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RESEARCH ARTICLE

NORMATIVE VALUES OF STAR EXCURSION BALANCE TEST IN YOUNG ADULTS: A CROSS SECTIONAL STUDY.

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Abstract

Background: Star Excursion Balance Test (SEBT) is a simple, reliable, cost effective screening test which is used to evaluate the dynamic balance of lower limbs in 8 selective directions to determine potential risk of injury. Reach distance values of SEBT can be used as an index of dynamic postural control. However, despite its global use, there are currently no normative values available for the SEBT in healthy young adults. In this test volunteer has to maintain balance on one lower extremity and performed 3 trials of the SEBT in each of the 8 directions while balancing with other lower extremity.

Materials & Methods: Normative values of star excursion balance test were measured on 240 young adults (114 males and 114 females) from 18 -30 years with different height and BMI.

Results: Total 228 number of volunteers (114 male and 114 female) with mean age of male 21.45 ±2.37 and mean age of female 21.19 ± 2.02 were selected for the study and according to height and BMI normative values were recorded in both gender.

Conclusion: The normative values of star excursion balance test can be used by physical therapists, coaches and athletic trainers in order to interpret and compare with the normal values which will help to find out the risk of injury. Individual data generated from this test which will help to find out the risk of injury.

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Introduction:-

Balance is the key to all functional movement. This is an integral component of almost every activity of daily living. From standing on toes to reach something on the top shelf, walking up and down the stairs or walking on an irregular surface, running, swimming, bike riding and in many other daily activities balance is essential. Any impairment in balance will lead to decrease in performance and increases the risk of injury and fractures as a result of which daily activities may be impaired. Thus balance is of key clinical relevance to any rehabilitation/prophylactic physiotherapy program. [1, 2]

There are many outcome measures to assess the balance but number of tests for evaluating the dynamic balance is very less. The standardized test that are present for examining balance clinically, mostly put emphasis on the static balance, whereas many activity of daily living required dynamic balance.[2] The majority of dynamic balance assessment tools e.g. functional reach tests and the berg balance scale, were developed specifically for paediatrics [4], geriatrics [5] and neurological patients [6]. There are very few practical methods like force plate analysis, modified bass test etc. for evaluating dynamic balance but due to the space and cost requirements associated with these devices, they are not affordable or practical for many clinical settings. Thus, a simple, reliable and valid method is needed to assess lower extremity functional performance [1].

The Star Excursion Balance Test (SEBT) is a simple, reliable and cost effective test which is quick to administer and typically accessible in clinical and field settings to assess dynamic balance of lower limb [1, 7] monitor rehabilitation progress, assess deficits following injury and identify athletes at high risk for lower extremity injury. SEBT requires neuromuscular characteristics such as lower extremity coordination, balance, flexibility and strength. [8]

In this test the volunteer has to maintain balance on one lower limb and with other lower limb the volunteer has to reach along a previously marked lines in eight different directions that challenges the subject´s postural control, strength, range of motion and proprioceptive abilities. The distance reached in each direction is measured separately and interpreted as a representation of dynamic balance which offers the clinicians a practical alternative for assessing dynamic balance [2]. More is the reach by the subject with one leg while balancing on the opposite leg, the better functional performance they have[9].

The body of literature that exists suggests that normative values of SEBT can provide objective measures to differentiate deficits and improvements in dynamic postural control related to lower limb injury or fatigue and it has the potential to predict the likelihood of injury to the lower extremity.[3] There is insufficient literature reviews for the normative values of star excursion balance test in young adults.Only one study was conducted in Pennsylvania, United States for normative values of SEBT in athletic individuals with 19-27 years of age. In their geographical zone, standard height is 161.8 to 175.7 cm but considering our country the standard height in this age group is 152.6-166.3 cm according to which the results of normative values may vary. So, the purpose of this cross-sectional study was to find out the normative values of star excursion balance test in young adults which will help the therapist to establish a more precise levels of neuromuscular function for the purposes of injury prevention and rehabilitation.

Methodology:-

This prospective cross sectional study measured the excursion values of SEBT from students, staffs and volunteers of NILD/nearby institution/locality of Kolkata, India between March, 2017 to February, 2018. Ethical approval was taken from the Institute Ethical Committee (IEC) before commencing the study. A stratified purposive sample design was used to select the volunteers.

The volunteers included were young healthy adults from 18years to 30years of age with normal range of motion at hip, knee and ankle. The volunteers excluded were the individuals with history of ankle trauma requiring medical attention within past 2 years, history of any dizziness and vertigo, pre-diagnosed inner ear disorder, pre-diagnosed nervous system problems like stroke, pre-diagnosed bone or joint abnormality, pre-diagnosed cardiovascular disease like hypertension, volunteers with visual loss and any other disorders that might adversely affect the control of balance.

Total 240 young adults were approached with the proposal of study out of which 12 were excluded and 228 volunteers were agreed to participate and signed the Informed consent form (which includes permission to use their data and photograph for presentation and publication purpose) written in their preferred language (English/ Hindi/ Bengali). Out of those, 114 were male and 114 were female.

Procedure: Volunteers were approached with proposal of the study. Aim and procedure of the study were explained to each subject in the most communicable language. Demographic data including age, sex, height, Body Mass Index (BMI) was collected. Prior to the test pre-test precautions and instructions were explained, light weight loose fitting clothes was provided for avoiding any hindrance to movement. The volunteers were supervised to perform warm up exercises in the form of 5 min walk at a self-determined pace around research venue in presence of the evaluator therapist.

A star like pattern as shown in the figure 1a and 1b was drawn on the floor in eight directions i.e. anterior (A), posterior (P), medial (M), lateral (L), anteromedial (AM), anterolateral (AL), posteromedial (PM), posterolateral (PL) and each of the line is 45º apart from each other. The grid was constructed by using a protractor and 3-inch (7.62-cm)-wide adhesive tape and was enclosed in a 182.9 square centimetre on the hard tile floor .[1]

STAR EXCURSION BALANCE TEST

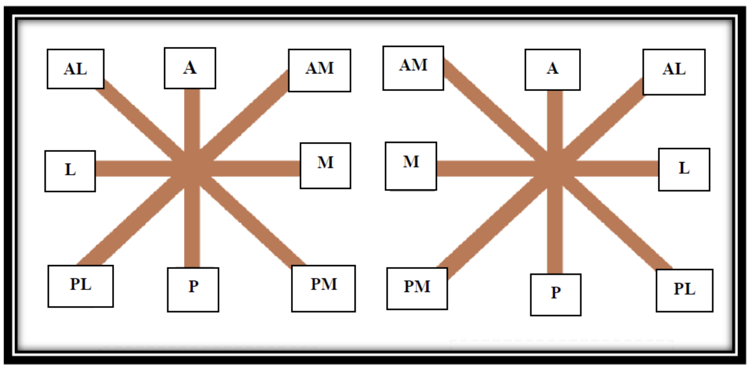

FIGURE : 1 a FIGURE : 1b

Procedure of the test

The evaluator demonstrated the test to all volunteers. The volunteers were asked to place one foot in the middle of the star pattern and with another foot volunteer were asked to reach as far as possible and lightly touch the line with their big toe before returning back to the starting position. With a marker, the researcher marked the spot at which the volunteer touched the line. Data was collected by measuring the length of reach (linear distance) with a measuring tape in all eight directions as shown in the figure 1. The linear distance was measured from the centre spot after the test to calculate the reach distance of each reach direction. When using the right foot as the reaching foot and the left leg to balance, the volunteer completed the circuit in a clockwise fashion and when balancing on the right leg, the volunteer performed the circuit in an anti-clockwise fashion. The volunteers were instructed to repeat this process for a total of 3 times in each direction by both feet. They were given 15 seconds of rest between the reaches. The average of the 3 reaches for each leg in each of the 8 directions was calculated. Trial was discarded and repeated when the volunteer-

a) Does not touch the line with the reach foot while maintaining weight bearing on the stance leg.
b) Lifted the stance foot from the centre grid.
c) Lost balance at any point in the trial.
d) Could not maintain start and return positions for one full second.
e) If a volunteer was judged by the examiner to have touched the ground with the reach foot in a manner that caused the reach leg to considerably support the body[1].

After completion of the test all reach distance of SEBT performance were measured for both the right and left leg and average reach distance was calculated by using the following simple equation:

Average distance in each direction (cm) = $$\frac{\text{Reach 1} + \text{Reach 2} + \text{Reach 3}}{3}$$

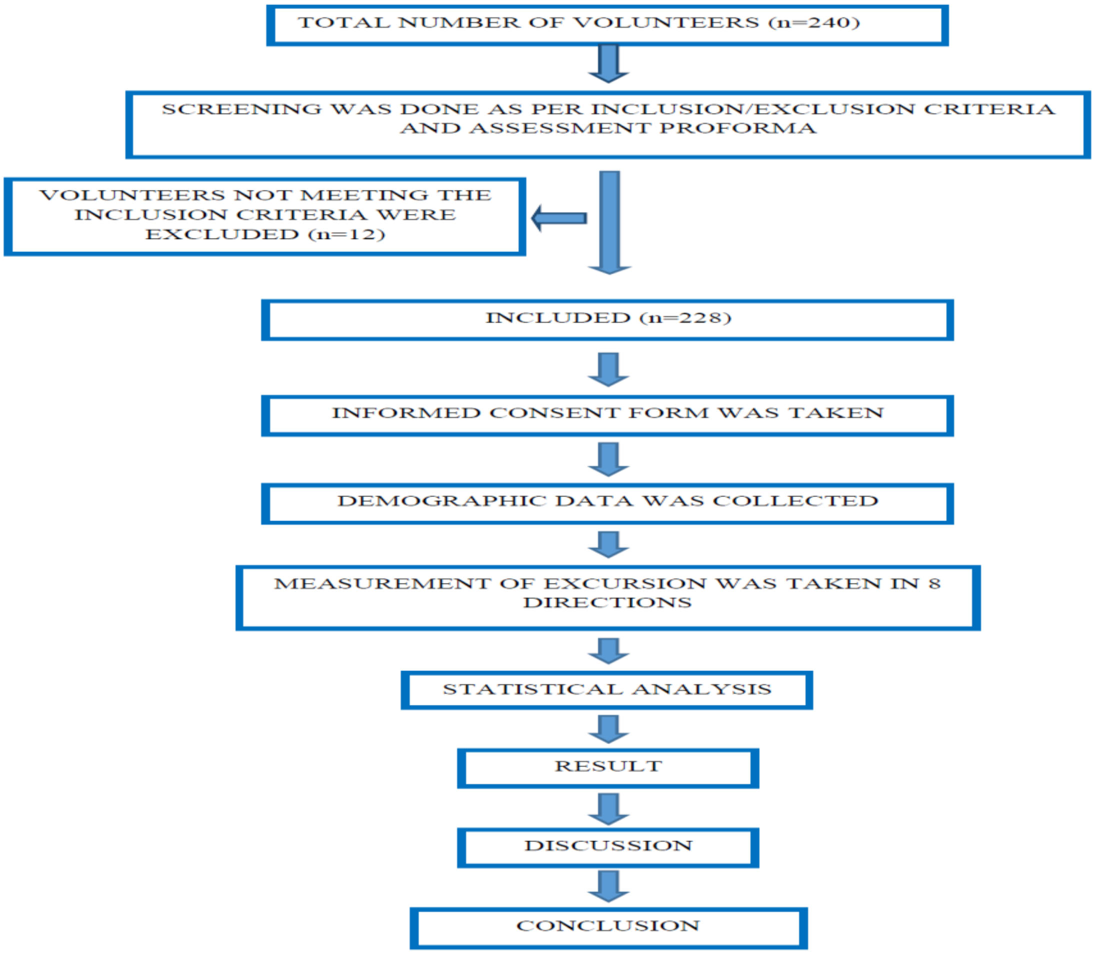

FIGURE-2: CONSORT FLOW DIAGRAM

Statistical analysis:-

Data were analysed using R Program (Statistical Software) Version 3.2.5. Descriptive statistics was used to show the mean and standard deviation of gender, height, B.M.I. and 8 excursion values of SEBT of right and left lower limb.

Results:-

The mean and standard deviation (SD) for demographic data- age, gender, height, BMI are shown in table 1 in the form of descriptive statistics.

Table 1:-Demographic Details

	MALE	**FEMALE**
AGE(18-30 years) MEAN ± SD	21.45 ±2.37	21.19 ± 2.02
HEIGHT(cm) MEAN±SD	166 ± 9.38	157 ± 8.59
BMI(Kg/m^2) MEAN±SD	22.34 ± 3.94	22.08 ± 4.09

The normative values of SEBT of right and left stance in male with different height are shown in the table 2.1

Table 2.1:-Normative Sebt Values Of Right And Left Stance In Male With Different Height

	RIGHT				LEFT			
SEBT Directions	**141-150 cm (n=11)**	**151-160 cm (n=13)**	**161-170 cm (n=37)**	**171-180 cm (n=53)**	**141-150 cm (n=11)**	**151-160 cm (n=13)**	**161-170 cm (n=37)**	**171-180 cm (n=53)**
Anterior	63.59±9.03	64.97±12.36	67.59±7.98	69.44±8.57	66.52±5.95	67.33±11.83	68.46±7.95	70.44±9.07
Posterior	56.3±4.99	58.14±9.01	57.63±8.33	62.10±8.56	57.14±3.93	58.12±11.34	58.44±8.58	62.37±9.26
Medial	66.96±4.96	67.29±8.92	68.52±9.37	68.14±7.93	60.02 ±5.63	63.61±12.06	66.11±8.34	68.63±0.05
Lateral	48.63±5.40	48.95±11.96	51.82±8.29	53.67±11.03	50.12±7.60	54.49±13.08	53.99±7.85	62.37±9.26
Anterolateral	60.61±11.3	61.71±15.10	63.09±11.26	63.80±11.62	62.96±12.3	65.94±12.49	63.15±9.86	66.77 ±11.7
Anteromedial	69.00±13.9	70.06±12.58	69.90±10.02	71.64±11.98	65.38±17.6	66.17±14.38	69.75±11.46	71.98±11.36
Posterolateral	45.36±8.14	46.54±13.34	48.13±11.07	49.31±14.15	44.91±9.74	47.78±14.96	47.07±11.52	51.33±14.28
Posteromedial	60.83±11.1	63.32± 11.74	62.61±11.64	64.72±10.81	62.13±12.4	61.38± 15.0	63.09±9.18	66.68±14.68

The normative values of SEBT of right and left stance in female with different height are shown in the table 2.2

Table 2.2:- Normative Sebt Values Of Right And Left Stance In Female With Different Height

	RIGHT					LEFT				
SEBT Directions	**131-140 cm (n=10)**	**141-150 cm (n=10)**	**151-160 cm (n=54)**	**161-170 cm (n=30)**	**171-180 cm (n=10)**	**131-140 cm (n=10)**	**141-150 cm (n=10)**	**151-160 cm (n=54)**	**161-170 cm (n=30)**	**171-180 cm (n=10)**
Anterior	62.20± 5.34	65.81± 10.5	67.72± 8.14	68.07± 7.81	73.77± 9.94	62.09± 8.31	62.67± 7.58	68.21± 8.05	68.35± 8.20	75.69± 9.82
Posterior	50.53± 8.06	51.96± 6.57	56.63± 7.74	57.56± 5.71	62.86± 9.71	54.07± 7.96	53.28± 5.89	58.13± 8.61	59.60± 7.56	65.45± 11.19
Medial	60.69± 9.46	63.39± 10.05	66.69± 8.89	67.98± 8.19	70.08± 7.45	59.59± 8.80	62.47± 6.28	67.05± 8.69	68.01± 8.14	69.43± 14.23
Lateral	44.24± 7.99	47.25± 2.69	53.52± 8.46	54.98± 9.63	52.75± 8.36	47.45± 7.36	51.71± 10.39	57.61± 8.81	58.88± 9.17	58.054 ±9.38
Anterolateral	56.52± 6.60	56.55± 9.14	65.83± 8.68	66.51± 9.42	68.43± 12.28	56.96± 7.40	59.53± 11.06	66.58± 11.65	66.58± 9.67	67.60 ±11.9
Anteromedial	58.46± 4.98	65.10± 9.54	69.57± 12.20	69.27± 9.21	73.34± 11.42	61.77± 11.2	66.82± 12.19	71.92± 10.23	72.14± 8.29	73.92± 12.89
Posterolateral	36.03± 10.13	38.14± 7.92	46.57± 8.82	47.91± 9.84	45.06± 9.32	44.02± 10.77	45.15± 9.08	49.64± 9.78	49.70± 10.33	52.17± 9.2
Posteromedial	56.23± 14.78	62.5±9.30	64.51± 13.54	65.56± 8.68	69.16± 6.18	57.92± 13.41	57.95± 13.24	67.16± 12.29	67.65± 10.45	68.90± 16.20

The normative values of SEBT of male and female of right and left stance (in cm) with different BMI are shown in the table 2.3

Table 2.3:- Normative Sebt Values Of Male And Female Of Right And Left Stance (In Cm)With Different Bmi

	RIGHT				LEFT			
SEBT	**Underwei**	**Normal**	**Overwei**	**Obese**	**Underwei**	**Normal**	**Overweig**	**Obese**

Directions	ght (<18.5 kg/m^2) (n=38)	(18.5-24.99 kg/m^2) (n=129)	ght (25-29.99 kg/m^2) (n=49)	(>=30 kg/m^2) (n=12)	ght (<18.5 kg/m^2) (n=38)	(18.5-24.99 kg/m^2) (n=129)	ht (25-29.99kg/m^2) (n=49)	(>=30 kg/m^2) (n=12)
Anterior	71.87±9.92	67.35±8.42	67.49±7.83	65.33±11.03	73.82±8.56	67.80±8.32	67.48±9.27	67.71±7.26
Posterior	60.88±8.23	57.08±8.16	57.49±8.51	56.7±7.43	63.16±10.0	57.81±8.81	56.58±8.58	56.56±4.68
Medial	71.0±8.2	65.35±8.53	67.19±9.09	64.61±8.14	61.12±8.02	54.46±9.59	52.43±8.33	46.64±7.41
Lateral	58.09±10.0	52.25±8.69	48.37±8.54	45.22±5.92	69.61±11.3	65.48±8.84	65.20±9.38	63.66±9.18
Anterolateral	69.40±12.0	63.08±10.5	61.24±10.16	60.22 ±4.68	74.65±9.97	69.81±11.46	69.23±12.94	66.27±8.45
Anteromedial	74.79±12.8	67.54±10.1	67.48±11.21	66.54±16.62	71.02±10.6	64.70±11.49	63.56±10.53	60.85±8.92
Posterolateral	50.20±10.5	46.40±11.4	41.38±9.01	40.10±16.21	69.88±14.4	63.00±11.53	62.97±13.69	59.77±13.6
Posteromedial	67.69±9.88	62.67±11.1	65.90±12.14	56.17±14.44	53.85±8.30	48.96±11.62	44.71±11.07	42.99±17.48

We observe that in anterior, posterior, medial & posterior-medial positions there is no significant difference between the right and left leg.

Discussion:-

One of the most significant step in rehabilitation is to evaluate the selective movement patterns to determine potential risk of injury as any abnormal findings can only be judged on the basis of normal findings. The SEBT is a promising test of postural control that not only used to assess physical performance, but also can be used to screen deficits in dynamic postural control due to musculoskeletal injuries (e.g. chronic ankle instability), to identify athletes at greater risk for lower extremity injury, as well as during the rehabilitation of orthopaedic injuries in healthy active adults. [10, 11]

The volunteers who participated (n=228) in this study were young healthy adults ranged from 18 to 30 years of age. So, the incidence of false negative values had been reduced by excluding volunteers above 30 years of age.

In this study gender, height and BMI specific reference values were obtained for the SEBT in healthy young adults. These gender, height and BMI specific reference values would enhance the interpretation of the SEBT in regular clinical practice and offer reference values against which the performance of patients could be compared; moreover, these reference values of SEBT could be used as reach targets during the progression of rehabilitation of patients.

The excursion reach of SEBT in accordance with gender shows that male individual's has higher normalized excursion reach scores in all 8 directions of the SEBT when compared with females because height and leg length of male subjects was comparatively higher than females. These findings are supported by Egwu et al (1994) where they mentioned that females are generally reported to have shorter legs as compared to males [12] as a result of which SEBT excursion reach may reduce in females.

Overstall P et al (1977) found that males possess better balance performance then women because in women postural sway increases due to increase in body weight. [13] When body weight is more in comparison to muscle mass then it will fail to maintain balance resulting in less excursion reach distance.

This study revealed that right lower limb of male have reduced reach distance in posterolateral, lateral, posterior direction and highest excursion reach in anteromedial, anterior and medial direction. Left lower limb of male has shown reduced excursion reach distance in posterolateral, lateral, posterior direction and highest excursion reach distance in anteromedial, anterior and medial direction.

The possible explanation for reduced excursion reach distance in posterolateral, lateral and posterior direction could be that the subjects got reduced visual feedback in these direction particularly in posterior and posterolateraldirection thus increasing demand on somatosensory system and joints .This findings are supported by Coughlan et al (2012) who found that in SEBT and Y-balance test the reach distance in posterolateral directions is decreased because in the posterolateral directions, visual awareness is reduced, thus it places an increased demand on the somatosensory system and therefore, the inability of the participants to see their scores may limit their reach. In the anterior reach direction, participants received visual feedback from the reach leg as they move and can observe the scored reach distance on each trial, so the excursion distance in this direction are more. [14]

This study revealed that SEBT excursion reach increases with increase in height. Excursion reach scores of individuals with 131-140 centimetre height is lower as compared to excursion reach scores of individuals with 171-180 centimetre in both right and left lower extremity. The possible cause may be due to the co-relation between height and leg length which was supported by the study done by Gribble et al (2003) who found that there is a significant co-relation between height, leg length & excursion distance. Height and leg length were found to be strongly correlated with each other as increase in height leads to increase in leg length [15].

The present study showed that SEBT excursion reach is more in volunteers with underweight and normal population and reduced in obese. In obese individuals more torque falls on lower extremity as a result of which excursion reach may reduce and in individual with normal BMI loading decreases significantly which increases the excursion reach. This finding is in accordance with the findings of study by Delporto et al (2012) on biomechanical effects of obesity on balance. They stated that obese individuals show higher knee joint torque compared to hip joint torque (maximal 0.75 $Nm \cdot kg^{-1}$) while this is reversed in normal weight persons (maximal 0.38 $Nm \cdot kg^{-1}$) [16, 17]. Subjects with normal BMI maximize forward trunk flexion in order to avoid high torque at the knee joint. Obese individuals may avoid this strategy in order to prevent vertebral column torque (which may exacerbate back pain) and as a result of limited capacity to flex the trunk.[18,19,20]Gilleard and Smith (2007) observed that there is a decreased capacity of forward flexion of the thoracolumbar spine in obese adults and thus ROM of trunk was limited due to decreased forward stability thus reducing the excursion reach. It was also observed that increased fatty tissue in the abdominal area may also create a physical barrier to full ROM during some movements. [21]

Browning and Kram[22] (2007) found that peak vertical ground reaction force were 60% greater for obese subjects as compared to their normal weight subjects. Obese subjects had a mass of 61% greater than normal weight subjects but experienced 91% greater ground reaction force. Similarly, Messier et al. [23] in the year 2005 found that joint loading decreases significantly with weight loss. For each step taken, joint load at the knee is reduced 4-fold for each one-pound reduction in body weight.

Prasetiowati L et al (2017) found that obese children have decreased postural balance when compared overweight and normal children aged 8-10 years. Weight of a person (and weight loss) is a crucial determinant of balance control. External and internal forces acting on the erect body create destabilizing events yielding postural oscillations. The postural control system regulates these oscillations by maintaining the vertical alignment of the body segments. When a person stands on a force platform, the point of application of the ground reaction forces under the feet (centre of foot pressure, COP) is the outcome of the inertial forces of the body and the restoring equilibrium forces of the postural control system. It is generally accepted that the mean speed of the COP displacements is an indicator of postural stability with a greater speed indicating a decrease in postural stability [24, 25]. Obese individuals shows greater balance impairment because with increase BMI centre of pressure displacement is higher which leads to balance problems. Thus Obesity could represent an important risk factor for falls; a factor that has been given, up to now, little attention. [26] Obese individuals are less stable than healthy-weight individuals and this decreased stability reduces the SEBT performance. The literature supports that the weight loss can improve balance. With high levels of weight loss, patients demonstrate significant increase in relative strength and significantly improved measures of postural stability.

In this study it was found that the SEBT excursion reach scores was more on right side as compared to left side because in most of the volunteers right side was dominant side as a result the excursion distance also increased. This findings was supported by Bahamonde R et al (2007) who conducted a study on the effects of leg dominance on the single leg hop functional test in non-injured adults and found that subjects were able to significantly jump farther by using dominant leg because dominant leg produces more vertical and horizontal ground reaction forces as compared to non-dominant leg. [27]

Limitations Of The Study:-

The normative values of star excursion balance test established in this study may not be generalized to all the Indian population, data was collected from a single centre and nearby locality, so the normative values cannot be generalized. Sample size was relatively small for a cross sectional study and co-relation between bilateral leg length and SEBT value was not established in this study.

Conclusion:-

This study provides the normative values for SEBT of young adults for different gender, height and BMI strata. SEBT excursion values in young adults increases with increase in height in both male and female. It can be also concluded from the result of this study the values of SEBT excursion is more on right stance leg as compared to left stance leg in different heights in both gender. The SEBT excursion values in underweight volunteers have highest excursion values followed by normal, overweight and obese volunteers respectively. Therefore, it is recommended that physical therapists and clinicians should assess SEBT values with respect to above mentioned normative values, taking into account the effects of height, BMI and gender variability.

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