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ORIGINAL ARTICLE

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

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Abstract

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, to and identity whether there is a relationship between the aforementioned metrics and age. Single measure study design. A single football club's female regional talent and development teams. Thirty-four uninjured female footballers, aged between 13 and 18 years. MSEBT and derived LSI scores. 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 to 250.4 cm while non-dominant total distance scores ranged from 234.3 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. 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

adolescent, age, female, football, Limb Symmetry Index, modified Star Excursion Balance Test

1 | 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] While it is recognized 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 programs 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] While 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 is an assumed relationship between increased symmetry and decreased injury risk. Within female basketball, LSI[3] 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] While asymmetry has been identified as an injury risk factor,[30-32] 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 dataset 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 (a) establish the extent of the variability within the mSEBT testing process and identify whether differences exist between the dominant and non-dominant legs, as each influence the derived LSI scores, (b) report normative performance value ranges for dominant, non-dominant leg, and LSI scores across the mSEBT components, and (c) investigate whether there is a relationship between age and either the mSEBT or LSI 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.

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 to identity whether there is a relationship between the aforementioned metrics and age.

2 | 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-U18 age groups during the 2018/2019 season. Data collection was completed over a 5-month period (October 2018-February 2019).

2.1 | Inclusion and exclusion criteria

Participants were included if they were female, aged between 13 and 18 years, enrolled within the regional talent (U14-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.

2.2 | 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

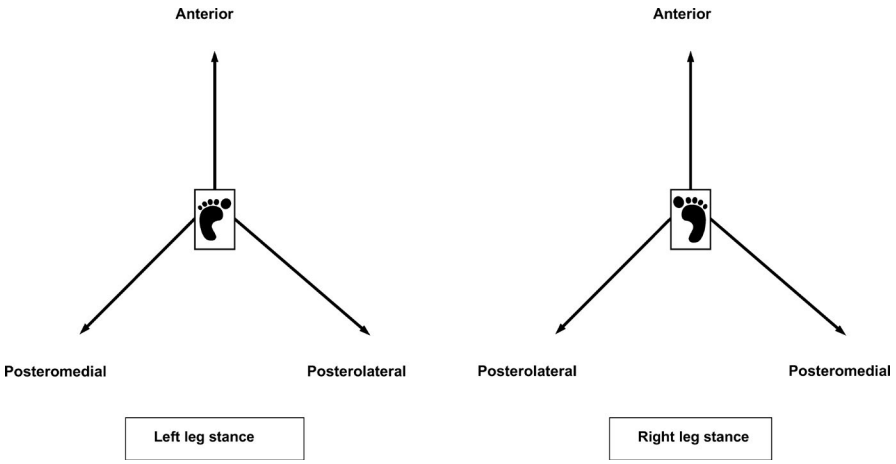

FIGURE 1 Reach directions tasks during for the mSEBT

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

the testing in shorts and barefoot. Prior to recording the measurements, participant's had 6 trials to minimize any learning effects.[4,33] Each measurement (taken in centimeters), for their dominant and non-dominant lower limb, was recorded three times. The following LSI formula was used, where:

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

2.3 | Analysis

Coefficient of variation values between attempts were 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 whether there was a linear relationship.

3 | 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 were 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.

3.1 | 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.

3.2 | 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

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		*P*-value
				Lower	Upper	
Distance (cm)	Anterior	0.43	3.60	−0.82	1.69	.49
	Posterolateral	1.46	4.25	−0.03	2.94	.054
	Posteromedial	0.70	5.06	−1.06	2.47	.43
	Total Distance	2.59	9.77	−0.82	6.00	.132

the mSEBT specific reach direction or composite scores (Table 2).

3.3 | 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.

3.4 | Dominant and non-dominant leg distance performance values

Across all age groups, mean dominant leg total distance scores ranged from 231.5 to 250.4 cm while non-dominant total distance scores ranged from 234.3 to 253.3 cm. The maximum mean total difference score between the non-dominant leg and dominant leg age groups was <3 cm, 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 to 8 cm and 20 cm, respectively.

3.5 | 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%.

3.6 | 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 .0782 identified for dominant leg performance (Figure 2). The lowest R^2 value of .00007 was identified for age and LSI based on total distance scores.

4 | 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, to and identity whether there is a relationship between the aforementioned metrics and age. Across U14-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 .0782 identified for dominant leg performance.

4.1 | 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 minimize any learning effects.[4,33] This may account for the consistency observed and highlights the importance of familiarizing 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

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

mSEBT component	Age group	Direction specific: Anterior Mean (SD)	Anterior 95% CI Lower	Anterior 95% CI Upper	Posterolateral Mean (SD)	Posterolateral 95% CI Lower	Posterolateral 95% CI Upper	Posteromedial Mean (SD)	Posteromedial 95% CI Lower	Posteromedial 95% CI Upper	Composite Mean (SD)	Composite 95% CI Lower	Composite 95% CI 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
	U18	98.5 (5.6)	93.8	103.8	97.9 (2.4)	94.9	101.0	100.5 (3.5)	97.6	103.5	99.0 (2.4)	96.7	101.3

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[4,33-35]).

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 and 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 and 25 cm, respectively. While no height or limb length data are 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 sport-specific datasets given the varying performance characteristics.

Within our study, approximately 8% of the variance within dominant and non-dominant total distance scores ($R^2 = .0782$ and .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 (stabilizing leg) while reaching out as far as possible with the non-stabilizing leg. Performance is therefore reflective of participant's muscle strength, co-ordination, kinesthetic awareness and functional capacity, biomechanical requirements of the task, and anthropometric characteristics, that is, 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.[36] 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 to 8 cm) and total distance scores (approximately 20 cm). 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/y.[37] 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,

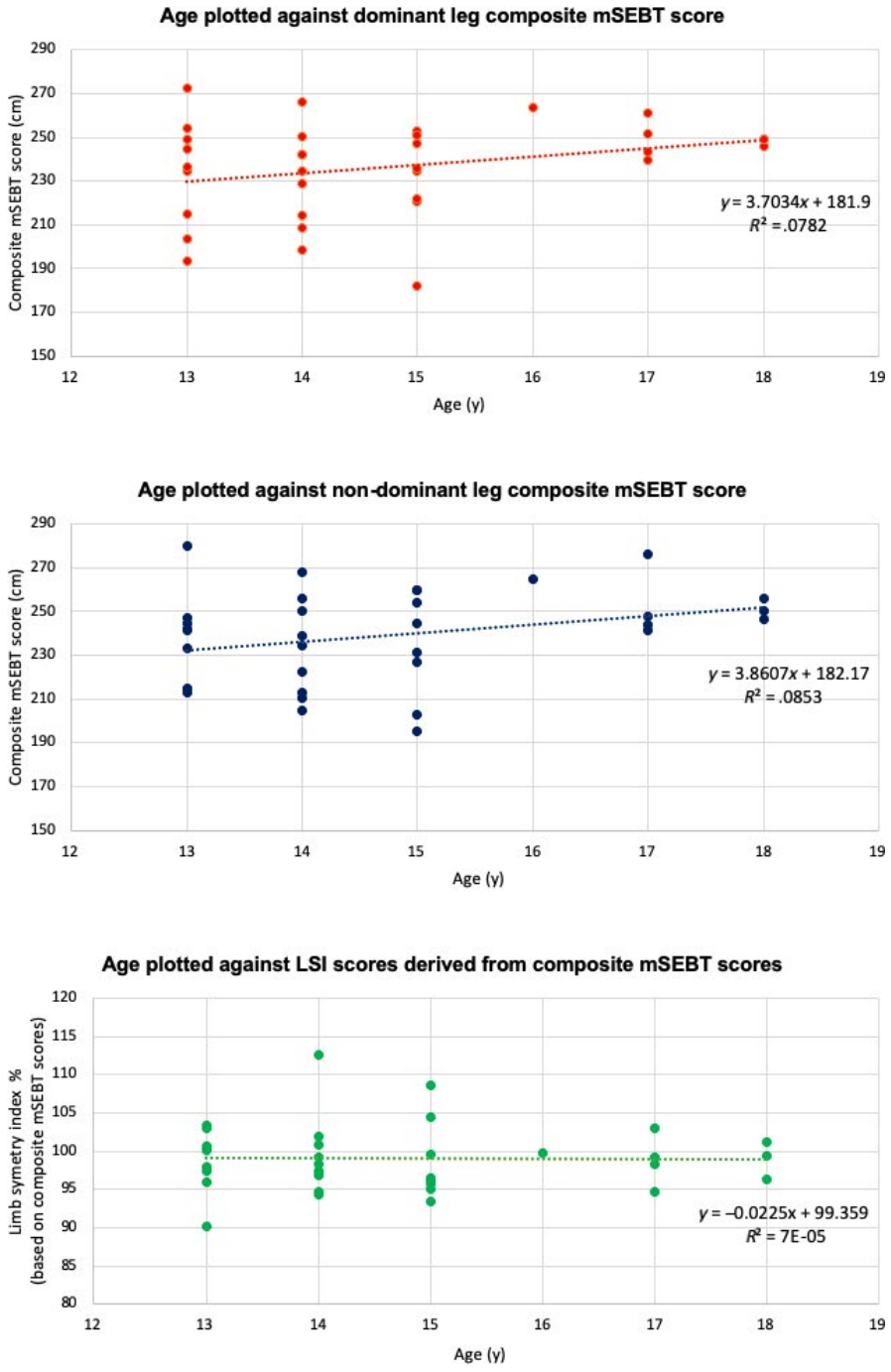

FIGURE 2 Age plotted against dominant, non-dominant, and LSI scores

participants will have also been undergoing changes associated with biological maturation, including development of the neuromuscular 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 with height or limb length, however, these factors are less likely to affect participant performance. Alternate methods of normalizing mSEBT scores, such as leg length used in previous studies,[1,21,36] 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 were no statistically significant differences between the dominant and non-dominant leg. A difference of 4 cm between limbs in mSEBT direction-specific scores has been associated with increased injury risk.[1,4,38] 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 2-3 cm in direction-specific scores.

The of absolute differences in direction-specific scores observed for uninjured adolescent female footballers were less than the 4 cm 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.

4.2 | 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 2-3 cm 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 vs uninjured leg or involved vs uninvolved may be used.[21,26] In this protocol, the dominant leg was defined as the preferred kicking leg. Leg dominance is arguably task specific. Therefore, footballers stabilizing leg during kicking would be the dominant leg within the mSEBT task constraints, given the stabilizing 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.[39,40] 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 .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.

4.3 | 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 were also more participants in the lower age ranges of 13-16 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 existing dataset by including additional mSEBT and LSI scores across different teams, levels of performance, and age groups.

We were unable to investigate whether mSEBT or LSI scores can be used to identify players at risk of injury within female adolescent football. Future research may 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 whether 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 were not collected at a single time point or training period, for example, 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. While 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.[41,42] 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.

5 | 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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CONFLICT OF INTEREST

None to declare.

AUTHOR CONTRIBUTIONS

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

ETHICAL APPROVAL

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