Title	Star Excursion Balance Test performance and application in elite junior rugby union players
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Publication date	2014-11
Publication information	Coughlan, Garrett, Eamonn Delahunt, Eoghan O'Sullivan, Karl Fullam, Brian Green, and Brian Caulfield. "Star Excursion Balance Test Performance and Application in Elite Junior Rugby Union Players" 15, no. 4 (November, 2014).
Publisher	Elsevier
Item record/more information	http://hdl.handle.net/10197/6555
Publisher's statement	This is the author's version of a work that was accepted for publication in Physical Therapy in Sport. Changes resulting from the publishing process, such as peer review, editing, corrections, structural formatting, and other quality control mechanisms may not be reflected in this document. Changes may have been made to this work since it was submitted for publication. A definitive version was subsequently published in Physical Therapy in Sport (VOL 15, ISSUE 4, (2014)) DOI: 10.1016/j.ptsp.2013.11.005
Publisher's version (DOI)	10.1016/j.ptsp.2013.11.005

Accepted Manuscript

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PII: S1466-853X(13)00109-0

DOI: 10.1016/j.ptsp.2013.11.005

Reference: YPTSP 585

To appear in: *Physical Therapy in Sports*

Received Date: 3 May 2013

Revised Date: 16 November 2013

Accepted Date: 20 November 2013

Please cite this article as: Coughlan, G.F., Delahunt, E., O'Sullivan, E., Fullam, K., Green, B.S., Caulfield, B.M., Star Excursion Balance Test performance and application in elite junior rugby union players, *Physical Therapy in Sports* (2013), doi: 10.1016/j.ptsp.2013.11.005.

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ABSTRACT

Objectives: To evaluate performance on selected reach directions of the Start Excursion Balance Test (SEBT) in an elite underage rugby union population, and determine if differences exist between the forward and back position units. This information may have implications for the application of this test in player injury prevention and management.

Design: Descriptive study.

Setting: Gymnasium at an elite junior rugby union screening camp.

Participants: 102 healthy male elite rugby union players (age = 17.9 ± 1.1 years, height = 1.83 ± 0.07 m, body mass = 90.5 ± 11.3 kg).

Main Outcome Measures: Participants were assessed on the Anterior (A), Posterior-medial (PM), and Posterior-lateral (PL) reach directions of the SEBT.

Results: Normative data for SEBT performance in the A, PM and PL reach directions were established for an elite junior rugby union population. No significant differences in dynamic postural stability were observed between the forward and back position units.

Conclusions: This study provides normative SEBT data on an elite junior rugby union population, which enables clinicians to compare player dynamic postural stability and has implications for use in the prevention and management of player injuries.

INTRODUCTION

Rugby union is a field based sport consisting of two teams of fifteen players. It is a complex, contact sport, comprising of bouts of walking, jogging and running, interspersed with sprinting and static exertions (Cahill, Lamb & Worsfold, 2012). Changes in direction and center of gravity, incorporating rapid reaction to other players' movements and events are required during play (Green, Blake & Caulfield, 2011), and must be performed accurately with high velocity to execute game demands at a high level. The maturation of elite junior players to successful senior players is dependent upon the effective development of numerous physical, technical, tactical and psychological attributes required to complete game-related tasks. Physical attributes such as fundamental movement, mobility, agility, hypertrophy, strength, power and endurance, as well as sport specific skills have all been proposed as part of the Youth Physical Development Model (YPDM) (Llyod & Oliver, 2012). This model provides a multistage overview of athletic development from early childhood (2 years of age) up to adulthood (21+ years of age). Dynamic postural stability is fundamental to the utilisation of many of these attributes, with their effective execution being dependent upon the ability to maintain single leg control with concomitant multi-planar movement demands. Neuromuscular training is typically used by sports medicine and conditioning staff to enhance team preparation, performance and recovery and this form of training can be incorporated into team activities to improve dynamic postural stability (Plisky, Rauh & Kaminski, 2006, Filipa, Byrnes & Paterno, 2010), which is an integral component of lower limb neuromuscular control.

The lower limb is the most commonly injured anatomical region in rugby union, with anterior cruciate ligament (ACL) injuries in forwards and hamstring injuries in backs responsible for the majority of missed days attributable to sustained lower limb injuries (Kaplan, Goodwille

& Strauss, 2008). Previous research has demonstrated the potential for increased knee joint ligament loading during sidestepping and crossover cutting manoeuvres compared to straight line running; which has been attributed to the increased frontal and transverse plane moments generated during these high velocity multi-planar game tasks (Besier, Llyod & Cochrane, 2001). This may result in increased risk of injury to the ACL and knee collateral ligaments during cutting tasks, particularly at knee flexion angles of 0-40 degrees, if appropriate muscle activation strategies are not used to counter these increased moments. A recent systematic review identified the Star Excursion Balance Test (SEBT) as a highly representative dynamic postural stability test for physically active individuals (Gribble, Hertel & Plisky, 2012). The SEBT requires the individual to move from a double to single-legged stance position while maximally reaching along set multidirectional lines with the opposite leg and touching down lightly on a tape measure with the distal end of the reach foot, without compromising equilibrium (Coughlan, Fullam & Delahunt, 2012). Application of the test in its original form of eight reach directions is time consuming in a clinical environment and there is sufficient evidence to support the reduction from eight directions to three [i.e. the Anterior (A), Posterior-medial (PM) and Posterior-lateral (PL)] (Hertel, Braham & Hale, 2006, Robinson & Gribble, 2008). These directions have been shown to assess unique elements of postural stability (Earl & Hertel, 2001) and may be useful in predicting future athletic injury (Plisky, Rauh & Kaminski, 2006).

Numerous research studies have utilized the SEBT for screening and injury prevention in an athletic population, namely soccer (Daneshjoo, Mokhtar & Rahnama 2012, Thorpe & Ebersole, 2008, Filipa, Byrnes & Paterno, 2010), and basketball (Bicici, Karatas & Baltaci, 2012, Sabin, Ebersole & Martindale, 2010, McLeod, Armstrong & Miller, 2009) cohorts, however there are no previously published studies evaluating dynamic postural stability as

quantified by performance on selected directions of the SEBT in rugby union. Owing to the importance of postural stability in the physical development of players and game related tasks, the purpose of this investigation was to evaluate SEBT performance in the A, PM and PL reach directions in a group of healthy elite junior rugby union players and investigate performance differences between position units in these directions. We expected that differences would exist between position units owing to the physical and tactical requirements of these players. This information may have implications for the use of this test in the prevention and management of player injuries.

METHODS

Participants

One hundred and two male players from the national under-19 and under-18 rugby union squads who were participating in a musculoskeletal and fitness screening camp participated in the study (Table 1). Prior to testing, the participants signed an informed consent form and players under the age of eighteen co-signed this form with their parents/guardians. Inclusion criteria were selection for the national age-grade panel, no neurological or balance disorders, no history of lower extremity surgery or fracture, no lower extremity injury in the previous three months and no pain reported during the testing procedure. Players were categorized into position units (i.e. forward or back) based on their selection by coaching staff. The study was approved by the University College Dublin Human Research Ethics Committee.

Protocol

Leg length was measured with the participant lying supine on a plinth; the participant bridged to lift the hips off the table and then returned to the starting position. The investigator then passively straightened the legs to equalize the pelvis. Limb length was then measured in

centimetres from the anterior superior iliac spine to the most prominent bony point of the ipsilateral medial malleolus with a standard tape measure. The reach directions were evaluated by affixing three tape measures to the gymnasium floor, one orientated anterior to the apex (A) and two aligned at 135° to this in the PM and PL directions (Fitzgerald, Trakarnratanakul & Smyth, 2010). Intra-tester reliability (ICC) in these directions has been reported to range from 0.84 to 0.87 and test-retest reliability from 0.89 to 0.93 (Plisky, Rauh, Kaminski, 2006). The order of the test leg and reach direction were randomized for each participant. Participants were provided with standardized instructions and a demonstration by a member of the research team in a familiarization session. Each participant undertook 4 practice trials in each direction to minimize learning effect (Robinson & Gribble, 2008, Munro & Herrington, 2010) immediately prior to the test session. The player's feet were measured and marked midway along the medial border of the foot. A line was drawn from this point laterally on the dorsal aspect of the foot in line crossecting with a line drawn up from the second toe. This was the point to be placed on the convergence of the tape measures. All trials were conducted barefoot to eliminate additional balance and stability gained from shoes (Gribble & Hertel, 2004a). Trials were deemed invalid if the participant removed his hands from the hips, movement or raising of the stance leg from the convergence point, failure to return to start position, placement of the reach foot at either side of the tape measure or application of sufficient weight through the reach foot as deemed by the investigator to maintain equilibrium or gain further distance (Coughlan, Delahunt & Fullam, 2012). Invalid trails were discarded and participants repeated the trial.

Statistical Analysis

Reach distances from 3 trials in each direction were averaged and normalized to limb length by calculating the maximized reach distance (%MAXD) using the formula (excursion

distance/limb length) x 100 = %MAXD (ROBINSON AND GRIBBLE, 2006). An independent-samples t-test was conducted to compare reach distance scores on the A, PM and PL reach directions for position units. The left and right lower limbs were evaluated separately. To account for multiple statistical testing the p-value was adjusted for both right and left limb performance using a Bonferroni correction, such that the new p value ($p < 0.01$) was utilized to indicate a significant result.

A one-way between-groups multivariate analysis of variance was performed to investigate the effect of position classification on the following dependent variables: (1) age, (2) height, (3) body mass, (4) body mass index, (5) left leg length and (6) right leg length. Preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of covariance matrices, and multicollinearity. Data for body mass index, left and right leg length were not normally distributed. Strong correlations were observed between height, left and right leg length, as well as between body mass and body mass index. Box's test of equality of covariance matrices was violated. Levene's test of equality of error variances was violated for body mass index and thus a more conservative alpha of $p < 0.025$ was set for body mass index. To account for the six independent variables being investigated an adjusted alpha level of $p < 0.008$ was used to assess for statistical significance.

RESULTS

Right lower limb performance

There was no significant difference in reach distances on the A reach direction between the forward and back units and the magnitude of the difference in the means (95% CI: -3.67 to 0.59) was small (eta squared = 0.05) (Table 1). There was no significant difference in reach

distances on the PM reach direction between the forward and back units and the magnitude of the difference in the means (95% CI: -4.75 to 0.48) was moderate (eta squared = 0.07). There was no significant difference in reach distances on the PL reach direction between the forward and back units and the magnitude of the difference in the means (95% CI: -5.10 to -0.01) was very small (eta squared = 0.01).

Left lower limb performance

There was no significant difference in reach distances on the A reach direction between the forward and back units and the magnitude of the difference in the means (CI: -3.67 to 1.53) was small (eta squared = 0.03). There was no significant difference in reach distances on the PM reach direction between the forward and back units and the magnitude of the difference in the means (95% CI: -5.37 to 0.20) was moderate (eta squared = 0.06). There was no significant difference in reach distances on the PL reach direction between the forward and back units and the magnitude of the difference in the means (95% CI: -4.68 to 1.77) was moderate (eta squared = 0.04).

Anthropometric Profile

There was a statistically significant difference between forwards (n = 59) and backs (n = 43) on the combined dependent variables, F (6, 95) = 9.17, p = 0.000; Pillai's Trace = 0.37; partial eta squared = 0.37. When the results for the dependent variables were considered separately, height [F (1, 100) = 17.61, p = 0.000, partial eta squared = 0.15], body mass [F (1, 100) = 53.71, p = 0.000, partial eta squared = 0.35], body mass index [F (1, 100) = 22.71, p = 0.000, partial eta squared = 0.19], left leg length [F (1, 100) =13.971, p = 0.000, partial eta squared = 0.12] and right leg length [F (1, 100) = 13.91, p = 0.000, partial eta squared = 0.12] were all statistically significant. The estimated marginal means for the dependent variables are presented in Table 2.

DISCUSSION

This study evaluated dynamic postural stability in a healthy elite junior rugby union population as quantified by performance on selected directions of the SEBT and has established normative performance values. We hypothesized that differences would exist between backs and forwards, however we observed no differences in normalized reach distances between position units. Completion of the SEBT requires many attributes including strength, flexibility, neuromuscular control, core stability, range of motion, balance and proprioception (Gribble, Hertel & Plisky, 2012). Rugby union players undertake open and closed kinetic chain movements utilizing these physical attributes to successfully perform game activities and multi-directional running tasks. The normative values measured in this investigation provide the rugby union clinician with objective data for dynamic postural stability evaluation for use in the areas of injury prevention and management, namely assessment, rehabilitation, screening and return to play.

Owing to the diverse physical demands experienced by different position units during rugby union competition, the physical components required for success vary (Smart & Gill, 2012). Variances in training and game demands may account for a performance difference, with forwards generally involved in close contact with the opposition and gaining possession, whereas the backs tend to undertake a greater number of running and evasion tasks that may require enhanced levels of postural stability (Kaplan, Goodwille & Strauss, 2008). Specialization of position has led to the identification of anthropometric and physiological characteristics specific to the different playing positions that are important to optimal performance (Nicholas, 1997). We observed that despite having the same age profile, forwards were significantly taller, heavier and had longer lower limbs than backs, however

when SEBT reach distances were normalized to limb length, there was no statistically significant differences in reach distances between position units. This was contrary to what we hypothesised, as owing to the differing physical and tactical demands of these units, we expected that backs may have reached further than forwards. Significant differences may be augmented at senior level where greater variance exists between the physical profiles and abilities, as well as skill demands of position units, however this has yet to be reported.

Comparison of SEBT performance with other sporting populations is difficult owing to variable methodologies and statistical analysis in the literature. High school mixed gender basketballers outperformed the rugby union players in the present study in all three directions (A, PM, PL) (Plisky, Rauh & Kaminski, 2006) and in another study a high school female soccer group had increased reach distances in the A direction only (Filipa, Byrnes & Paterno, 2010). The rugby union players demonstrated superior performance to that of two unpublished studies in high school mixed gender basketballers (Sato, 2010) and male American footballers (Pollock, 2010). All of these sports involve considerable multidirectional movements with a reliance on postural stability. These differences may be due to anthropometric profile, development stage and sports specific demands of these athletes, as well as the numerous variances in test protocol that limit these comparisons.

Numerous SEBT studies have identified postural stability deficits in pathological populations namely patellofemoral pain syndrome (Aminaka & Gribble, 2008), anterior cruciate ligament (Herrington, Hatcher & Hatcher, 2009) and chronic ankle instability (Gribble & Hertel, 2004b, Nakagawa & Hoffman, 2004). The normative performance values presented in this investigation may be used for comparison with similarly aged injured players as part of their

physical assessment following injury. For example, lateral ankle ligament injuries are common injuries in professional rugby union players (Brooks and Kemp, 2011) and deficits in dynamic postural stability have previously been found post injury (Hoch, Staton & McKeon, 2012, Gribble, Hertel & Denegar, 2007). Using our data, the clinician, coach and player have an objective outcome measure at the initial assessment, as well as a marker of improvement throughout the rehabilitation and return to play process. Likewise the clinician can modify the player's exercise programme and progress the intensity and volume of exercise in a safe and effective manner using this marker. Improvements in SEBT performance have been observed following the inclusion of neuromuscular training activities (McKeon, Ingersoll & Kerrigan, 2008, O'Driscoll & Delahunt, 2011) and these activities should emphasize sound athletic positioning to help create dynamic control of the athlete's center of gravity in the early stages of rehabilitation (Myklebust & Bahr, 2005). Players use specific postural stability strategies when undertaking movements to deceive opponents, whereby they are required to minimize movements of parts of the body related to the final running direction (i.e. centre of mass displacement) whilst exaggerating the movement of other parts of the body (i.e. out-foot placement, head and upper trunk yaw) (Brault, Bideau & Kulpa, 2010). The incorporation of the SEBT reaches as controlled functional exercises in lower limb rehabilitation and conditioning programmes, may assist in the enhancement of dynamic postural stability and subsequently game related tasks, and warrants further investigation.

The development of screening tests may be a crucial component in preventing lower extremity injuries (Dallinga, Benjaminse & Lemmink, 2012) and there is a need for simple, low-cost tools, which can be used on a large scale in the clinic or the field (Dennis, Finch & Elliott, 2008). The SEBT has previously been reported to predict injury risk in mixed gender adolescent basketball players (Plisky, Rauh & Kaminski, 2006). Despite many professional

teams undertaking regular musculoskeletal screening, there are a paucity of studies in the literature investigating measures of dynamic postural stability performance and the efficacy of these measures in identifying injury risk in rugby union. In the present study, we have established these normative values in a group of elite age-grade players. Establishing these values in standardized and objective screening tests, such as the SEBT, allows for the identification of deficits and/or asymmetries. Players with reduced test performance, may be identified as requiring a more detailed assessment by the sports medicine team and the integration of specific postural stability exercises in their prehabilitation and conditioning programmes. Utilizing the SEBT as part of a weekly monitoring programme may also identify potential injury risk in players developing dysfunction, resulting in early intervention and/or modification of training/competition load. Players at this age group begin to increase training/competition load and therefore systematic measurement of their postural stability is required to ensure that these values remain accurate.

A limitation of this study is that we did not follow up players throughout the season to evaluate injury incidence and areas injured. Future studies should investigate the efficacy of the SEBT in injury prediction to identify potential deficits in performance that may contribute towards injury occurrence. It would be beneficial to undertake a year on year analysis of players to allow for comparison of performance as they develop into senior players. Testing could also be conducted in the same junior teams annually to allow for a more detailed position categorization analysis (i.e. locks, centres etc). The sample size in this study was too small to undertake this type of analysis at this stage.

CONCLUSION

The aims of this study were to evaluate the use of the SEBT in an elite underage rugby population and provide implications for its use. This test is an affordable and easy to use measure of dynamic postural stability for the rugby union sports medicine and conditioning clinician in injury assessment, screening, rehabilitation and guiding return to play criteria.

Ethical Approval: University College Dublin Human Research Ethics Committee (LS-11-120)

Funding: None

Conflict of Interest: None disclosed

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Table 1. Demographic Information

	Position	Mean	Standard Deviation	95% CI	P-value	Effect size (partial eta squared)
Age (years)	Forward	17.64	0.79	17.48 – 17.79	0.59	0.00
	Back	17.57	0.88	17.40 – 17.75		
Height (m)	Forward	1.85	0.08	1.83 – 1.87	0.00	0.15
	Back	1.80	0.09	1.78 – 1.82		
Body Mass (kg)	Forward	96.17	12.19	93.78 – 98.57	0.00	0.35
	Back	82.85	13.73	80.16 – 85.55		
Body Mass Index (kg/m^2)	Forward	28.08	3.46	27.40 – 28.76	0.00	0.19
	Back	25.62	3.90	24.86 – 26.39		
Left Leg Length (m)	Forward	0.98	0.06	0.97 – 0.99	0.00	0.12
	Back	0.94	0.07	0.93 – 0.96		
Right Leg Length (m)	Forward	0.98	0.06	0.97 – 0.99	0.00	0.12
	Back	0.94	0.07	0.93 – 0.96		

Table 2. SEBT Reach Distances

Reach Direction		Reach distance as a % of limb length (Mean ± SD)	
		Right Leg	Left Leg
Anterior	Forward	75.18 ± 4.79	75.13 ± 6.49
	Back	76.72 ± 6.13	76.20 ± 6.70
	Mean Difference	-1.54	-1.06
	P-Value	0.15	0.41
Posteromedial	Forward	96.59 ± 6.82	94.91 ± 7.32
	Back	98.72 ± 6.37	97.50 ± 6.68
	Mean Difference	-2.13	-2.58
	P-Value	0.11	0.06
Posterolateral	Forward	88.96 ± 6.97	87.94 ± 8.66
	Back	91.52 ± 5.63	89.70 ± 5.29
	Mean Difference	-2.55	-1.75
	P-Value	0.04	0.23

Conflict of Interest: None disclosed.

Ethical Approval: University College Dublin Human Research Ethics Committee (LS-11-120)