DR. CALLUM TELFORD (Orcid ID : 0000-0003-4252-741X)
MR. MICHAEL MCCLUSKEY (Orcid ID : 0000-0001-9195-873X)

Article type : Original Article

Title page

Title

Normative performance values of modified Star Excursion Balance Test and Limb Symmetry in female adolescent footballers.

Authors and affiliation

Fraser Philp[1] **ORCID ID** https://orcid.org/0000-0002-8552-7869

Callum Telford[1]

Danielle Reid[2]

Michael McCluskey[1]

[1] School of Allied Health Professions, Keele University, UK

[2] The Royal Wolverhampton NHS Trust, Wolverhampton, UK

Co-authorship statement: Each of the authors has read and concurs with the content in the manuscript. As per the authorship statement document, all authors have made substantial contributions to all of the following:

1. the conception and design of the study, or acquisition of data, or analysis and interpretation of data
2. drafting the article or revising it critically for important intellectual content
3. final approval of the version to be submitted

Corresponding author details

Michael McCluskey

m.mccluskey@keele.ac.uk

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1002/TSM2.146

Abstract

Objectives: to establish normative performance values for the modified Star Excursion Balance Test (mSEBT) and derived Limb Symmetry Index (LSI) scores in non-injured female adolescent footballers, and identity if there is a relationship between the aforementioned metrics and age

Design: single measure study design

Setting: A single football club's female regional talent and development teams

Participants: Thirty-four uninjured female footballers**,** aged between 13 to 18 years.

Main Outcome Measures: MSEBT and derived LSI scores.

Results: There were no statistically significant differences between dominant and non-dominant leg distance scores in any of the mSEBT specific reach direction or composite scores. Across all age groups, mean dominant leg total distance scores ranged from 231.5 cm to 250.4 cm whilst non-dominant total distance scores ranged from 234.3 cm to 253.3 cm. Mean LSI values ranged from 97.8% to 100.5%. Age accounted for approximately 8% of the variance within dominant, non-dominant total distance and LSI scores.

Conclusions: Our study has established normative performance values for the mSEBT and derived LSI scores in non-injured female adolescent footballers. Age had a very limited ability in accounting for the variance observed for composite scores in dominant, non-dominant and LSI based scores.

Highlights

- This is the first study to provide normative mSEBT and LSI values for uninjured female adolescent footballers
- Age is poorly related to composite mSEBT and LSI scores
- Increasing age is not related to increasing levels of symmetry

Keywords

football, female, modified star excursion balance test, limb symmetry index, adolescent, age

Introduction

The Star Excursion Balance Test (SEBT), subsequent modified SEBT (mSEBT) and derived limb symmetry index (LSI) scores have demonstrated potential in identifying athletes at risk increased lower limb injury [1-4] but require further evaluation in female adolescent footballers. The availability of established normative performance values within this population is limited. Comparative data sets containing typical performance values, can serve as a baseline for monitoring athletic development, rehabilitation progress and be used to inform injury prevention strategies. Between the 2014/15 and 2016/17 seasons, female participation within football has increased from 89,118 to 106,910 participants respectively across Europe. Of this, the number of footballers under the age of 18 has increased from 62,442 to 69,485 [5]. Whilst it is recognised that there are many health benefits associated with increased participation in football and physical activity [6], it has also been identified that increased participation is associated with increased injury risk [7].

Injury rates in female footballers are known to be disproportionately high when compared to male counterparts. Anterior cruciate ligament (ACL) injuries are among the most prevalent lower limb injuries within football [8] and females are reportedly two to eight times more likely to sustain an ACL rupture[9,10]. Causes of the gender discrepancy are multifactorial with differences in anatomical [8,11], neuromuscular [12], hormonal [13] and training features [14] [15] being identified as contributory factors. Age has also been identified as an important factor, with younger athletes having a three to six times increased risk of initial injury [16], and a 20-40% increased risk of re-injury following ACL reconstruction [16-18].

Given the increased injury burden and risk profile of female footballers, several movement screening and injury prevention programmes have been developed, which look to replicate the task or movement constraints of the associated injury mechanism. Recently however, the measurement validity of movement screening tests and accuracy of associated measurements has been questioned [19,20]. The SEBT reportedly assesses the dynamic balance and strength of a player [1]. Whilst standing on a single leg, and without falling over, a player is required to reach out with their opposite leg in 8 separate planar directions from which a distance is recorded [21,22]. The modified SEBT (mSEBT) requires completion of three out of eight directions, namely the anterior, posterior-medial and posterior-lateral directions [4,23]. The mSEBT has been demonstrated sensitivity in detecting differences in specific reach direction values for ACL deficient participants [1] and was designed to be more time effective [24], increasing usability in fast-paced sporting environments. Based on evaluation of both limbs, a LSI score can be generated to inform decision making [25]. For LSI scores, values ranging from 90% to 94% have been suggested as a threshold for participation in training and competitive match play, irrespective of the sports or underlying metric [4,16,26,27].

Within female adolescent football, normal performance values during the mSEBT and subsequent LSI scores have not been well established [28]. Asymmetrical performance has been identified as a characteristic of adolescent footballers during completion the mSEBT [29], with a trend for decreasing asymmetry with increasing age. There an assumed relationship between increased symmetry and decreased injury risk. Within female basketball, LSI [30] scores derived from the SEBT of less than 94%, has identified players as being 6.5 times more likely to sustain a lower limb injury [4]. Whilst asymmetry has been identified as an injury risk factor [31-33], it is important not to neglect asymmetry as a manifestation of adaption for performance. Furthermore, asymmetry within this demographic may be expected given the ongoing developmental changes associated with puberty.

A comparative reference data set for normal mSEBT and derived LSI scores are therefore required for identification of thresholds for participation and injury risk in female adolescent footballers [28]. Prior to this, it is important to 1) establish the extent of the variability within the mSEBT testing process and identify if differences exist between the dominant and non-dominant legs, as each influence the derived LSI scores 2) report normative performance value ranges for dominant, non-dominant leg and LSI scores across the mSEBT components and 3) investigate if there is a relationship between age and either the mSEBT or LSI scores.

Therefore, the aim of this study is to establish normative performance values for the mSEBT and derived LSI scores in non-injured female adolescent footballers, and identity if there is a relationship between the aforementioned metrics and age.

Methods

Ethical approval was gained from X Ethics Review Panel 2018/19_SHAR_CA_015 at X. Participants were recruited from a single women's football club across the U14 to U18 age groups during the 2018/2019 season. Data collection was completed over a 5-month period (October 2018 to February 2019).

Inclusion and exclusion criteria

Participants were included if they were female, aged between 13 to 18 years old, enrolled within the regional talent (U14 to U16) or development squad (U18) and injury free for 3 months. Players with a previous injury within the last 3 months, suspected or confirmed pregnancy or unable to comply with instructions, were not included in the study.

Test Protocol

All participants were required to complete a Health Status Questionnaire. Testing was carried out by a single assessor with a second assessor present to verify the measurements. For evaluation of the mSEBT, The Y Balance Test Kit™ (YBT) produced by Functional Movement Systems was used. As per the mSEBT, participants were required to complete three direction specific reach tasks, namely in the anterior, posterior-medial and posterior-lateral directions as per figure 1. The dominant leg was defined as the preferred kicking leg of participants. Participants were required to complete the testing in shorts and barefoot. Prior to recording the measurements, participant's had 6 trials to minimise any learning effects [4,34] . Each measurement (taken in centimetres), for their dominant and non-dominant lower limb, was recorded three times. The following LSI formula was used, where:

$$\text{LSI} = \frac{Dominant\ leg\ score}{Non\ Dominant\ leg\ score} * 100$$

Figure 1. Reach directions tasks during for the mSEBT

Analysis

Coefficient of variation values between attempts was used to establish the extent of individual variability during the mSEBT testing process. A paired sample t-test was used to identify differences between dominant and non-dominant leg performance during all components of the mSEBT; all assumptions were tested for and the requirements for use of parametric statistical testing were met. Mean and 95% CI values have been reported for all age groups for dominant, non-dominant, LSI and all mSEBT components. Age was plotted against total dominant, non-dominant and LSI score values to identify if there was a linear relationship.

Results

Fifty-five participants were recruited for this study. Following eligibility checks 21 participants were excluded after having sustained an injury within the previous 3 months. Data for 34 participants was included within this study (U14 n= 12; U16 n=14; U18 n=8). Participants had a mean age of 14.74 (1.62 SD). The right leg was identified as the dominant leg for 30 participants and the left leg was identified as the dominant leg for 4 participants.

Combined age group coefficient of variation results for dominant, non-dominant leg distance and LSI scores.

The coefficient of variation values for combined age groups have been presented in table 1. Overall, the largest coefficient of variation value (10.6%) was observed for LSI scores in the posteromedial direction. Similar maximum coefficient of variation values were identified for the dominant (8.7%) and non-dominant legs (10.1%) in the anterior and posteromedial mSEBT specific reach direction scores.

Table 1. Combined age group coefficient of variation results for dominant, non-dominant leg distances and LSI score.

Results for differences between dominant and non-dominant legs for mSEBT subcomponent and total distance scores using paired sample t-test

There were no statistically significant differences between dominant and non-dominant leg distance scores in any of the mSEBT specific reach direction or composite scores (table 2).

Table (2) Results for differences between dominant and non-dominant legs for mSEBT subcomponents and total distance scores using paired sample t-test

Results for dominant, non-dominant and LSI normative performance values across all age groups

Normative performance values for dominant, non-dominant and LSI score across all age groups have been presented in table 3.

Dominant and non-dominant leg distance performance values

Across all age groups, mean dominant leg total distance scores ranged from 231.5 cm to 250.4 cm whilst non-dominant total distance scores ranged from 234.3 cm to 253.3 cm. The maximum mean total difference score between the non-dominant leg and dominant leg age groups was less than 3cm, with higher scores observed for the non-dominant leg. The highest mean score for subcomponents of the mSEBT was 96.0 cm achieved in the posterolateral direction. For the dominant and non-dominant leg performance, the U18 participants achieved the highest mean distance scores in all subcomponents and total distance scores of the mSEBT, with differences ranging from approximately 3 cm to 8 cm and 20 cm respectively.

LSI performance values

Mean LSI scores based on any specific direction and composite scores of the mSEBT were similar with differences of less than 2%. Mean LSI values ranged from 97.8% to 100.5%.

Table (3) Normative performance values for dominant, non-dominant and LSI score across all age groups

Results for the relationship of age and total dominant, non-dominant and LSI scores.

Age has very limited ability in accounting for the variance observed for total distance dominant, non-dominant and LSI based scores, with the highest R^2 value of 0.0782 idenfitied for dominant leg performance (figure 2). The lowest R^2 value of 0.00007 was identified for age and LSI based on total distance scores.

Figure 2. Age plotted against dominant, non-dominant and LSI scores.

Discussion

The aim of this study was to is to establish normative performance values for the mSEBT and derived LSI scores in non-injured female adolescent footballers, and identity if there is a relationship between the aforementioned metrics and age. Across U14 to U18 age groups, we were able to report normative performance values for direction specific and composite scores, as well as the derived LSI scores. Additionally, we identified between attempt coefficient of variation values as being less than 11% across all components and age groups. There was no statistically significant difference between dominant and non-dominant leg performance in direction specific and composite mSEBT scores. Age was identified as having very limited ability in accounting for the variance observed for composite scores in dominant, non-dominant and LSI based scores, with the highest R^2 value of 0.0782 idenfitied for dominant leg performance.

Sources of variability associated with the mSEBT testing process for dominant and non-dominant leg

For all components of the mSEBT, the coefficient of variance values ranged from 0.2% to 10.1% between attempts. These results indicate that between attempt variation for uninjured female adolescent footballers is relatively consistent at approximately 10%. Knowledge of normal between attempt variability may inform performance monitoring, rehabilitation and injury screening process, where consistency of performance is an important factor. Within our study, participant's had 6 trials to minimise any learning effects [4,34] . This may account for the consistency observed and highlights the importance of familiarising players with the testing process to ensure accurate measures of performance. Accuracy of results is high given that the same single assessor carried out all testing with a second assessor present to verify recorded measurements. These results support the mSEBT as having suitable reliability and are consistent with the wider literature which report the mSEBT having good to excellent intra and inter-rater reliability measurements (ICC values ranging from 0.82 to 0.87 [4,34-36]). .

A direct comparison of our results with the published literature is not possible given the limited availability of adolescent female football datasets. Previous studies have reported normative ranges in male and female basketballers of similar age ranges, with males achieving greater direction specific and composite scores between approximately 5 cm to 20 cm [4]. The mean anterior and posteromedial direction specific, and composite scores are less than the female basketball group studied by Plisky et al [4] with differences of approximately 10 cm and 25cm respectively. Whilst no height or limb length data is available in our study for comparison, these factors are known to affect reach distance and may account for the differences observed between studies. . This further highlights the need for gender and sports specific datasets given the varying performance characteristics.

Within our study, approximately 8% of the variance within dominant and non-dominant total distance scores (R^2 = 0.0782 and 0.0853 respectively) can be explained by age between the U14 and U18 age groups. The mSEBT test requires participants to maintain single leg balance with one leg (stabilising leg) whilst reaching out as far as possible with the non-stabilising leg. Performance is therefore reflective of participant's muscle strength, co-ordination, kinaesthetic awareness and functional capacity, biomechanical requirements of the task and anthropometric characteristics i.e. height, lower limb length, muscle length and joint range. We did not control for, or measure height and lower limb length which are known to affect reach distance in a non-injured population [37]. This is likely to account for the increased mean mSEBT distance scores of the U18 team when compared to the U14 and U16 teams, who achieved the highest mean distance scores in all subcomponents (ranging from approximately 3 cm to 8 cm) and total distance scores (approximately 20cm). For the mSEBT to be used in performance monitoring, rehabilitation and injury screening process, the effect of injury subtypes on absolute mSEBT performance values and variability requires further investigation. Further research is required to validate the task constraints of the mSEBT and the performance characteristics and injury mechanics associated with adolescent female football.

Decreased variance in height and lower limb length, associated with biological maturation, may explain the trend for decreasing between participant variation with increasing age. Peak height velocity in adolescent females is known to occur between 11.8 (SD 0.9) years of age with changes in height of 8.6 (SD 1.1) cm/year[38]. This would account for the increased variability observed within our results given that the most variable age group corresponds to the largest changes in height. Alongside changes associated with growth, participants will have also been undergoing changes associated with biological maturation, including development of the neuro-muscular system, co-ordination and cyclical hormonal fluctuations which may affect tissue stiffness properties and laxity. Having not directly measured these, it is difficult to establish the extent to which these factors could affect performance. In comparison to height or limb length, however, these factors are less likely to affect participant performance. Alternate methods of normalising mSEBT scores, such as leg length used in previous studies [1,37,39], or stratifying participants according to biological maturity may help account for the observed variability.

Despite participants achieving further distances with their non-dominant leg, there was no statistically significant differences between the dominant and non-dominant leg. A difference of 4cm between limbs in mSEBT direction specific scores has been associated with increased injury risk [1,4,40]. Within our study, higher mean total distance scores were achieved by the non-dominant leg when compared to the dominant leg age groups with a difference of approximately 2 to 3 cm in direction specific scores.
the of absolute differences in direction specific scores observedfor uninjured adolescent female footballers were less than the 4cm threshold associated with injury risk in previous studies. This provides support for use of absolute distance differences as an injury risk profiling tool. The absence of statistically significant differences between the dominant and non-dominant leg is an important result. Significant differences in leg performance of a normative population would negate the stability of derived LSI scores if used as a proxy measure for performance monitoring, rehabilitation or injury screening processes.

The mSEBT direction specific and composite scores can therefore be considered reliable for measuring performance in uninjured female adolescent footballers and our study provides a normative dataset against which comparative gender and sport disciplines can be evaluated.

Sources of variability associated with the mSEBT testing process and stability of the LSI scores

It was identified that for LSI scores coefficient of variance values ranged from 0.4% to 10.6% between attempts. For the LSI to be considered a suitable index measure, it should reflect values of a similar magnitude to the measurements on which it is based. Coefficient of variation values for LSI did reflect similar ranges to those of direction specific and composite mSEBT scores. Our results therefore provide support for the use of LSI sores derived from direction specific and composite mSEBT scores as a measure of symmetry in a single leg stability task.

In this study some LSI values exceeded the 100% mark with the largest 95% CI upper limit of 104.5% identified. This indicates that in some cases the non-dominant leg outperformed the dominant leg. This is evident in the mean direction specific differences of approximately 2 cm to 3cm observed in our results. Within the LSI formula, the assumed greater performing leg serves as the denominator value, and the index score can be interpreted as a measure of symmetry. Alternately a comparison of injured versus uninjured leg or involved versus uninvolved may be used [26,39]. In this protocol the dominant leg was defined as the preferred kicking leg. Leg dominance is arguably task specific. Therefore, a footballers stabilising leg during kicking would be the dominant leg within the mSEBT task constraints, given the stabilising requirements of the non-moving limb. Use of the LSI for performance monitoring, rehabilitation and injury screening processes therefore requires careful consideration around definitions of leg dominance and selection of the time point of the uninjured leg value.

Previous studies have suggested that increasing levels of symmetry are positively associated with increasing age, and negatively associated with injury risk [41,42]. In this study, age was found to have the most limited ability in accounting for the variance observed in composite LSI scores (R^2 value of 0.00007). Despite a trend for decreasing variability in performance with age for dominant and non-dominant compisite scores, there was little effect on the mean LSI scores based on any specific direction and composite scores of the mSEBT with differences of less than 2%. Our results therefore do not support the association of increasing symmetry with age.

Study limitations

Sample size in this study may be considered a limitation given that our sample consisted of 34 footballers from a single club. There was also more participants in the lower age ranges of 13 to 16 when compared to those above the age of 16. This may account for the decreased variance associated with increasing age. Our research provides a normative dataset against which comparative gender and sport disciplines can be evaluated and future research may add to the existig dataset by including additional mSEBT and LSI scores across different teams, levels of performance an dage groups.

We were unable to investigate if mSEBT or LSI scores can be used to identify players at risk of injury within female adolescent football. Future research my look to identify alternate threshold values that are age, gender and football specific in order to inform rehabilitation and injury screening processes. LSI scores of 94% or less have been identified as thresholds of asymmetry which are linked to sustaining injury in other sporting disciplines [1,4,26]. Within our results, all the mean LSI scores based on direction specific and composite scores were above the 94% threshold. It is noted however that the lower limits for some of the 95% CI were close to the suggested threshold of 94% (lowest value 94.3%) and therefore further research is needed to identify if these thresholds are also applicable in identifying players at risk of injury in female adolescent football.

As LSI values may be used to inform performance and rehabilitation processes, it is important that these are evaluated against the absolute metrics on which they are based and testing time point . Our participant data was not collected at a single time point or training period e.g. preseason. It was collected over a 5-month period and so between participant performance may be influenced by factors such as level of training or development in their biological maturity. Whilst not evaluated in our study, a decline in performance may be associated with removal from the previous level of conditioning due to injury in both limbs [43,44]. This may therefore result in an instance in which high levels of symmetry are achieved despite both legs not returning to their original levels of performance prior to injury. Baseline preinjury values may therefore be a more appropriate denominator value for sports and exercise medicine practitioners to use for calculating LSI.

Conclusion

Our study has established normative performance values for the mSEBT and derived LSI scores in non-injured female adolescent footballers. Age was identified as having a very limited ability in accounting for the variance observed for composite scores in dominant, non-dominant and LSI based scores. Our study supports the use of the mSEBT and derived LSI scores as a reliable measures of single leg stability performance in female adolescent footballers. Further research is needed to identify thresholds for injury risk in female adolescent footballers and validate the task constraints of the mSEBT to injury mechanisms.

Conflicts of Interest

None to declare

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors

Acknowledgements: The authors would like to thank Professor Anand Pandyan for his review and comments on this manuscript.

References

1. Clagg S, Paterno MV, Hewett TE, Schmitt LC. Performance on the modified star excursion balance test at the time of return to sport following anterior cruciate ligament reconstruction. *J Orthop Sports Phys Ther.* 2015;45(6):444-452.
2. Dallinga JM, Benjaminse A, Leinmink KAPM. Which Screening Tools Can Predict Injury to the Lower Extremities in Team Sports?: A Systematic Review. *Sports Medicine.* 2012;42(9):791-815.
3. Herrington L, Myer G, Horsley I. Task based rehabilitation protocol for elite athletes following Anterior Cruciate ligament reconstruction: a clinical commentary. *Physical Therapy in Sport.* 2013;14(4):188-198.
4. Plisky PJ, Rauh MJ, Kaminski TW, Underwood FB. Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. *J Orthop Sports Phys Ther.* 2006;36(12):911-919.
5. UEFA. Women's Football Across the National Associations 2016/17. 2017. https://www.uefa.com/MultimediaFiles/Download/OfficialDocument/uefaorg/Women%27sfootball/02/43/13/56/2431356_DOWNLOAD.pdf.
6. McCluskey M, Bridges J, Gilson N, Buurke J, Hermens H, Pandyan A. Evaluating the Associations between Physical Activity, Weight Gain and Academic Attainment in Primary School Children. *Journal of Physical Activity Research.* 2019;4(2):90-96.
7. Drawer S, Fuller CW. Evaluating the level of injury in English professional football using a risk based assessment process. *British journal of sports medicine.* 2002;36(6):446-451.
8. Prentice WE. *Rehabilitation Techniques for Sports Medicine and Athletic Training.* Forth Edition ed. New York: McGraw-Hill; 2003.
9. Prodromos CC, Han Y, Rogowski J, Joyce B, Shi K. A meta-analysis of the incidence of anterior cruciate ligament tears as a function of gender, sport, and a knee injury–reduction

regimen. *Arthroscopy: The Journal of Arthroscopic & Related Surgery.* 2007;23(12):1320-1325. e1326.

10. Waldén M, Hägglund M, Werner J, Ekstrand J. The epidemiology of anterior cruciate ligament injury in football (soccer): a review of the literature from a gender-related perspective. *Knee surgery, sports traumatology, arthroscopy.* 2011;19(1):3-10.
11. Ireland ML. The female ACL: why is it more prone to injury? *Orthop Clin North Am.* 2002;33(4):637-651.
12. Voskanian N. ACL Injury prevention in female athletes: review of the literature and practical considerations in implementing an ACL prevention program. *Curr Rev Musculoskelet Med.* 2013;6(2):158-163.
13. Slauterbeck JR, Fuzie SF, Smith MP, et al. The Menstrual Cycle, Sex Hormones, and Anterior Cruciate Ligament Injury. *Journal of athletic training.* 2002;37(3):275-278.
14. O'Kane JW, Neradilek M, Polissar N, Sabado L, Tencer A, Schiff MA. Risk Factors for Lower Extremity Overuse Injuries in Female Youth Soccer Players. *Orthopaedic journal of sports medicine.* 2017;5(10):2325967117733963.
15. Renstrom P, Ljungqvist A, Arendt E, et al. Non-contact ACL injuries in female athletes: an International Olympic Committee current concepts statement. *Br J Sports Med.* 2008;42(6):394-412.
16. Wiggins AJ, Grandhi RK, Schneider DK, Stanfield D, Webster KE, Myer GD. Risk of Secondary Injury in Younger Athletes After Anterior Cruciate Ligament Reconstruction: A Systematic Review and Meta-analysis. *Am J Sports Med.* 2016;44(7):1861-1876.
17. Webster K, Feller J. Exploring the High Re-Injury Rate in Younger Patients Undergoing Anterior Cruicate Ligament Reconstruction. *Journal of Science and Medicine in Sport* 2017;20:e84.
18. Tan SH, Lau BP, Khin LW, Lingaraj K. The Importance of Patient Sex in the Outcomes of Anterior Cruciate Ligament Reconstructions: A Systematic Review and Meta-analysis. *Am J Sports Med.* 2016;44(1):242-254.
19. Philp F, Blana D, Chadwick EK, et al. Study of the measurement and predictive validity of the Functional Movement Screen. *BMJ Open Sport & Exercise Medicine.* 2018;4(1).
20. Philp F, Leboeuf F, Pandyan A, Stewart C. “Dynamic knee valgus” – are we measuring what we think we’re measuring? An evaluation of static and functional knee calibration

methods for application in gait and clinical screening tests of the overhead squat and hurdle step. *Gait & posture.* 2019.

21. Coughlan GF, Fullam K, Delahunt E, Gissane C, Caulfield BM. A comparison between performance on selected directions of the star excursion balance test and the Y balance test. *Journal of athletic training.* 2012;47(4):366-371.
22. Gribble P, Hertel J, Plisky P. Using the Star Excursion Balance Test to Assess Dynamic Postural-Control Deficits and Outcomes in Lower Extremity Injury: A Literature and Systematic Review. *Journal of athletic training.* 2012;47(3):339-357.
23. Earl J, E., & Hertel, J. Lower-Extremity Muscle Activation During the Star Excursion Balance Tests. *Journal of Sport Rehabilitation.* 2001;10(2):93-104.
24. Plisky PJ, Gorman PP, Butler RJ, Kiesel KB, Underwood FB, Elkins B. The reliability of an instrumented device for measuring components of the star excursion balance test. *N Am J Sports Phys Ther.* 2009;4(2):92-99.
25. Abrams GD, Harris JD, Gupta AK, et al. Functional Performance Testing After Anterior Cruciate Ligament Reconstruction: A Systematic Review. *Orthop J Sports Med.* 2014;2(1):2325967113518305.
26. Rohman E, Steubs JT, Tompkins M. Changes in involved and uninvolved limb function during rehabilitation after anterior cruciate ligament reconstruction: implications for Limb Symmetry Index measures. *Am J Sports Med.* 2015;43(6):1391-1398.
27. Zwolski C, Schmitt LC, Thomas S, Hewett TE, Paterno MV. The utility of limb symmetry indices in return-to-sport assessment in patients with bilateral anterior cruciate ligament reconstruction. *The American journal of sports medicine.* 2016;44(8):2030-2038.
28. Linek P, Booysen N, Sikora D, Stokes M. Functional movement screen and Y balance tests in adolescent footballers with hip/groin symptoms. *Physical Therapy in Sport.* 2019.
29. Gkrilias P, Zavvos A, Fousekis K, Billis E, Matzaroglou C, Tsepis E. Dynamic balance asymmetries in pre-season injury-prevention screening in healthy young soccer players using the Modified Star Excursion Balance Test-a pilot study. *J Phys Ther Sci.* 2018;30(9):1141-1144.
30. Herrington L, Myer G, Horsley I. Task based rehabilitation protocol for elite athletes following Anterior Cruciate ligament reconstruction: a clinical commentary. *Phys Ther Sport.* 2013;14(4):188-198.

31. Kvist J. Rehabilitation following anterior cruciate ligament injury. *Sports Medicine.* 2004;34(4):269-280.

32. Paterno MV, Ford KR, Myer GD, Heyl R, Hewett TE. Limb asymmetries in landing and jumping 2 years following anterior cruciate ligament reconstruction. *Clinical Journal of Sport Medicine.* 2007;17(4):258-262.

33. Paterno MV, Schmitt LC, Ford KR, et al. Biomechanical measures during landing and postural stability predict second anterior cruciate ligament injury after anterior cruciate ligament reconstruction and return to sport. *The American journal of sports medicine.* 2010;38(10):1968-1978.

34. Hertel J, Miller SJ, Denegar CR. Intratester and intertester reliability during the Star Excursion Balance Tests. *Journal of sport rehabilitation.* 2000;9(2):104-116.

35. van Lieshout R, Reijneveld EA, van den Berg SM, et al. REPRODUCIBILITY OF THE MODIFIED STAR EXCURSION BALANCE TEST COMPOSITE AND SPECIFIC REACH DIRECTION SCORES. *Int J Sports Phys Ther.* 2016;11(3):356-365.

36. Hyong IH, Kim JH. Test of intrarater and interrater reliability for the star excursion balance test. *Journal of physical therapy science.* 2014;26(8):1139-1141.

37. Gribble PA, Hertel J. Considerations for normalizing measures of the Star Excursion Balance Test. *Measurement in physical education and exercise science.* 2003;7(2):89-100.

38. Iuliano-Burns S, Mirwald RL, Bailey DA. Timing and magnitude of peak height velocity and peak tissue velocities for early, average, and late maturing boys and girls. *American Journal of Human Biology: The Official Journal of the Human Biology Association.* 2001;13(1):1-8.

39. Coughlan GF, Fullam K, Delahunt E, Gissane C, Caulfield BM. A comparison between performance on selected directions of the star excursion balance test and the Y balance test. *J Athl Train.* 2012;47(4):366-371.

40. Olmsted LC, Carcia CR, Hertel J, Shultz SJ. Efficacy of the Star Excursion Balance Tests in Detecting Reach Deficits in Subjects With Chronic Ankle Instability. *J Athl Train.* 2002;37(4):501-506.

41. Gkrilias P, Zavvos A, Fousekis K, Billis E, Matzaroglou C, Tsepis E. Dynamic balance asymmetries in pre-season injury-prevention screening in healthy young soccer players using the Modified Star Excursion Balance Test—a pilot study. *Journal of physical therapy science.* 2018;30(9):1141-1144.

42. Fousekis K, Tsepis E, Vagenas G. Lower limb strength in professional soccer players: profile, asymmetry, and training age. *Journal of sports science & medicine.* 2010;9(3):364.
43. HIEMSTRA LA, WEBBER S, MacDONALD PB, KRIELLAARS DJ. Knee strength deficits after hamstring tendon and patellar tendon anterior cruciate ligament reconstruction. *Medicine & Science in Sports & Exercise.* 2000;32(8):1472-1479.
44. Thomeé R, Neeter C, Gustavsson A, et al. Variability in leg muscle power and hop performance after anterior cruciate ligament reconstruction. *Knee Surgery, Sports Traumatology, Arthroscopy.* 2012;20(6):1143-1151.

Table 1. Combined age group coefficient of variation results for dominant, non-dominant leg distances and LSI score.

	Dominant leg		***Non-dominant leg***		***Limb Symmetry Index***	
mSEBT subcomponent	***MIN***	***MAX***	***MIN***	***MAX***	***MIN***	***MAX***
Anterior	1.0%	8.4%	0.3%	8.7%	0.6%	10.5%
Posterolateral	0.3%	5.0%	0.4%	7.7%	0.6%	9.6%
Posteromedial	0.6%	8.7%	0.5%	10.1%	0.4%	10.6%
Total	0.2%	4.7%	0.5%	4.8%	0.6%	6.2%

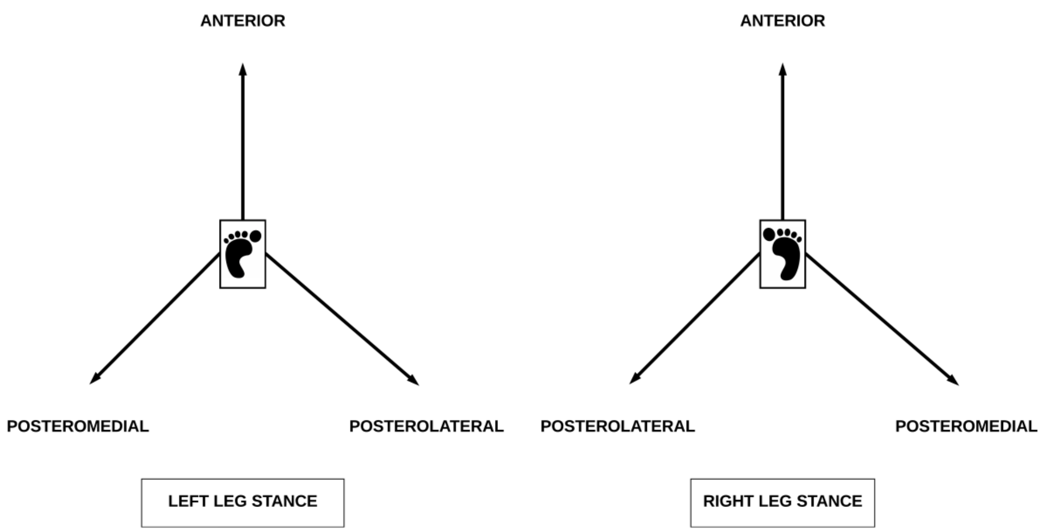
Table (2) Results for differences between dominant and non-dominant legs for mSEBT subcomponents and total distance scores using paired sample t-test

	mSEBT subcomponent	Mean difference	SD	Confidence interval Lower	Confidence interval Upper	p-value
Distance (cm)	*Anterior*	.43	3.60	-.82	1.69	.49
	Posterolateral	1.46	4.25	-.03	2.94	0.054
	Posteromedial	.70	5.06	-1.06	2.47	.43

Table (3) Normative performance values for dominant, non-dominant and LSI score across all age groups

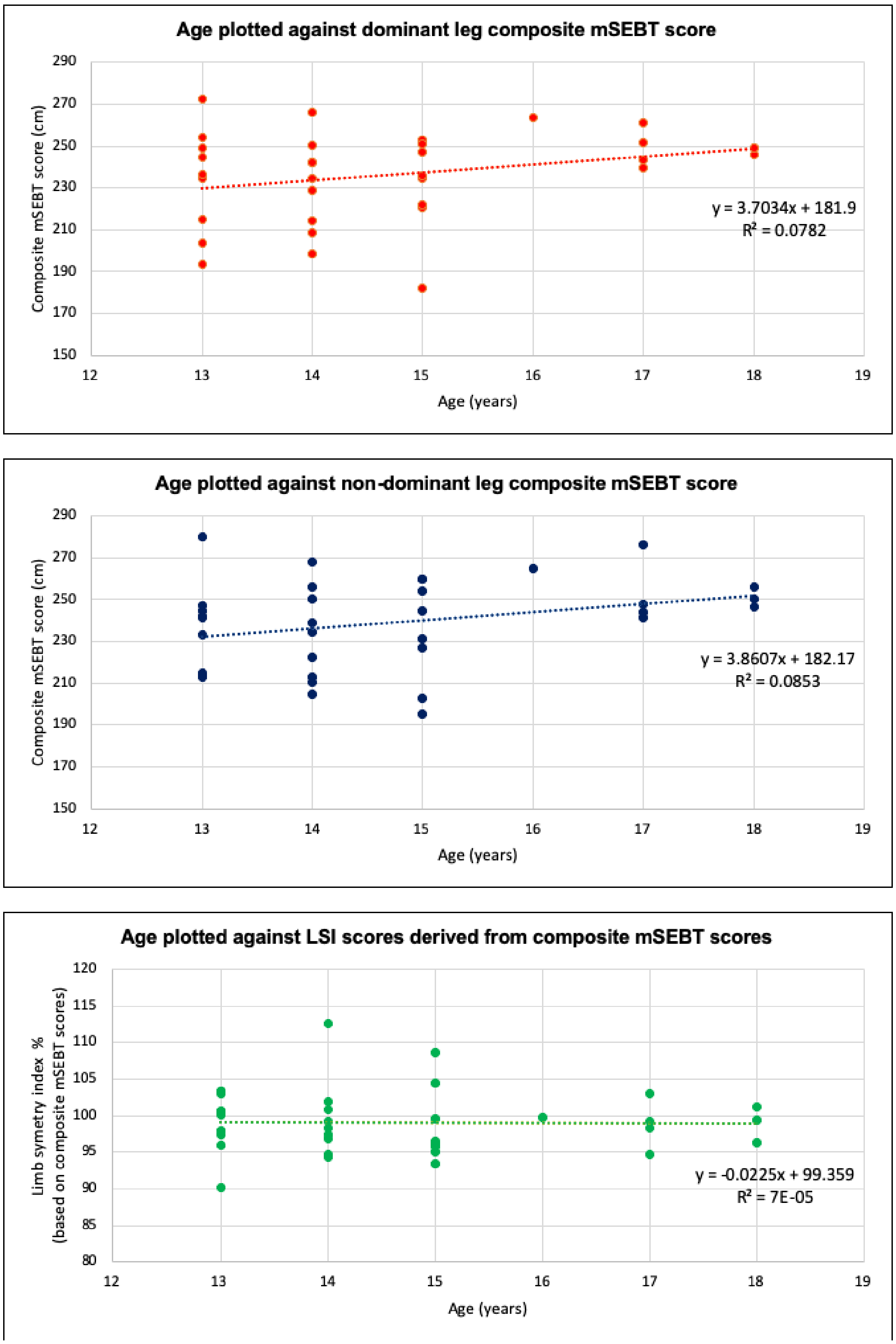
mSEBT component		Direction Specific									Composite		
		Anterior			Posterolateral			Posteromedial					
	Age Group	*Mean (SD)*	*95% CI*		*Mean (SD)*	*95% CI*		*Mean (SD)*	*95% CI*		*Mean (SD)*	*95% CI*	
			Lower	*Upper*		*Lower*	*Upper*		*Lower*	*Upper*		*Lower*	*Upper*
Dominant (cm)	***U14***	59.7 (7.6)	54.9	64.5	86.5 (9.1)	79.7	93.2	85.3 (10.7)	78.5	92.1	231.5 (25.9)	214.3	248.7
	U16	58.1 (6.9)	54.1	62.0	88.6 (7.2)	83.8	93.4	86.1 (5.7)	82.8	89.4	232.8 (18.1)	221.9	243.7
	U18	63.0 (3.9)	59.8	66.3	93.9 (3.5)	91.5	96.2	93.5 (3.2)	90.8	96.2	250.4 (9.5)	243.5	257.4
Non Dominant (cm)	***U14***	59.7 (7.5)	54.9	64.4	88.3 (9.3)	82.5	94.2	86.4 (8.5)	81.1	91.8	234.4 (24.0)	219.2	249.7
	U16	58.5 (6.3)	54.9	62.2	89.6 (9.0)	84.2	94.5	87.0 (7.5)	82.7	91.4	234.3 (21.0)	222.8	247.0
	U18	64.2 (5.4)	59.7	68.6	96.0 (3.5)	93.0	98.9	93.1 (5.5)	88.5	97.8	253.3 (11.8)	243.5	263.1
LSI (%)	***U14***	100.1 (2.7)	98.4	101.8	97.8 (4.8)	94.3	101.4	98.6 (6.0)	94.8	102.4	98.8 (3.2)	96.6	101.1
	U16	99.4 (8.8)	94.3	104.5	99.3 (5.0)	96.4	102.3	99.3 (7.4)	95.0	103.6	99.4 (6.0)	95.3	102.8

Figure 1. Reach directions tasks during for the mSEBT



tsm2_146_f1.png

Figure 2. Age plotted against dominant, non-dominant and LSI scores.



tsm2_146_f2.png