Female	30	Mean	1.58	58.30	23.03	54.04	45.68	85.12	20.69	16.48
			SD	0.04	12.58	4.42	3.19	3.19	2.79	5.84	4.45
	Total	64	Mean	1.64	65.76	24.00	55.64	47.34	88.29	26.22	20.26
			SD	0.08	16.31	5.55	3.43	3.67	4.65	8.09	5.68
23 years	Male	29	Mean	1.69	75.34	26.28	57.66	50.84	91.07	33.08	24.33
			SD	0.05	17.24	5.69	2.72	3.03	4.16	7.20	3.89
	Female	20	Mean	1.57	55.18	22.05	53.15	46.88	84.50	20.01	16.32
			SD	0.03	12.86	5.11	2.57	3.58	3.21	4.97	3.66
	Total	49	Mean	1.64	67.11	24.55	55.82	49.22	88.39	27.74	21.06
			SD	0.08	18.42	5.80	3.45	3.78	4.98	9.06	5.47
Whole	Male	120	Mean	1.70	72.59	25.08	57.61	49.17	91.60	31.00	23.18
			SD	0.06	16.32	5.59	4.61	3.35	4.31	6.81	5.19
Whole	Female	120	Mean	1.57	56.13	22.33	53.10	46.44	84.53	19.93	16.37
			SD	0.05	12.13	4.33	2.95	5.75	5.06	4.99	3.85
Total	Sample	240	Mean	1.63	64.36	23.71	55.36	47.80	88.06	25.46	19.78
			SD	0.08	16.55	5.17	4.48	4.89	5.88	8.14	5.70

No. – number of subjects; SD – standard deviation; BMI – body mass index; ULL – upper limb length; TL – trunk length; LLL – lower limb length; FRT – forward reach test; LRT – lateral reach test; m – meters; Kg – kilograms; cm – centimeters.

Table 2. Correlation between various demographic parameters and FRT & LRT.

Variables	Correlation parameter	FRT	LRT
Age	r-value	.186**	.141*
	Significance	0.004	0.029
Height	r-value	.559**	.554**
	Significance	<0.001	<0.001
Weight	r-value	.340**	.444**
	Significance	<0.001	<0.001
BMI	r-value	.161*	.275**
	Significance	0.012	<0.001
ULL	r-value	.442**	.411**
	Significance	<0.001	<0.001
TL	r-value	.291**	.270**
	Significance	<0.001	<0.001
LLL	r-value	.479**	.437**
	Sig. (2-tailed)	<0.001	<0.001

* Correlation is significant at the 0.05 level (2-tailed);
 ** correlation is significant at the 0.01 level (2-tailed).
 ULL – upper limb length; TL – trunk length; LLL – lower limb length; FRT – forward reach test; LRT – lateral reach test.

completed between males and females using an independent-samples *t* test, and the results showed a significant difference between males and females, with a *p*-value of less than 0.001 for reaching in both the forward and lateral directions.

Additionally, a comparison between FRT and LRT distances was done for the whole sample by using an independent-samples *t* test, showing a significant difference between FRT and LRT values, with a *p*-value of less than 0.001. The details of all of the mean and SD values are presented in Table 1. The correlation evaluation between FRT and LRT was conducted by Pearson correlation analysis for all 240 individuals, indicating a significant positive correlation with an *r*-value of 0.718 and a *p*-value of less than 0.001.

In assessing the possible correlation between age, height, weight, BMI, upper limb length, lower limb length, trunk length, and FRT and LRT values using Pearson correlation coefficient analysis, the correlation of height, lower limb length, and upper limb length with FRT was moderate, with *r*-values of 0.56, 0.47, and 0.44, respectively (*p*<0.001). Similarly, the correlation of height, weight, lower limb length, and upper limb length with LRT was also moderate, with *r*-values of 0.55, 0.44, 0.44,

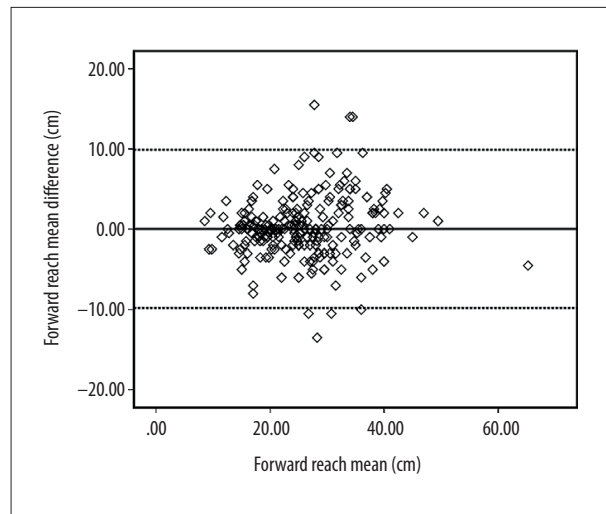


Figure 3. Intra-rater differences for FRT with upper bound and lower bound values.

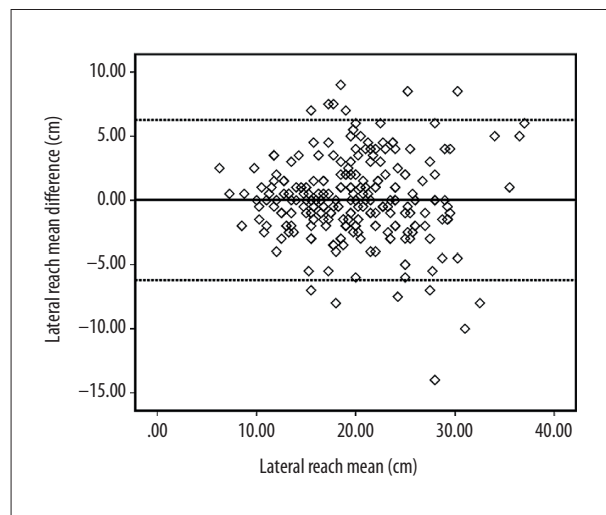


Figure 4. Intra-rater differences for LRT with upper bound and lower bound values.

and 0.41, respectively (*p*<0.001). The details of these correlations are presented in Table 2.

The intra-rater reliability for FRT and LRT was done by using the ICC. The ICC values for intra-rater reliability of FRT and LRT values were 0.91 and 0.92, respectively, with significant *p*-values of less than 0.001. The intra-rater mean differences for FRT and LRT are presented in Figures 3 and 4 as Bland-Altman graphs.

Discussion

FRT and LRT are 2 unique tests for assessing functional balance. The present study assessed outcomes for FRT and LRT in 240 young adults (120 males and 120 females) ages 20–23

years in the Kingdom of Saudi Arabia. The aim of this research was to establish normative reference values for FRT and LRT in young adults of the Kingdom of Saudi Arabia and to identify the demographic factors that can affect them.

A multidirectional reach test was previously used by Tantisuwat et al. to determine the limits of stability in people ages 20–79 years [11]. In a subgroup analysis of those ages 20–29 years, the authors found the mean \pm SD values of age, height, weight and BMI were 21.6 ± 1.8 years, 160.1 ± 5.2 cm, 55.3 ± 6.3 kg, and 21.6 ± 2.0 kg/m², respectively. In the present study, the mean \pm SD values for age, height, weight and BMI for people ages 20–23 years were 21.41 ± 1.09 years, 163 ± 8 cm, 64.36 ± 16.55 kg, and 23.71 ± 5.17 kg/m², respectively. The average anthropometric parameters were similar except in terms of body weight. The forward and lateral reach distance mean \pm SD values were 28.3 ± 8.1 cm and 17.9 ± 5.2 cm in a study by Tantisuwat et al. [11]. When we compared our study values with reach distances, we found values for FRT and LRT mean \pm SD was 25.46 ± 8.14 and 19.78 ± 5.70 , respectively. There was a 2–3 cm difference in reach distance mean values for FRT and LRT between the Tantisuwat study and the present study. These differences show that age group and ethnic group of the sample influence the reach values.

In the present study, a significant correlation was found between FRT and LRT, with an r-value of 0.718. In a different study involving 98 healthy Brazilian people ages 20–87 years, Silveira et al. found a similar correlation between FRT and LRT, with an r-value of 0.696 [13]. DeWaard et al. [20] found a moderate correlation between FRT and LRT (r-value 0.52), which is in agreement with our study.

Brauer et al. assessed mediolateral postural stability using the LRT in 60 healthy females, reporting mean \pm SD values of 72.5 ± 5 years for age and 1.58 ± 0.08 meters for height. In the present study, the mean \pm SD values for age and height measured were 21.4 ± 1.08 years and 1.63 ± 0.08 meters respectively. The LRT value in the Brauer et al. study was 20.04 ± 0.49 cm and that in our study was 19.78 ± 5.70 cm. The Brauer et al. study assessed the correlation between height and arm length with LRT distances, yielding r-values of 0.43 and 0.34, respectively, with a significant p-value of less than 0.05 [9]. In the present study, we obtained similar correlations between height and arm length, with LRT distances with r-values of 0.55 and 0.41, respectively, and a significant p-value of less than 0.001.

Yuksel et al. performed an assessment of FRT and LRT on 280 Turkish children ages 6–12 years [12], showing a moderate

correlation among height, lower limb length, and upper limb length and FRT and LRT. The correlation r-values in their study for height, lower limb length, and upper limb length with FRT were 0.749, 0.736, and 0.727, respectively. In the present study, we obtained a moderate correlation for height, lower limb length, and upper limb length with FRT, and the r-values were 0.56, 0.47, and 0.44, respectively. Separately, the correlation r-values in their study for height, lower limb length, and upper limb length with LRT were 0.673, 0.661, and 0.639, respectively. In the present study, we obtained moderate correlation values for height, lower limb length, and upper limb length with LRT, and the r-values were 0.55, 0.44, and 0.44, respectively.

The intra-rater reliability of the FRT and LRT was assessed in our study for 240 subjects and we obtained excellent intra-rater reliability with ICC values of 0.91 and 0.92, respectively. Rockwood et al. also assessed intra-rater reliability of FRT in 1161 subjects and they attained an ICC value of 0.92, which is similar to that in the present study [21]. Brauer et al. [9] assessed LRT test–retest reliability among 60 elderly women and obtained an excellent r-value of more than 0.94, which is similar to values found in our study.

The comparison of means between males and females in our study revealed a significant difference for both FRT and LRT, with a p-value of less than 0.001. Similar findings were also observed by Silveira et al. [13] in a group of 98 healthy Brazilian people ages 20–87 years, with a significant p-value of less than 0.001.

Importantly, the present study performed FRT and LRT only in a narrow age group of those aged 20–23 years in a single area of the Kingdom of Saudi Arabia. Future studies could be performed including more age groups in a multicentric manner.

Conclusions

The mean \pm SD values for FRT and LRT were 25.46 ± 8.14 and 19.78 ± 5.70 , respectively, for normal young Saudi adults 20–23 years old. Height and limb length demonstrated a moderate correlation with FRT and LRT, while there was a significant difference noted in reach distances for FRT and LRT between the males and females. The intra-rater reliability findings of FRT and LRT were excellent, with ICC values of 0.91 and 0.92.

Conflicts of interest

None.

References:

1. Lendraitienė E, Petruševičienė D, Savickas R et al: The impact of physical therapy in patients with severe traumatic brain injury during acute and post-acute rehabilitation according to coma duration. *J Phys Ther Sci*, 2016; 28(7): 2048–54
2. Rogers ME, Page P, Takeshima N: Balance training for the older athlete. *Int J Sports Phys Ther*, 2013; 8(4): 517–30
3. Al-Habib A, A-shail A, Alqeel A et al: Causes and patterns of adult traumatic head injuries in Saudi Arabia: Implications for injury prevention. *Ann Saudi Med*, 2013; 33(4): 351–55
4. Robert AA, Zamzami MM: Traumatic spinal cord injury in Saudi Arabia: A review of the literature. *Pan Afr Med J*, 2013; 16: 104
5. Robert AA, Zamzami MM: Stroke in Saudi Arabia: a review of the recent literature. *Pan Afr Med J. African Field Epidemiology Network*. 2014;17: 14.
6. Bassiony M: Substance use disorders in Saudi Arabia: Review article. *J Subst Use*, 2013; 18(6): 450–66
7. DeRenzo JS: Registry of outcome measures with MDC 2010 | pain | balance (ability). http://www.greatseminarsonline.com/course_documents/mc-stroke/Resources-MC-Stroke.pdf
8. Duncan PW, Weiner DK, Chandler J, Studenski S: Functional reach: A new clinical measure of balance. *J Gerontol*, 1990; 45(6): M192–97
9. Brauer S, Burns Y, Galley P: Lateral reach: A clinical measure of medio-lateral postural stability. *Physiother Res Int*, 1999; 4(2): 81–88
10. Newton RA: Validity of the multi-directional reach test: A practical measure for limits of stability in older adults. *J Gerontol A Biol Sci Med Sci*, 2001; 56(4): M248–52
11. Tantisuwat A, Chamonchant D, Boonyong S: Multi-directional reach test: An investigation of the limits of stability of people aged between 20–79 years. *J Phys Ther Sci*, 2014; 26(6): 877–80
12. Yuksel E, Ozcan Kahraman B, Nalbant A et al: Functional reach and lateral reach tests in Turkish children. *Phys Occup Ther Pediatr*, 2017; 37(4): 389–98
13. Silveria KRM, Matas SLA, Rodrigues Perracini M: Assessment of performance in the functional reach and lateral reach test in a Brazilian population sample. *Rev Bras Fisioter*, 2006; 10(4): 351–55
14. Deshmukh AA: Normal values of functional reach and lateral reach tests in children with knee hypermobility. *Pediatr Phys Ther*, 2014; 26(2): 230–36
15. Deshmukh AA, Ganesan S, Tedla JS: Normal values of functional reach and lateral reach tests in Indian school children. *Pediatr Phys Ther*, 2011; 23(1): 23–30
16. Shah FY, Kotwal HA, Shahid-ul-islam M: Psychogenic limb length discrepancy of upper limbs. *International Journal of Contemporary Research*, 2017; 4(4): 962–64
17. Magee DJ: Orthopedic physical assessment. Enhanced edition. Elsevier Sciences, 2006
18. Egwu MO, Mbada CE, Olowosejeje D: Normative values of spinal flexibility for Nigerians using the inclinometric technique. *J Exerc Sci Physiother*, 2008; 8(2): 32–104
19. Lord SR, Sherrington C, Menz HB, Close JCT: Falls in older people. Falls in older people: Risk factors and strategies for prevention. Second Edition, 2007; 1–395
20. DeWaard BP, Bentrup BR, Hollman JH et al: Relationship of the functional and lateral reach tests in elderly females. *J Geriatr Phys Ther*, 2002; 25(3): 31
21. Rockwood K, Awalt E, Carver D, MacKnight C: Feasibility and measurement properties of the functional reach and the timed up and go tests in the Canadian study of health and aging. *J Gerontol A Biol Sci Med Sci*, 2000; 55(2): 70–74