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Title

Establishing normative performance values of modified Star Excursion Balance Test (mSEBT) and Limb Symmetry Index (LSI) scores and their relationship to age in female adolescent footballers.

Authors and affiliation

Fraser Philp¹ @fdphilp ORCID ID <https://orcid.org/0000-0002-8552-7869>

Callum Telford¹

Danielle Reid²

Michael McCluskey¹ @MMC_Physio

¹ School of Allied Health Professions, Keele University, UK

² The Royal Wolverhampton NHS Trust, Wolverhampton, UK

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Corresponding author details

Fraser Philp
f.d.philp@keele.ac.uk

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What are the new findings? / Clinical implications

- This is the first study to provide normative modified Star Excursion Balance Test and Limb Symmetry Index values for uninjured female adolescent footballers
- Age was found to be poorly related to composite modified Star Excursion Balance Test dominant and non-dominant leg, and Limb Symmetry Index scores
- Our results do not support previous studies which have found a positive relationship between increasing age and increasing levels of symmetry

Abstract

Objectives: to establish normative performance values for the modified Star Excursion Balance Test and derived Limb Symmetry Index scores in non-injured female adolescent footballers, and identify 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: Modified Star Excursion Balance Test and derived Limb Symmetry Index scores.

Results: There were no statistically significant differences between dominant and non-dominant leg distance scores in any of the modified Star Excursion Balance Test 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 Limb Symmetry Index values ranged from 97.8% to 100.5%. Age accounted for approximately 8% of the variance within dominant, non-dominant total distance and Limb Symmetry Index 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.

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 injury¹⁻⁴ 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. Of this, the number of footballers under the age of 18 has increased from 62,442 to 69,485⁵. Whilst it is recognised that there are many health benefits associated with increased participation in football and physical activity⁶, it has also been identified that increased participation is associated with increased injury risk⁷.

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 football⁸ and females are reportedly two to eight times more likely to sustain an ACL rupture. Causes of the gender discrepancy are multifactorial with differences in anatomical^{8,9}, neuromuscular¹⁰, hormonal¹¹ and training features^{12,13} 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 injury¹⁴, and a 20-40% increased risk of re-injury following ACL reconstruction¹⁴⁻¹⁶.

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^{17,18}. The SEBT reportedly assesses the dynamic balance and strength of a player. 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^{19,20}. The modified SEBT (mSEBT) requires completion of three out of eight directions, namely the anterior, posterior-medial and posterior-lateral directions^{4,21}. The mSEBT has been demonstrated sensitivity in detecting differences in specific reach direction values for ACL deficient participants¹ and was designed to be more time effective²², increasing usability in fast-paced sporting environments. Based on evaluation of both limbs, a LSI score can be generated to inform decision making²³. 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 14 24 25}.

Within female adolescent football, normal performance values during the mSEBT and subsequent LSI scores have not been well established ²⁶. Asymmetrical performance has been identified as a characteristic of adolescent footballers during completion the mSEBT ²⁷, with a trend for decreasing asymmetry with increasing age. There an assumed relationship between increased symmetry and decreased injury risk. Within female basketball, LSI ²⁸ 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 ²⁹⁻³¹, 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 ²⁶. 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 School of Health and Rehabilitation Ethics Review Panel 2018/19_SHAR_CA_015 at Keele University. 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. 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 32}. Each measurement (taken in centimetres), for their dominant and non-dominant lower limb, was recorded three times. The LSI formula according to Hildebrandt, et al.³³ was used, where:

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

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. 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.

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

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

	mSEBT subcomponent	Mean difference	SD	Confidence interval		Significance
				Lower	Upper	
Distance (cm)	<i>Anterior</i>	.43	3.60	-.82	1.69	.49
	<i>Posterolateral</i>	1.46	4.25	-.03	2.94	0.054
	<i>Posteromedial</i>	.70	5.06	-1.06	2.47	.43
	<i>Total Distance</i>	2.59	9.77	-.82	6.00	.132

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%.

195 **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	Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI	
	Group		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper
Dominant (cm)	U14	59.7	54.9	64.5	86.5	79.7	93.2	85.3	78.5	92.1	231.5	214.3	248.7
	U16	58.1	54.1	62.0	88.6	83.8	93.4	86.1	82.8	89.4	232.8	221.9	243.7
	U18	63.0	59.8	66.3	93.9	91.5	96.2	93.5	90.8	96.2	250.4	243.5	257.4
Non Dominant (cm)	U14	59.7	54.9	64.4	88.3	82.5	94.2	86.4	81.1	91.8	234.4	219.2	249.7
	U16	58.5	54.9	62.2	89.6	84.2	94.5	87.0	82.7	91.4	234.3	222.8	247.0
	U18	64.2	59.7	68.6	96.0*	93.0	98.9	93.1	88.5	97.8	253.3	243.5	263.1
LSI (%)	U14	100.1	98.4	101.8	97.8	94.3	101.4	98.6	94.8	102.4	98.8	96.6	101.1
	U16	99.4	94.3	104.5	99.3	96.4	102.3	99.3	95.0	103.6	99.4	95.3	102.8
	U18	98.5	93.8	103.8	97.9	94.9	101.0	100.5	97.6	103.5	99.0	96.7	101.3

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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 identified for dominant leg performance (figure 1). The lowest R^2 value of 0.00007 was identified for age and LSI based on total distance scores. It was identified that for the dominant, non-dominant leg and LSI total distance performance, there was a trend for reduced variability in performance with increasing age.

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Discussion

The aim of this study was to establish normative performance values for the mSEBT and derived LSI scores in non-injured female adolescent footballers, and identify 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 identified for dominant leg performance.

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

It was identified that for all components of the mSEBT, coefficient of variance values ranged from 0.2% to 10.1% between attempts. These results indicate that normal between attempt variation for uninjured female adolescent footballers as being relatively consistent at approximately 10%. Knowledge of normal between attempt variability may therefore inform performance monitoring, rehabilitation and injury screening process, where consistency of performance is an important factor. Within our study, participants had 6 trials to minimise any learning effects^{4 32}, this may account for the consistency of performance observed. Familiarisation of players with the testing process is therefore important to ensure accurate measures of performance. Accuracy of results is high within our study given that the same single assessor carried out all testing with a second assessor present to verify recorded measurements. Whilst not evaluated within this study, the mSEBT demonstrates good to excellent intra and inter-rater reliability measurements with ICC values ranging from 0.82 to 0.87^{4 32 34 35}. These results indicate the mSEBT as having suitable reliability.

Given the limited availability of an adolescent female football dataset, a direct comparison is not possible. Previous studies have reported normative ranges in both male and female basketballers of similar age ranges, with males achieving greater direction specific and composite scores between approximately 5 cm to 20 cm⁴. The mean anterior and posteromedial direction specific and composite scores observed within our study are less than the comparator female group studied by Plisky et al⁴ with differences of approximately 10 cm and 25cm respectively. Whilst no height or limb length data is available within our study for comparative purposes, it may be assumed that performance

differences may be attributed to differences in these features as they are known to affect reach distance. Variations in performance for normative mSEBT scores between sporting disciplines highlights the importance of having to have gender and discipline specific normative datasets.

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 in varying directions. Participant performance in the mSEBT 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. Within our study we did not control/measure height and lower limb length are known to affect reach distance in a non-injured population ³⁶. This is likely to account for the increased mean 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) of the mSEBT. For the mSEBT to be considered for use in performance monitoring, rehabilitation and injury screening process, the effect of injury subtypes on absolute mSEBT performance and variability requires further investigation. Further research is also required to validate the task constraints of the mSEBT and the injury mechanics and performance characteristics 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. 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 within our study will have also been undergoing other 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. In comparison to height or limb length, these factors are likely to have a less significant effect on participant performance. Having not directly measured these within our study, it is difficult to establish the extent to which these factors could affect performance. Alternate methods of normalising mSEBT scores, such as leg length used in previous studies ^{136 37}, or stratifying participants according to biological maturity may help account for the observed variability. It is noted that within our study more participants the lower age ranges of 13 to 16 when compared to those above the age

of 16. This may additionally account for the decreased variance associated with increasing age and is a limitation of our study.

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 risk¹⁴³⁸. 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 direction specific scores within our study of uninjured adolescent female footballers are less than the 4cm threshold associated with injury risk in previous studies. This therefore provides support for use of this metric as an injury risk profiling tool. Additionally, the absence of statistically significant differences between the dominant and non-dominant leg is an important result, as significant differences in leg performance of a normative population would negate the stability of derived LSI scores if index values are to be used as a proxy measure for informing performance monitoring, rehabilitation and injury screening process.

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. Within our study, 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 scores derived from direction specific and composite mSEBT scores as a measure of symmetry in a single leg stability task.

Within our 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 the 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 used²⁴³⁷. 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.

Within our study 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. Within our study 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 may look to identify age, gender and football specific thresholds that may be used 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 disciplines¹⁴²⁴. 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.

Previous studies have suggested that increasing levels of symmetry are positively associated with increasing age, and negatively associated with injury risk. 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 composite 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. Sample size within our study may be considered a limitation given that our sample consisted of 34 footballers from a single club. Future research may also look to develop the normative dataset through additional mSEBT and LSI values across multiple teams, levels of performance and age groups.

It is important to note that whilst 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 associated timing. A limitation of our study was that participant data was not collected at a single time point or training period e.g. preseason. Our data 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 limbs³⁹

⁴⁰. 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.

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