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Original Article

Lower Quarter Y Balance Test: reliability and relation to anthropometric parameters

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Abstract:
This study aimed to analyze the Lower Quarter Y Balance Test (Y-BT) reliability in prepubescent male soccer players, as well as the relation between this dynamic balance test performance and some anthropometric parameters. In a field testing, 104 prepubescent male soccer players (mean ± SD: age: 12.03 ± 1.81 year; Weight: 43.48 ± 10.39 kg; Stature: 154.14 ± 12.44 cm; Maturity offset: -2.40 ± 1.21) volunteered for this study. In this study, the Y-BT outcome measures were expresses as the composite scores for dominant and non-dominant legs. The study was performed in two stages. In the first stage was investigated the reliability of the Y-BT, using a test-retest method. The Y-BT test and retest were performed, one week apart at the same time of day and on the same day of the week. The Intraclass Ccorrelation Coefficient ($ICC_{(3.1)}$) was used for the analysis of relative reliability. Absolute reliability was analysed using 95% limits of agreement (LOA) and the standard error of measurement (SEM). In the second stage of the study, linear relations between Y-BT and age, stretch stature, body mass and sitting height, were investigated. Multiple linear regressions with backward method were used to test the relationship between the Y-BT and the explanatory variables. The reliability of the Y-BT was good, with an $ICC_{(3.1)} > 0.90$, a SEM% < 5% and 95% LOA of -0.003 ± 1.32 % and -0.23± 1.37 % for dominant and non-dominant leg, respectively and talked about influence of anthropometric variables on Y-BT. Significant correlations were found between Y-BT, stature and leg length for both legs. Thus, Y-BT is a reliable tool for measuring dynamic balance, and its performance is anthropometric dependant in prepubescent soccer players.
Key words: dynamic balance; reproducibility; youth testing; anthropometry..

Introduction

Core stability has become a common fitness trend that has transcended into sports medicine world. Core stability is often incorporated into a functional exercise program. It becomes an important facet that has gained renewed emphasis in the sports training (Zech, Hübscher, Vogt, Banzer, Hänsel, & Pfeifer, 2010; Hill,Wdowski, Pennell, Stodden, & Duncan, 2019). It has been suggested that deficits in core stability discern between individuals with a history of ankle and knee injuries (Aminaka, & Gribble, 2008; Akabari, Karimi, Farahini,& Faghihzadeh, 2006; Gribble, Hertel, & Denegar, 2007). Moreover, training programs focused on balance training have also been associated with reduced injuries, (Emery, Rose, McAllister, & Meeuwisse, 2007; McGuine, & Keene, 2006) and increased neuromuscular power and motor control during vertical jumps. Thus, tracking balance impairments seems important for prediction and prevention of musculoskeletal conditions of the lower limbs (Fusco, Giancotti, Fuchs, Wagner, Varalda, Capranica, & Cortis, 2020; Fusco, Giancotti, Fuchs, Wagner, Varalda, Cortis, 2019).

Core stability is often defined statically and dynamically. Static core stability is the ability to maintain a base of support with minimal movement. However, dynamic core stability is the ability to perform a task while maintaining a stable position (de Noronha, Franca, Haupenthal, & Nunes, 2012; Winter, Patla, & Frank, 1990).
In the field of sport, the ability to maintain postural control during dynamic actions is critical for the successful performance of fundamental movement skills such as kicking and jumping (Faigenbaum, Bush, Mc Loone, Kreckel, Farrell, Ratamess, & Kang, 2015). Screening balance impairments seems warranted based on its potential to track training-related adaptations in balance during childhood and adolescence (Bullock, Arnold, Plisky, & Butler, 2018; Filipa, Byrnes, Paterno, Myer, & Hewett, 2010; Robert, Snowy, & Cheung, 2018).
The Lower Quarter Y Balance Test (Y-BT) is a tool, validated to assess dynamic postural control. The Y-BT consists to maintain single-leg stance balance while reaching as far as possible with the contralateral leg in the anterior, posteromedial and posterolateral maximal reach directions (Faigenbaum et al. (2015) and Filipa et al. (2010)).

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The Y-BT has found large application in the examination of children and adolescents (Faigenbaum, Bush, Mc Loone, Kreckel, Farrell, Ratamess, & Kang, 2015; Gonell, Romero, & Soler, 2015; Linek, Sikora, Wolny, & Saulicz, 2017). Y-BT score performance can be expressed as reach distances, or as composite scores calculated as the average of the normalized AT, PM, and PL reach distances (Stiffler, Bell, Sanfilippo, Hetzel, Pickett, & Heiderscheit, 2017). Schwiertz et al. (2019) advised to express Y-BT performance as composite score (CS) to evaluate dynamic balance performance in healthy adolescents because this Y-BT performance parameter is the most reliable Y-BT score performance.

It is well known that any physical fitness test or measurement, to be properly employed must satisfy some crucial properties including: objectivity, responsiveness, validity, sensitivity, and reliability and these aspects have been addressed for quantifying balance ability (Hertel, Miller, & Denegar, 2000; Lanning, Uhl, Ingram, Mattacola, English, & Newsom, 2006). Reliability gives information regarding the consistency and stability of a measurement. Systematic error in administration or scoring, affects the validity of the data. Thus, every test should include a statement regarding its reliability.

Previous reliability assessment, specific to the Y-BT was established (Bressel, Yonker, Kras, & Heath, 2007; Butler, Lehr, Fink, Kiesel, & Pliski, 2013; Chaouachi, Brughelli, Chamari, Levin, Ben Abdelkrim, Laurencelle, & Castagna, 2009; Chimera, Smith, & Warren, 2015; Linek, Sikora, Wolny, & Saulicz, 2017; Plisky, Gorman, Butler, Kiesel, Underwood, & Elkins, 2009; Plisky, Rauh, Kaminski, & Underwood, 2006; Schwiertz, Brueckner, Schedler, Kiss, & Muehlbauer, 2019; Shaffer, Teyhen, Lorenson, Warren, Koreerat, Straseske, & Childs, 2013; Sirotic, & Coutts, 2008; Winter, Patla, & Frank, 1990). However, only one study exists that examined this issue in youth soccer players (mean age: 15.6 years) (Linek, Sikora, Wolny, & Saulicz, 2017). Irrespective of the reach direction considered, findings yielded ICC values ranging between "moderate-to-good" and "excellent" (i.e., 0.57 to 0.82). To the best of our knowledge, there is no study available that investigated the reproducibility of the Y-BT composite scores in prepubescent male soccer players.

Controlling the human balance depends on the integrity of the visual, vestibular, and sensory-somatic systems (Cattaneo, Regola, & Meotti, 2006). If one of the involving systems in postural control mechanisms declines, or loses its activity, the functions of other mechanisms in this process will be decreased or lost (Cipriani, Armstrong, & Gaul, 1995). Other factors, such as gender, age, and anthropometric factors, are also mentioned to be effective on balance (Sadeghi, & Noori, 2015; Lara, Graup, Balk, Teixeira, Farias, Alves, & Leiria, 2018; Fabunmi, & Gbiri, 2008; Goulding, Jones, Taylor, Piggot, & Taylor, 2003; Maffiuletti, Agosti, Riva, Resnik, & Lafortuna, 2005; Mainenti, Rodrigues, Oliveira, Ferreira, Dias, & Silva, 2011; McGraw, McClenaghan, Williams, Dickerson, & Ward, 2000; Singh, Park, Levy, & Jung, 2009).

These studies have been conducted on groups of prepubescent children and adolescents (Goulding, Jones, Taylor, Piggot, & Taylor, 2003; McGraw, McClenaghan, Williams, Dickerson, & Ward, 2000), adults (Maffiuletti, Agosti, Riva, Resnik, & Lafortuna, 2005; Singh, Park, Levy, & Jung, 2009), and elderly people (Fabunmi, & Gbiri, 2008; Mainenti, Rodrigues, Oliveira, Ferreira, Dias, & Silva, 2011). In all of these studies body mass influenced postural stability.

It therefore seemed valuable to determine whether or not body size indices interfere with postural balance in prepubescent athletes and particularly in prepubescent male soccer players, and if these indices better explanation for the variations encountered, and should these variables be considered or not during balance assessments.

There are no sufficient research studies taking into account the above mentioned factors. Thus, this study aimed to examine the reliability of Y-BT test in prepubescent male soccer players, as well as the relation between the Y-BT composite score and some anthropometric parameters.

Materiel & Methods

Study Setting and Ethical Approval

The study was conducted according to the declaration of Helsinki. After explanation of the experimental protocol and its potential benefits and harms, verbal and written informed consent was obtained from legal children representatives.

Procedure

Measures of postural control have been used in laboratory and clinical settings as a means of assessing stability and neuromuscular control in healthy and inured subjects. Therefore, assessing the postural control in young prepubescent male soccer players is extremely needed and must be done with reliable and valid tests. To that end, prepubescent subjects involved within the present study and performed many Y-BT tests. To gain familiarity with the Y-BT one practice session was performed one week before the initiation of baseline testing. Two other sessions of the Y-BT were evaluated by having the subjects perform the Y-BT on two separate occasions (7 days apart) at the same time of day. All tests were administered by the same researcher. Each participant's dominant leg was determined prior to testing by asking which leg the participants would choose to kick a soccer ball for maximal distance (Giblle, Tucker, & White, 2007). Subjects were asked to refrain from exercise and consumption of food or beverages, other than water, for two hours before each testing session. The subjects performed the Y-BT trials wearing shorts and T-shirts for all test sessions. Moreover, all testing was conducted barefoot to eliminate additional balance and stability from the shoes (Coughlan, Fullam, Delahunt, Gissane, & Caulfield, 2012). Before each testing session, participants performed a 10 min warm-up (six min alternate step-up on 25 cm bench, static stretching and calisthenics) (Sarabon, Mlaker, Markovic, 2010). Test procedures were performed in a synthetic surface.

Participants

A total of 104 healthy youth male soccer players from a football club academy (mean ± SD: age: 12.03 ± 1.81 year; Weight: 43.48 ± 10.39 kg; Stature: 154.14 ± 12.44 cm; Maturity offset: -2.40 ± 1.21), took part in this study. All participants had been involved in their sports training regularly for more than two years before the study. The maturity age was determined according to peak height velocity, (maturity offset = 27.999994 + [0.0036124 × age × height]) (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002).

Data collection

Anthropometric Measurements

All measurements were taken by the same experienced researcher. Dimensions included stature, body mass and sitting height. Stretch stature was measured with a wall-mounted stadiometer (± 0.1 cm, Holtain Ltd, Crosswell, UK), sitting height with a stadiometer mounted on a purpose-built table (± 0.1 cm, Holtain Ltd, Crosswell, UK) body mass with a weighing device (± 0.1 kg). Skinfolds measurements were taken in the right-hand side of the body (Stewart, Marfell-Jones, Olds, de Ridder, 2011) at four sites (biceps, triceps, subscapular and supraspinal) using Harpenden skinfold calipers (Harpenden Instruments, Cambridge, UK). Skinfold data were used to estimate body fat mass and fat free mass.

Y-Balance-Test

To perform the Y-BT, the participant stood on one foot on the center foot plate with the most distal aspect of the toes just behind the starting line. The starting position for the reach foot was between the center foot plate and the pipe opposite the stance foot. While maintaining single-leg stance, the participant was instructed to push the reach indicator along the pipe with the reach foot as far as possible in the direction being tested; and then return the reach limb to the starting position resuming a bilateral stance. The maximal reach distance was measured by reading the tape measure at the edge of the reach indicator, at the point where the most distal part of the foot reached in half centimeters. The reach was discarded and repeated if the subject: (a) failed to maintain unilateral stance on the platform; (b) failed to maintain reach foot contact with the reach indicator; (c) used the reach indicator for stance support; (d) failed to return the reach foot to the starting position under control. The testing order was three trials standing on the right foot reaching in the AT direction followed by three trials standing on the left reaching in the AT direction. This procedure was repeated for the PM and the PL directions. The specific testing order was right AT, left AT, right PM, left PM, right PL, and left PL. If a proper reach was not performed in three trials for any direction, an additional three trials were allowed. The furthest successful reach for each direction was used for analysis. The Y-BT composite score (CS) was calculated (Filipa, Byrnes, Paterno, Myer, & Hewett, 2010) and taken as dependent variable using the following formula:

$$CS(\%) = \frac{(\text{MaxAT} + \text{MaxPM} + \text{MaxPL})}{\text{Leg Lengh} \times 3} \times 100$$

Statistical Analysis

The statistical analyses were carried out using SPSS 19.0 program for Windows (SPSS, Inc, Chicago, IL, USA). Descriptive statistics were generated for all variables. The significance level considered in the present study was set at $p < 0.05$. The normality assumption was checked using a Kolmogorov-Smirnov test and all variables in the two stages of the study showed a normal distribution ($p > 0.05$). Heteroscedasticity in test data exists when the amount of random error increases as the measured values increase (Winter & Nevil, 2001). In this study heteroscedasticity was investigated by calculating the zero order correlation coefficient between the mean of test and retest scores and the absolute differences between test and retest scores. In the first stage of our study the relative reliability of the Y-BT composite score was determined by calculating intraclass correlation coefficient ($ICC_{(3.1)}$) (Coppieters, Stappaerts, Janssens, & Jull, 2002). We considered an $ICC_{(3,1)}$, below 0.40 as poor, between 0.40 and 0.70 as fair, between 0.70 and 0.90 as good, and >0.90 as excellent (Coppieters, Stappaerts, Janssens, & Jull, 2002). To test absolute reliability, the absolute (SEM = pooled SD x √[1- ICC]) and relative $\text{SEM}\ \% = \left(\left[\frac{\text{SEM}}{\text{Mean of all measurement}}\right] \times 100\right)$ standard error of measurement were calculated.

The agreement between test-retest performances were also calculated (Bland, & Altman, 1986). The effect size (***d***) was calculated using GPOWER software (Bonn FRG, Bonn University, Department of Psychology) (Faul, & Erdfelder, 2004). The modified Hopkins scale (Hopkins, 2000) was used for the interpretation of ***dz***: [*trivial*]: 0.2, [*small*]: 0.2-0.6, [*moderate*]: 0.6-1.2, and [*large*]: 1.2. In the second stage of our study, Pearson product --moment correlation was computed between Y-BT composite score and body size indices. Vincent, (1999) has suggested that an absolute correlation coefficient of 0.5 – 0.7 is considered low, one of 0.7 – 0.8 is considered moderate, and one of 0.9 or above is considered high or strong. Multiple linear regression was also used to test the relationship between the vertical jump height and the explanatory body size variables.

Results

The descriptive statistics of the Y-BT performance test retest trials of both limbs are reported in Table 1. Results of the test-retest absolute and relative reliability analyses are presented in Table 1. Inter-rater test-retest reliability for the Y-BT composite score had good $ICC_{(3,1)}$ values of 0.98 with an associated SEMs of 1.18% and 1.76%, for dominant and non-dominant legs respectively (Table 1).

Table 1. Descriptive statistics and results of relative and absolute reliabilities of Y-BT for prepubescent male soccer players (n= 104)

		Test	Retest	Paired sample p-value	d	ICC	SEM	SEM%
Y-BT	CS Dom Leg (%)	97.55 (6.40)	97.54 (6.53)	0.98	0.007	0.98	0.91	1.18
	CS NDom Leg (%)	92.15 (6.48)	91.91 (6.63)	0.08	0.18	0.98	1.32	1.76

Legend: Y-BT: Lower Quarter Y Balance Test; CS DOM Leg: Normalized Composite Score for dominant leg; CS NDom Leg: Normalized Composite Score of Non Dominant Leg; p: p value; ***d****: Magnitude of the difference the d of Cohen; ICC: Intraclass Correlation Coefficient; SEM: Standard Error of Measurement; SEM%: Standard Error of Measurement.*

The results from Bland and Altman test seen in (Figures 1 and 2) demonstrate good test retest agreement for CS Dom Leg and CS N Dom Leg. The Bland and Altman distribution graph (Figure 1 and Figure 2) indicated a bias between CS Dom Leg (-0.003 ± 1.32) and CS N Dom Leg (-0.23 ± 1.37), with those of CS N Dom Leg being larger.

Figure 1. Distribution plot from Bland and Altman test showing mean measurements against differences between measurements for Y-BT dominant leg composite score inter-rater reliability.

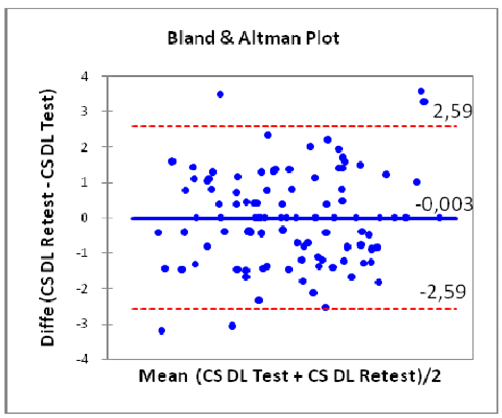
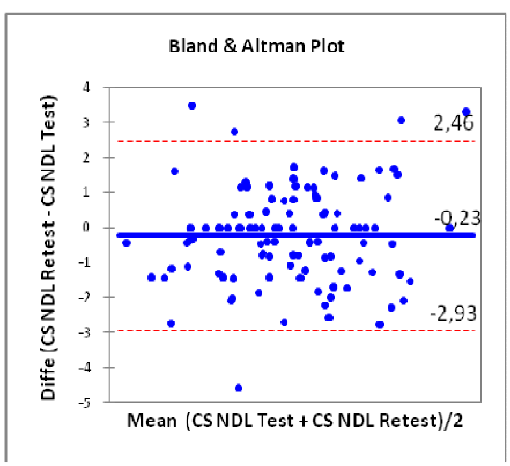


Figure 2. Distribution plot from Bland and Altman test showing mean measurements against differences between measurements for Y-BT non-dominant leg composite score inter-rater reliability.



The step wise correlation exploring the association between Y-BT CS Dom Leg and the different somatic characteristics estimated that age and LLength are the only significant predictors of Y-BT performance

(Table 3). Calculation of the CS Dom Leg from age and LLength in our prepubescent male soccer players was as follow: 122.25 + (-0.69 × LLength + 2.49×Age).

Discussion

To the authors' knowledge, this is the first study to analyze the reliability of Y-BT in prepubescent male soccer players, as well as the relation between this dynamic balance test performance and some anthropometric parameters. The main finding of this study was that the Y-BT composite score of both legs is a reliable tool for field evaluation of dynamic balance and that age and LLength are the only related indices of Y-BT performance in prepubescent male soccer players.

According to Impellizzeri, & Marcora, (2009), reliability results are commonly used to judge whether a test protocol should be widely used. Relative reliability is a method that commonly relies on determining the ICC (Weir, 2005). In the present study the $ICC_{(3,1)}$ was 0.98 approaching unity, for both CS Dom Leg and CS N Dom Leg (Table 1). It has been reported that an ICC above 0.90 defines a high level of relative reliability (Vincent, 1995). The $ICC_{(3,1)}$ values calculed in our study, were better than those previously reported by Plisky, Gorman, Butler, Kiesel, Underwood, & Elkins, (2009) (0.85-0.89); Linek, Sikora, Wolny, & Saulicz, (2017) (0.57-0.82) in adolescent athletes and by Schwiertz, Brueckner, Schedler, Kiss, & Muehlbauer, (2019) (0.40-0.90) in healthy adolescents from grade 6 to 11 years, and similar to the reported results by Van Lieshout, Reijneveld, Van den Berg, Haerkens, Koenders, De Leeuw, & Stukstette, (2016) and by Onofrei, Amaricai, Petroman, & Suciu, (2019) in healthy young adults and healthy elite athletes respectively.

The ICC cannot be the only statistical measure of reliability as it is affected by the heterogeneity of the sample (Bland, & Altman, 1986). Thus, as measures of absolute reliability, SEM is recommended to be used, in conjunction with the ICC (Looney, 2000) particularly if data are homoscedastic. In the current study, data were homoscedastic ($p > 0.05$) thus, absolute reliability was assessed by SEM, which was presented in absolute and relative forms (Table 1). The coefficient of variation replaces SEM with heteroscedastic data (Bland, & Altman, 1986) accordingly, absolute reliability was evaluated by the SEM only in the current study.

According to Nevill, & Atkinson, (1997), any two tests would differ, because of measurement error (SEM in the current study) by no more than 5%. The absolute reliability of the Y-BT CSs for dominant and non dominant legs, were very good, with SEMs far below the 5% limit (Table 1). Our findings are in line with the results of the aforementioned studies (Plisky, Gorman, Butler, Kiesel, Underwood, & Elkins, 2009; Schwiertz, Brueckner, Schedler, Kiss, & Muehlbauer, 2019) and imply that the both leg Y-BT CSs are a reproducible tests for the assessment of dynamic balance performance, in prepubescent male soccer players.

The mechanisms that underlay the motor control system of dynamic stability are not yet fully understood (Lencioni, Carpinella, Rabuffetti, Cattaneo, & Ferrarin, 2020). One still open question is related to the possible influence of age, anthropometric data and spatio-temporal gait parameters on dynamic stability (Eriksrud, Federolf, & Cabri, 2019; Ludwig, 2017). If such influence exists, the effects of these confounding factors must be took in to consideration when dynamic stability is evaluated either in athletes or in sedentary subjects of different ages and anthropometry. With this second phase of our study we investigated the linear relations between Y-BT and age, stretch stature, body mass and sitting height. Not all anthropometric features were correlated to Y-BT CS Dom Leg. In our athletes, age, stature and LLength influenced the Y-BT CS Dom Leg (Table 2). This mean that the taller a player is, the higher the dynamic balance performance will be. The present study was in accordance with Chiari et al. (2002) and Berenjian et al. (2014). They showed that the height has a significant positive correlation with dynamic balance. However our results were non compatible with those of Berger et al. (1992). Their findings showed that the shorter a subject is, the co-activation and the electrical activity of the plantar flexor muscles and the ankle's dorsiflexors are higher and the ankle movement is also more, consequently, more movements are done to control the pressure center movements in the base of support.

Table 2. Correlation between Y Balance test and anthropometric parameters (n = 104).

	BM	Stature	UpBoH	LLength	BFM	BFFM
Y-BT	r= 0.12	r= 0.21	r=-0.08	r=-0.28	r=0.10	r=0.16
	p = 0.21	p=0.02	p=0.38	p=0.004	p=0.31	p=0.09

Legend: BM: Body Mass ; UpBoH: Upper Body Height; LLength: Leg Length; BFM: Body Fat Mass ; BFFM: Body Fat Free Mass.

Age was significantly correlated to Y-BT CS Dom Leg in our athletes (Table 2). Similar correlation were reported by Paniccia et al. (2018) and Guskiewicz, & Broglio, (2015). These authors stipulated that Y-BT scores improve throughout childhood between the ages of 2 and 13 years old and the mechanisms for this continued development of balance include vestibular contributions. These contributions have been speculated to be the slowest sensory system associated with core stability, resulting in longer adaptation time and greater magnitudes of balance responses (Hirabayashi, & Iwasaki, 1995).

After multiple regression analysis, only age and LLength were selected as significant determinants of Y-BT CS Dom Leg (Table 3). In our study, the reference equation for predicting Y-BT CS Dom Leg presented a squared correlation coefficient of 24% (Table 3). No other studies established reference equation for prediction of Y-BT CS, so it is difficult to compare this result to those of the specific literature.

Table 3. Relationship between Y-BT composite score and body size indices for prepubescent male soccer players (n = 104).

Regression	Coefficients	SD	Beta	t	p-value
Constant	122.25	5.82		20.99	0.000
LLength	-0.69	1.23	-0.84	-5.63	0.000
Age	2.49	0.54	0.69	4.60	0.000
Dependent variable: Y-BT dominant leg composite score; $p < 0.001$; $R = 0.489$; $R^2 = 0.24$; estimated standard error (ESE) = 5.75.					
B: Unstandardized coefficient beta; SD: Standard Deviation; Beta: Standardized coefficient Beta; LLength: Leg Length					

About 76% of the variance in Y-BT CS Dom Leg remains unexplained by our models. Future population-based studies of more heterogeneous athletes that include Y-BT, may be able to provide models, that explain more of the variance and increase the lower limit of the normal range provided by our reference equation. Caution should be exercised when applying our regression equation. Our results may not be generalizable to athletes who play sports other than soccer, since a homogeneous sample of prepubescent male soccer players was enrolled. Thus, the generalizability of the current study's protocol results in other athletes (including females) requires further investigation.

Conclusion

Determination of the reliability of the Y-BT and the relation between some morphological characteristics and its composite score in prepubescent soccer players were conducted in a group of 104 subjects. Any studies on the aforementioned questions have yet to be implemented. Based on the results of previous researches we can be assume that some anthropometric indices can somewhat affect on dynamic balance evaluated by Y-BT. Results of this study talk about good relative and absolute reliability of the Y-BT, and about its significant relation to leg length and age when Y-BT was expressed as a composite score (dominant leg) in prepubescent male soccer players. Additional investigations are needed to confirm the relationships noted in this paper among other populations.

Conflicts of interest

There is no conflict of interest including any financial, personal or other relationships with other people or organizations that have influenced the performance of this work.

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