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Original Article

Intra- and inter-rater reliability of the star excursion balance test in primary school boys

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Abstract
In this study, the authors aimed to establish the intra- and inter-rater reliability of the Star Excursion Balance Test (SEBT) in two different age groups (6-9 years and 10-13 years) of school boys. The participants in this study were 42 primary school boys, aged from 6-13 years (9.71±2.00). For the intra-rater and inter-rater reliability of SEBT, school boys aged 6-9 years showed fair to excellent reliability (ICC = 0.58-0.90; SEM = 11.14-27.36; SDD = 4.02-9.87) in all directional reaches except posterolateral direction (ICC = 0.20) while school boys aged 10-13 years showed good reliability (ICC = 0.72-0.87; SEM = 2.97-7.63; SDD = 8.22-21.15). In conclusion, SEBT showed good intra-rater and inter-rater reliability in anterior, posteromedial and posterolateral directional reaches in school boys aged 6-13 years old but not in inter-rater reliability in posterolateral directional reach of school boys aged 6-9 years old. The findings suggest that SEBT is a reliable and practical test to assess dynamic balance in school boys aged from 10 to 13 years old in school setting.
Key words: SEBT, dynamic, PE lesson, teachers

Introduction

Balance refers to the control of centre of gravity and the base of support in reference to the limits of stability (Lephart, Riemann & Fu, 2000). Balance is not only one of the components of skill-related fitness, but it also has a direct relationship to health throughout the span of life (Payne & Isaacs, 2017). Good balance promotes the participation of children in a variety of physical activities and prevents injuries and falls at different stages of their lives (Claxton, Troy & Dupree, 2006). Some major roles of Physical Education (PE) teachers are to monitor physical development of school children (Ng, 2002), and promote their physical activity participation in school (Ng, 2011, Ng et al., 2017) and after school (Ng et al., 2016). PE teachers can regularly monitor and assess dynamic balance abilities in school children and tailored training programme for students who have balance deficits. In order to measure the balance of the students, we can conduct a simple and reliable field test which only requires short measuring time during PE classes.

The Star Excursion Balance Test (SEBT) is a standing, dynamic, single-leg, maximal-reach balance test performed in eight directions in a radial pattern (Gribble & Hertel, 1999). Previous research has reported good to excellent reliability for the SEBT in studies of healthy collegiate aged participants, yielding intraclass correlation (ICC) values and standard error of measurement (SEM) ranged from 0.84 to 0.92 and from 2.21 to 2.94 for each direction respectively (Munro & Herrington, 2010). Hyong and Kim (2014) also reported that the SEBT showed high intra-rater and inter-rater reliability with ICC scores (SEM values) of 0.88 to 0.93 (2.41-3.30) and 0.83 to 0.93 (3.19-4.26), respectively. However, limited research has been done to evaluate the reliability of SEBT in children especially in the age of primary school children ranged from 6 to 13 years old. Calatayud, Borreani, Colado, Martin and Flandez (2014) examined the intra-rater reliability of the SEBT in three directions in a study of 12 boys and 12 girls with a mean age of 11.0±0.8 years. Participants performed four practice trials prior to the three scored trials during PE classes.

The normalized SEBT scores showed moderate to high intra-rater reliability with ICC values ranged from 0.51 to 0.93, and the SEM values ranged from 3.03 to 12.32. The comparatively lower reliability for the SEBT of children is noted. It is questionable whether the SEBT is a reliable test for primary school children and for a single gender. There are two purposes in this study: 1) to establish the intra-rater and inter-rater reliability of SEBT for balance assessment in anterior, posteromedial and posterolateral directions in both legs in boys between 6 and 13 years old; 2) to examine if there is any reliability score differences of SEBT between boys of ages 6-9 years old and of ages 10-13 years old. It is hypothesized that 1) the SEBT would be a reliable test to evaluate dynamic balance ability in this population; 2) there is no significant reliability score differences of the SEBT between the two age groups of 6-9 years old and 10-13 years old.

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Methods:

Participants

A total of 42 school boys aged 6-13 years old were recruited from a primary school. They were studying primary 1 to 6 at the school. Their self-reported health records indicated an absence of musculoskeletal, cardiovascular, vestibular, visual, neurologic disorder or surgery within the 6 months prior to recruitment. No previous SEBT experience was recorded among all participants. Consents were obtained from their parents.

Procedure

Anthropometry measurements

Their body height (measured with a measuring tape) and body weight (BF-531, Tanita, Japan) were collected before the commencement of the test. Their leg length, measured from the anterior superior iliac spine to the medial malleolus, from both legs was determined with a tape measure while lying supine on the floor (Gribble & Hertel, 2003). The average of the sum of both leg lengths was used to normalize excursion distances by dividing the distance reached by leg length and then multiplying by 100.

SEBT Protocol

Two raters attended a 3-hour SEBT training session prior to the commencement of the test.

The rater provided each participant with a verbal instruction and visual demonstration of the SEBT testing procedure described by Plisky and his colleagues (2006). All the SEBT was conducted at covered playground during PE lesson. The participants stood, bared feet, in the middle of a grid formed by three lines which were located by adhering three 120 cm measuring tapes to the floor. Two measuring tapes were aligned at an angle of 135 degree to a third measuring tape in the posteromedial and posterolateral directions. They were asked to maintain a single leg stance while reaching as far as possible with the contralateral leg along each of the three lines. Participants were instructed to keep their hands on their hips while making a light touch on the ground with the most distal part of the reaching leg and return to a bilateral stance without allowing the contact to affect overall balance. After performing four trials of SEBT in anterior, posteromedial and posterolateral directions at randomized order, the participants completed 3 trials in randomized order of stance leg, raters and reach directions with a 10 second break between trials and a 20 second break between directions. Inter-rater reliability test was conducted on the first day by both raters and an intra-rater test was performed 6 days after by the first rater. The reach distances were taken to the nearest millimeter, where the most distal part of the foot reached. No encouragement was given to the participants during testing. The trial was completed when the participant returned to the starting position by placing the reaching leg within 5 in. (12.7 cm) of the stance leg. The maximum of 2 mis-trials were allowed if 1) the reach leg rested on the floor; 2) the stance leg moved from the starting position; 3) the reach leg could not return to the starting position (Hardy, Huxel, Brucker & Nesser, 2008). The greatest of three measurements was recorded for each directional reach for statistical analysis.

Statistical Analysis

Paired sample t-tests with Bonferroni corrections were employed to explore any significant differences between right and left limb for each directional reach. Relative reliability was analyzed using ICC. Data obtained was assessed for each of the 3 normalized directional reach for both right and left legs by calculating ICC with two-way random model (2,1) (Rankin & Stokes, 1998). ICC values were interpreted in accordance with the following criteria: Poor < 0.40; Fair = 0.40 - < 0.70; Good = 0.70 - < 0.90; Excellent ≥ 0.90 (Coppieters, Stappaerts, Janssens & Jull, 2002).

The presence of systematic error was determined using absolute reliability by calculating 95% confidence intervals (95% CI). The random error scores were established using 1) Standard Error of Measurement (SEM) which was calculated with the formula: $SD * (\sqrt{(1 - ICC)}$) (Thomas et al., 2005) and 2) Smallest Detectable Difference (SDD) which was calculated using the formula: $(SEM * 1.96 * \sqrt{2}$) (Kropmans et al., 1999). SPSS 20.0 was employed for data analysis purpose. The level of significance was preset at .05 for all analyses.

Results:

Demographic and physiological data of boys with different age groups were shown in Table 1. Results of paired t-test showed that no significant difference between the use of right leg or left leg as the supporting leg for each directional reach (P>0.05); therefore they were grouped for all further analysis, giving an overall number of 84 limbs. The reaches between right and left legs were significantly correlated with Pearson correlation coefficient ranged from 0.41 to 0.63. For the three directional reaches of both stance legs, the ICC values of intra-rater reliability were reported for all school boys (0.70-0.88), age group 6-9 (0.58-0.90) and age group 10-13 (0.78-0.87), SEM values ranged from 2.97 to 7.47 and SDD values ranged from 8.22 to 20.70. The ICC values of inter-rater reliability are found for all school boys (0.65-0.82), age group 6-9 (0.20-0.86), and age group 10-13 (0.72-0.84). SEM values ranged from 4.02 to 9.87, and SDD values ranged from 11.14 to 27.36 (see Table 2).

Comparing the intra- and inter-rater reliability, intra-class correlation coefficients (ICCs, represented as dots), inter-class coefficients (ICCs, represented as crosses) and corresponding confidence intervals at $\alpha = 0.05$ (CIs, represented as error bars) for 3 directional reaches were showed in Figure 1 and 2. The confidence intervals

($\alpha = 0.05$) of reliabilities for the age group of 6-9 years and 10-13 years are overlapping except the inter-rater reliability of posterolateral direction in boys aged from 6 to 9 years, indicating that they do not differ from each other (see Figure 1 and 2 for ICCs and the corresponding confidence intervals).

Table 1: Demographic and physiological data of the school boys (Mean ± SD)

Variables	Age Group	All (n = 42)	6-9 (n = 22)	10-13 (n = 20)
Age (years)		9.71±2.00	4±0.90	11.45±1.30
Height (m)		1.37±0.14	6±0.70	1.49±0.10
Weight (kg)		33.38±10.90	55±8.40	39.80±9.77
Body Mass Index (kg m^{-2})		17.41±3.70	04±3.95	17.83±3.45
Average leg length of left and right legs (cm)		71.90±8.51	86±4.73	78.55±6.53

Table 2: Measurements from Intra-rater and Inter-rater on 3 Normalized Maximum Excursion Distances of both stance limbs

	Distance Mean ± SD (cm)			Reliability							
Directions	Rater 1 (Day1)	Rater 1 (Day7)	Rater 2 (Day1)	Intra-rater ICC	95% CI	SEM	SDD	Inter -rater IC	95% CI	SEM	SDD
All boys	(n = 42)										
Anterior	76.8±9.0	76.6±8.4	80.2±8.7	8	.93			0.3	-0.91		
Posteromedial	92.8±10.7	91.5±10.9	93.8±11.6	'0	.84			0.-	-0.84		
Posterolateral	76.3±11.6	76.8±10.3	73.8±12.9	'8	.88			0.5	-0.81		
Boys aged 6-9 (n = 22)											
Anterior	77.8±9.6	78.1±8.4	81.0±9.7	90	).96			0.3	-0.95		
Posteromedial	92.1±11.2	92.3±13.0	90.5±11.6	0.66	2-0.8			68	).87		22.25
Posterolateral	73.8±10.2	75.5±8.7	70.4±11.7	58	0.83			0.9	1-0.66		
Boys aged 10-13 (n = 20)											
Anterior	75.7±8.3	75.0±8.4	79.2±7.7	84	).94			0.2	-0.89		
Posteromedial	93.6±10.3	90.7±8.2	97.4±10.6	0.78	5-0.9			74	).90		21.15
Posterolateral	79.2±12.6	78.1±11.9	77.5±13.4	87	).95			0.1	-0.94		

ICC = Interclass correlation; Standard Error of Measurement (SEM) = $SD * (\sqrt{(1 - ICC)})$

95% CI = 95% confidence interval; Smallest Detachable Difference (SDD) = $SEM*1.96*\sqrt{2}$

Figure 1: Comparison of intra-rater reliability on SEBT of two age groups (Dots and crosses represented ICC, error bars represented 95% CI).

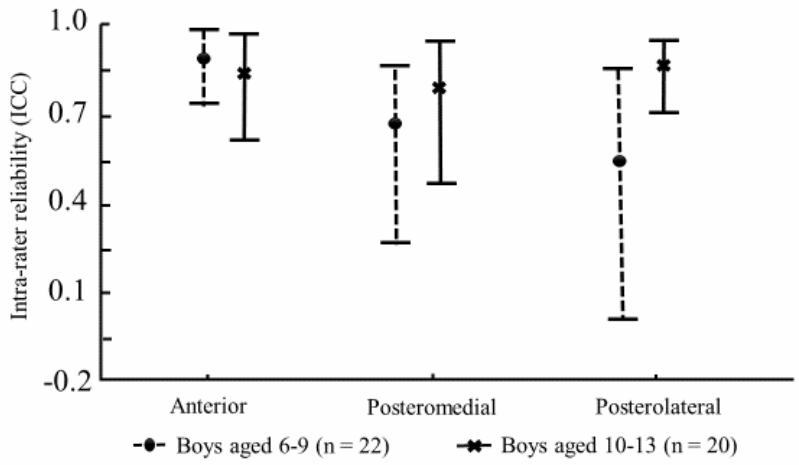
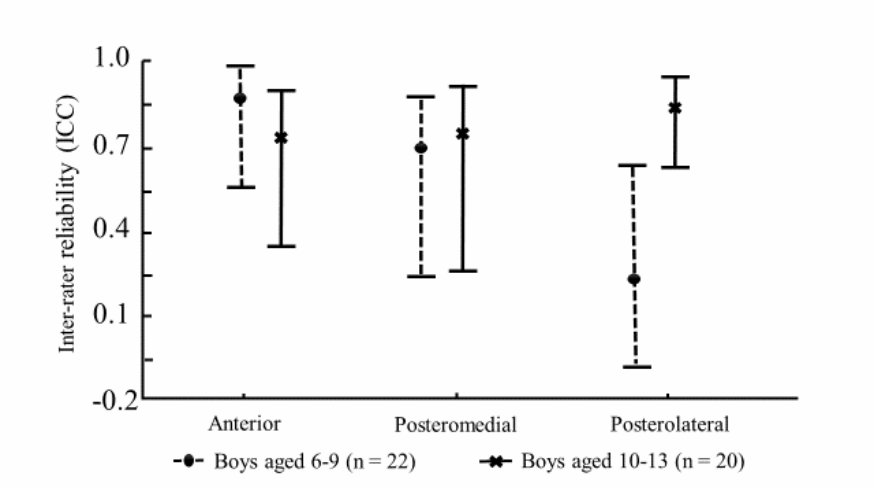


Figure 2: Comparison of inter-rater reliability on SEBT of two age groups. (Dots and crosses represented ICC, error bars represented 95% CI).



Discussion:

In this study, the intra-rater reliability scores of SEBT showed good ICC values ranging from 0.70 to 0.88 and from 0.78 to 0.87 in school boys aged from 6 to 13 years and from 10 to 13 years, respectively. Similar intra-rater reliability scores of SEBT with ICC values ranged from 0.51 to 0.93 were reported in the study employing school children with mixed gender aged from 10 to 12 years in school setting (Calatayud, Borreani, Colado, Martin & Flandez, 2014). The findings in this study showed that SEBT was a reliable instrument measuring dynamic balance in primary school boys. As only limited research using SEBT in primary school girls, therefore, it is important to validate the SEBT in the population of primary school girl.

A significant difference was observed in reliability of SEBT between school boys with age groups of 6-9 years and 10-13 years. A high intra-rater reliability scores and inter-rater reliability score of SEBT were reported in school boys aged from 10 to 13 years with ICC values ranging from 0.72 to 0.87. For all directional reaches, except posteriorlateral (ICC = 0.20), showed fair to excellent (ICC = 0.58-0.90) intra-rater and inter-rater reliability in boys aged from 6 to 9 years. The absolute reliability indices (SEM and SDD) provides information on the accuracy and precision of the measured values. The measurement is considered reliable when the values of SEM and SDD are less than 10% of the highest measured score (Liaw et al., 2008). A lower SEM value for normalized scores ranged from 2.97 to 9.87 was obtained in this study that were comparable to the findings of Calatayud, Borreani, Colado, Martin and Flandez (2014) that a higher SEM values ranged from 3.03 to 12.32 were reported. Comparing the normalized intra-rater and inter-rater ICC, SEM and SDD values were determined with healthy young adults by SEBT experienced tester using standardized measuring tools (Hyong & Kim, 2014; Munro & Herrington, 2010). The comparatively low absolute reliability in the present study might be partly due to the employment of ordinary PE teachers as raters who were not specialized in conducting SEBT. Moreover, all the school boys had no previous experience in taking SEBT. The SEBT is a dynamic balance test with multi-dimensional natures that demands strength, flexibility and proprioception such as visual, vestibular, and somatosensory systems (Palmieri et al., 2002). The unstable dynamic balance control of school children may require additional familiarization session, which consists of greater number of demonstrations and practice trials to improve the reliability of the SEBT. Demura and Yamada (2010) stated that the measurements of SEBT on the posteromedial and posterolateral directions require rotational movement of the trunk and lower limbs. The lower ICC scores achieved were due to the lack of visual assistance when reaching in the backward or oblique-backward direction. Future work should identify an optimal number of practices before the trials were conducted in children with no experience of SEBT in a school setting. There are limitations in this study. In order to test the inter-reliability of the test, participants needed to take the test two times by two raters on the first day of the test. This procedure may impose a fatigue error on participants (Gribble, Hertel, Denegar & Buckley, 2004). In addition, as the participants had practice sessions before the test and that may impose a learning effect (Hertel, Miller & Denegar, 2000).

Conclusion:

The three trials of SEBT in 3-directional reach have shown good intra-rater and inter-rater reliability in school boys aged from 10 to 13. The test was conducted in PE lesson within short period of time. In addition, both the dominant or non-dominant legs were found valid in the test using as supporting leg. In order to improve the inter-rater reliability of the SEBT of school boys aged from 6-9 especially in posterolateral directional reach, greater number of demonstrations and practice trials might be needed. To conclude, SEBT is a reliable and practical test to assess dynamic balance in school boys aged from 10 to 13 years old in school setting.

Practical Implication: The testing time of the SEBT has been shortened and therefore it is more time efficient for PE teachers to conduct the 3-directional reach of SEBT in PE lesson (Gribble, Hertel & Plisky, 2012). In addition, the single leg stance position used in the test is similar to hopping movement which is familiar to school children and therefore it is easier for children to perform the movement. To conclude, the procedures used

for SEBT test are time efficient and reliable to assess dynamic balance in school boys with aged from 10 to 13. In addition, if we can do the SEBT assessment continuously in long term throughout the school years of the children, we can identify the dynamic balance deficiency of school boys and obtain the rate of improvement in balance scores over time and age. As a result, PE teachers can monitor the changes of the balance performance of the children and provide suitable training to those in need.

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