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Performance and reliability of the Lower Quarter Y Balance Test in healthy adolescents from grade 6 to 11

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ABSTRACT

Background: The Lower Quarter Y Balance Test (YBT-LQ) has been widely used in the field to assess dynamic balance performance in various populations. However, no study has demonstrated test-retest reliability of the YBT-LQ in adolescents including several age cohorts, even though reliability is necessary to provide repeatable performance data.

Objective: Thus, we examined test-retest reliability of the YBT-LQ in healthy adolescents.

Methods: In a school setting, 178 secondary school students (93 female, 85 male) in sixth to eleventh grades (11–19 years) performed the YBT-LQ twice, 7 days apart. Normalized maximal reach distances (% leg length) for all three directions (i.e., anterior, posterolateral, posteromedial) and both legs and the composite score were used as outcome measures. Intraclass correlation coefficient (ICC_{3,1}) and standard error of measurement (SEM) were calculated to assess relative and absolute test-retest reliability, respectively. Practical relevance of the YBT-LQ was determined by calculating the minimal detectable change (MDC_{95%}).

Results: Irrespective of grade, test-retest reliability for all distances reached was predominately "excellent" (i.e., ICC_{3,1} > 0.75) and the rather small SEM values ranged from 1.77 to 5.81%. Depending on grade and reach direction, MDC values of 4.90 to 16.10% represent the minimum amount of change needed to identify clinically relevant effects in repeated measurements of the YBT-LQ performance.

Conclusions: The observed values suggest that the YBT-LQ is a reliable test and suitable to detect changes of dynamic balance performance in healthy adolescents from grade six to eleven (i.e., aged 11–19 years).

1. Introduction

In everyday life as well as in sports-related activities, dynamic balance performance (i.e., the ability to maintain postural stability while the body parts are in motion) represents an important determinant to safely manage weekday activities and to specify the risk of sustaining lower limb injuries in youth [1]. Therefore, dynamic balance tests are frequently applied to investigate age- and training-related adaptations in balance during childhood and adolescence [2,3]. A well-established field-based method to investigate dynamic balance performance is the Lower Quarter Y Balance Test (YBT-LQ) [4]. During the YBT-LQ, participants maintain one-legged stance while reaching as far as possible with the contralateral leg in anterior (AT), posteromedial (PM), and posterolateral (PL) directions. Subsequently, dynamic balance performance can be determined by calculating the maximal reach distance in relation to the subject's leg length.

Previous studies [5–7] on the test-retest reliability of the YBT-LQ mainly investigated young adults. However, only a few studies exist that examined this issue in youth. Specifically, Faigenbaum et al. [8] examined test-retest reliability of the YBT-LQ in 188 children (6.9 to 12.1 years) in first through fifth grades and found intraclass correlation coefficients (ICC) ranging between "poor" and "excellent" (i.e., 0.38–0.80); irrespective of reach direction. Further, Calatayud et al. [9] determined test-retest reliability in 24 children aged 11.0 ± 0.8 years. ICC values ranged from "moderate-to-good" to "excellent" (i.e., 0.51–0.93) for all three-reach directions. Lastly, Linek et al. [10] investigated test-retest reliability in 38 male adolescent soccer players aged 14–17 years. Irrespective of the reach direction considered, findings yielded ICC values ranging between "moderate-to-good" and "excellent" (i.e., 0.57–0.82). Translating these findings in children and physically trained youth athletes to a common cohort of adolescents appears to be disputable, given that development of dynamic balance

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significantly differs between children and adolescents as well as trained and untrained youth. In this regard, several studies [11–14] indicated that adolescents and trained youth show better dynamic balance performance compared to children and untrained peers, respectively.

To the best of our knowledge, there is no study available that investigated the reproducibility of the YBT-LQ in healthy adolescents including males and females from several age cohorts. Therefore, the purpose of the present study was to determine test-retest reliability of the YBT-LQ in healthy adolescents from grade six to eleven (i.e., aged 11–19 years). With reference to the relevant literature [8–10], we expected that the YBT-LQ would be a reproducible test for the assessment of dynamic balance in this population.

2. Methods

2.1. Subjects

Participants were a sample of 178 adolescents attending an urban public school. Healthy adolescents (93 female, 85 male) in grades six ($n = 13$; 11.6 ± 0.5 years), seven ($n = 15$; 12.4 ± 0.5 years), eight ($n = 41$; 13.3 ± 0.6 years), nine ($n = 48$; 14.6 ± 0.7 years), ten ($n = 34$; 15.6 ± 0.8 years), and eleven ($n = 27$; 16.8 ± 0.7 years) volunteered to participate after experimental procedures were explained (Table 1). No subjects had prior experience performing the YBT-LQ. Students were excluded from participation if they had (1) a musculoskeletal, neurological or orthopedic disorder or (2) other medical conditions that could have affected their ability to execute the YBT-LQ. Participants' assent and parents' written informed consent was obtained prior to the start of the study. The Human Ethics Committee at the University of Duisburg-Essen, Faculty of Educational Sciences approved the study protocol.

2.2. Procedures

All participants performed the YBT-LQ twice, separated by seven days during the physical education class in the school setting. Upon entering the testing room, all participants received standardized verbal instructions and a visual demonstration regarding the testing procedure that included the measurement of anthropometric variables followed by performance assessment in the YBT-LQ.

2.2.1. Anthropometry

Body height was determined without shoes to the nearest 0.5 cm with a stadiometer (seca 217, Basel, Switzerland). Further, body mass was measured in light clothing and without shoes to the nearest 100 g with an electronic scale (seca 803, Basel, Switzerland). Body mass index

was calculated using body mass divided by height squared (kg/m^2). Length of the left and right leg was determined by measuring the distance from the anterior superior iliac spine to the most distal aspect of the medial malleolus with the participant lying supine [6].

2.2.2. Lower Quarter Y Balance Test

YBT-LQ performance was assessed using the commercially available Y Balance Test Kit (Functional Movement Systems, Chatham, USA) that was positioned on the floor. The Y Balance Test Kit consists of a centralized stance platform to which three pipes are attached that represent the AT, PM, and PL reach directions. Each pipe is marked in 0.5-cm increments for measurement purposes and equipped with a moveable reach indicator. Each participant was instructed to reach with one leg as far as possible while maintaining his/her balance in the AT, PM, and PL directions while standing without shoes on the stance platform. The YBT-LQ was performed with the left and right leg. Each participant was instructed to perform three practice trials followed by three data-collection trials. Following the recommendations by Plisky et al. [6], participants started with the right leg placed behind the red starting line of the stance platform and the left leg touching and moving the reach indicator with the most distal part of the foot. Afterwards, the participants returned to a bipedal stance position. The specific testing orders were as follows: 1) right leg stance and reaching with the left leg in the AT direction, 2) left leg stance and reaching with the right leg in the AT direction, 3) right leg stance and reaching with the left leg in the PM direction, 4) left leg stance and reaching with the right leg in the PM direction, 5) right leg stance and reaching with the left leg in the PL direction, and 6) left leg stance and reaching with the right leg in the PL direction. An examiner documented the distance (i.e., from the center of the stance platform to the maximal reach indicator distance) after each reach to the nearest 0.5 cm. Trials were discarded and repeated until a total of three valid trials were achieved if the participants: a) lost their balance (i.e., stepped with the reach leg on the ground) at any point during the trial, b) lifted the stance leg from the stance platform, c) stepped on top of the reach indicator for support, or d) kicked the reach indicator. All examiners had experience administering the YBT-LQ protocol. The normalized maximal reach distance per reach direction and leg was calculated as follows and used as an outcome measure (Eq. (1)):

$$\text{normalized maximal reach distance (\% leg length [LL])} = (\text{absolute maximal reach distance [cm]} / \text{LL [cm]}) \times 100. \quad (1)$$

Further, the normalized composite score ([CS] i.e., sum of the three maximal reach distances per reach direction) per leg was calculated by using the following formula provided by Filipa et al. [3] and additionally used as outcome measure (Eq. (2)):

Table 1
Characteristics of the study participants by grade.

Grade	Age (yrs)	Sex (f/m)	Height (cm)	Mass (kg)	BMI (kg/m^2)	Length (cm)	
						Left leg	Right leg
6 th ($n = 13$)	11.6 ± 0.5	7/6	151.6 ± 11.0	42.7 ± 6.6	17.8 ± 5.9	81.2 ± 5.5	81.6 ± 5.0
7 th ($n = 15$)	12.4 ± 0.5	8/7	159.1 ± 8.0	62.1 ± 16.2	24.4 ± 5.5	87.1 ± 6.3	87.1 ± 6.1
8 th ($n = 41$)	13.3 ± 0.6	18/23	167.2 ± 9.1	55.5 ± 10.8	19.8 ± 2.8	89.9 ± 6.1	90.3 ± 6.1
9 th ($n = 48$)	14.6 ± 0.7	20/28	174.3 ± 9.4	61.3 ± 12.3	20.0 ± 2.8	95.6 ± 5.8	95.0 ± 5.5
10 th ($n = 34$)	15.6 ± 0.8	20/14	172.7 ± 9.8	58.7 ± 7.7	19.9 ± 2.2	92.2 ± 6.3	92.0 ± 6.6
11 th ($n = 27$)	16.8 ± 0.7	20/7	175.6 ± 7.5	64.3 ± 9.1	21.0 ± 2.1	92.4 ± 5.7	92.8 ± 5.5

Values are mean values \pm standard deviations. BMI = body mass index; f = female; m = male.

$$CS (\% LL) = ((AT + PM + PL) / (LL \times 3)) \times 100. \tag{2}$$

2.3. Statistical analyses

Group mean values \pm standard deviations (SD) were calculated for the maximum distance reached in each direction for both legs. Relative reliability (i.e., the degree to which individuals maintain their position in a sample with repeated measurements) was determined using the ICC_{3,1} and the 95% confidence interval (CI) [15]. Using the classification of Fleiss [16], ICC > 0.75 was considered "excellent", 0.40 < ICC < 0.75 was considered "moderate-to-good", and ICC < 0.40 was considered "poor". The absolute reliability of the data (i.e., the degree to which repeated measurements vary for individuals) was assessed using the standard error of measurement (SEM) that estimates the amount of error related with the measurement [15]. The formula for the calculation is (Eq. (3)):

$$SEM = \text{pooled } SD * \sqrt{(1-ICC)} \tag{3}$$

The lower the SEM value, the more reliable the measurement. Further, practical significance of the YBT-LQ was determined by calculating the minimal detectable change (MDC_{95%}), which is needed to identify clinically relevant effects between repeated measurements of one subject [15,17]. In other words, the MDC_{95%} provides information about the minimal threshold of a measurement to ensure that differences between test and retest measurements were real and outside the error range. The corresponding formula is as follows (Eq. (4)):

$$MDC_{95\%} = SEM * 1.96 * \sqrt{2} \tag{4}$$

Analyses were carried out using Statistical Package for Social Sciences (SPSS) version 24.0 (SPSS Inc., Chicago, IL).

3. Results

Means and SDs for the normalized (% LL) YBT-LQ performance by grade are presented in Table 2. Irrespective of grade, ICC_{3,1} values for the three reach directions ranged between 0.40 and 0.96 (Table 3), which is indicative of "moderate-to-good" to "excellent" test-retest reliability. Moreover, the highest ICC values (0.83 to 0.96) were detected for the CS in both legs. In addition, the SEM values ranged from 2.11% to 4.93% for grade 6, from 1.79% to 5.52% for grade 7, from 2.84% to 4.98% for grade 8, from 2.92% to 5.81% for grade 9, from 2.55% to 4.53% for grade 10, and from 1.77% to 4.20% for grade 11 (Table 3). Further, the MDC_{95%} values ranged from 5.86% to 13.66% for grade 6, from 4.95% to 15.30% for grade 7, from 7.87% to 13.80% for grade 8, from 8.11% to 16.10% for grade 9, from 7.07% to 12.55% for grade 10, and from 4.90% to 11.64% for grade 11 (Table 4).

4. Discussion

The present study investigated test-retest reliability of the YBT-LQ in a sample of 178 healthy female and male adolescents from grade six to eleven. In this regard, we compared YBT-LQ performance for all three directions and both legs on two occasions in a field-based school setting. In accordance with our hypothesis, that the YBT-LQ would be a reliable test to assess dynamic balance in school-aged youth, we found "moderate-to-good" to "excellent" ICC values (i.e., 0.40 to 0.96) and rather smaller SEM values ranging between 1.77 and 5.81%. Further MDC_{95%} values, which represent the change needed to identify clinically relevant effects between repeated measures ranged from 4.90 to 16.10%.

In terms of relative and absolute test-retest reliability, our findings are in line with the literature [8–10]. In a previous study, Linek et al. [10] investigated semi-professional adolescent soccer players and reported ICC values between 0.57 and 0.82 for the three reach directions indicating "moderate-to-good" to "excellent" reliability. The

Table 2 Lower Quarter Y Balance Test (YBT-LQ) performance data for the test and retest assessment by grade.

	6 th		7 th		8 th		9 th		10 th		11 th	
	Test	Retest	Test	Retest	Test	Retest	Test	Retest	Test	Retest	Test	Retest
Left leg stance												
AT (% LL)	75.4 ± 6.2	73.9 ± 9.1	70.1 ± 6.2	73.5 ± 11.8	74.4 ± 9.3	73.5 ± 11.8	72.6 ± 9.1	72.8 ± 7.7	76.1 ± 10.2	75.3 ± 8.4	72.8 ± 7.0	72.7 ± 7.5
PM (% LL)	107.4 ± 18.0	106.1 ± 16.1	99.9 ± 10.5	108.5 ± 10.8	108.3 ± 13.1	108.5 ± 10.8	109.2 ± 11.9	112.4 ± 12.4	114.0 ± 13.5	114.9 ± 12.5	111.0 ± 10.8	112.8 ± 8.6
PL (% LL)	107.7 ± 16.2	108.6 ± 17.0	101.2 ± 11.3	103.6 ± 12.3	104.2 ± 13.1	103.0 ± 13.2	104.7 ± 11.5	108.1 ± 12.6	108.8 ± 12.3	108.9 ± 10.3	109.4 ± 10.3	109.9 ± 7.9
CS (% LL)	96.8 ± 12.7	96.2 ± 13.1	90.4 ± 8.6	91.7 ± 9.5	95.6 ± 10.6	95.1 ± 10.4	95.5 ± 9.5	97.8 ± 9.8	99.6 ± 10.6	99.7 ± 8.5	97.7 ± 8.1	98.8 ± 7.1
Right leg stance												
AT (% LL)	74.2 ± 5.1	70.7 ± 7.9	69.1 ± 6.4	71.9 ± 12.4	72.9 ± 10.1	71.9 ± 12.4	70.5 ± 6.6	71.9 ± 6.3	74.5 ± 6.6	73.9 ± 8.6	71.9 ± 5.6	72.3 ± 6.4
PM (% LL)	104.1 ± 12.5	102.8 ± 15.5	99.4 ± 10.9	107.5 ± 11.0	107.7 ± 13.7	107.5 ± 11.0	108.0 ± 10.2	112.3 ± 12.2	112.1 ± 14.3	112.6 ± 12.7	111.1 ± 10.3	112.8 ± 8.6
PL (% LL)	106.7 ± 15.9	104.8 ± 15.6	96.8 ± 10.5	103.6 ± 10.3	103.5 ± 13.0	103.6 ± 10.3	103.0 ± 13.0	108.5 ± 13.6	110.6 ± 13.3	110.9 ± 14.6	106.8 ± 10.2	108.0 ± 7.8
CS (% LL)	95.0 ± 10.7	92.8 ± 12.0	88.4 ± 7.6	94.3 ± 9.8	94.7 ± 11.1	94.3 ± 9.8	93.8 ± 8.8	97.6 ± 9.6	99.1 ± 10.1	99.1 ± 10.5	96.6 ± 7.5	97.7 ± 6.5

Values are mean values \pm standard deviations. AT = anterior; CS = composite score; LL = leg length; PL = posterolateral; PM = posteromedial.

Table 3
Intraclass correlation coefficient with 95% confidence interval and standard error of measurement by grade.

	6 th			7 th			8 th			9 th			10 th			11 th		
	ICC _{3,1} (95% CI)	SEM (%)	ICC _{3,1} (95% CI)	SEM (%)	ICC _{3,1} (95% CI)	SEM (%)	ICC _{3,1} (95% CI)	SEM (%)	ICC _{3,1} (95% CI)	SEM (%)	ICC _{3,1} (95% CI)	SEM (%)	ICC _{3,1} (95% CI)	SEM (%)	ICC _{3,1} (95% CI)	SEM (%)		
Left leg stance																		
AT (% LL)	0.78 (0.27-0.93)	3.62	0.90 (0.71-0.97)	2.24	0.88 (0.77-0.93)	3.72	0.74 (0.54-0.86)	4.26	0.76 (0.52-0.88)	4.53	0.92 (0.82-0.96)	2.04	0.92 (0.82-0.96)	4.53	0.92 (0.82-0.96)	2.04		
PM (% LL)	0.93 (0.78-0.98)	4.33	0.96 (0.87-0.99)	2.21	0.87 (-0.76-0.93)	4.31	0.86 (0.74-0.92)	4.63	0.93 (0.87-0.97)	3.34	0.86 (0.68-0.93)	3.69	0.86 (0.68-0.93)	3.34	0.86 (0.68-0.93)	3.69		
PL (% LL)	0.96 (0.87-0.99)	3.21	0.95 (0.84-0.98)	2.71	0.87 (0.75-0.93)	4.81	0.89 (0.80-0.94)	4.05	0.92 (0.83-0.96)	3.26	0.83 (0.63-0.92)	3.73	0.83 (0.63-0.92)	3.26	0.83 (0.63-0.92)	3.73		
CS (% LL)	0.97 (0.91-0.99)	2.11	0.96 (0.88-0.99)	1.79	0.93 (0.86-0.96)	2.84	0.91 (0.84-0.95)	2.92	0.92 (0.85-0.96)	2.63	0.95 (0.88-0.98)	1.77	0.95 (0.88-0.98)	2.63	0.95 (0.88-0.98)	1.77		
Right leg stance																		
AT (% LL)	0.79 (0.31-0.94)	3.10	0.40 (-0.80-0.80)	4.93	0.84 (0.71-0.92)	4.46	0.69 (0.45-0.83)	3.62	0.83 (0.66-0.92)	3.14	0.71 (0.36-0.87)	3.22	0.71 (0.36-0.87)	3.14	0.71 (0.36-0.87)	3.22		
PM (% LL)	0.87 (0.59-0.96)	4.93	0.69 (0.82-0.90)	5.52	0.89 (0.80-0.94)	4.04	0.74 (0.53-0.85)	5.81	0.91 (0.83-0.96)	3.96	0.93 (0.84-0.97)	2.52	0.93 (0.84-0.97)	3.96	0.93 (0.84-0.97)	2.52		
PL (% LL)	0.93 (0.77-0.98)	4.15	0.92 (0.76-0.97)	3.19	0.82 (0.66-0.90)	4.98	0.83 (0.70-0.91)	5.52	0.94 (0.88-0.97)	3.33	0.78 (0.53-0.90)	4.20	0.78 (0.53-0.90)	3.33	0.78 (0.53-0.90)	4.20		
CS (% LL)	0.94 (0.81-0.98)	2.69	0.83 (0.50-0.94)	3.15	0.92 (0.85-0.96)	2.97	0.83(0.69-0.90)	3.92	0.94 (0.88-0.97)	2.55	0.89 (0.76-0.95)	2.30	0.89 (0.76-0.95)	2.55	0.89 (0.76-0.95)	2.30		

AT = anterior; CI = confidence interval; CS = composite score; ICC_{3,1} = intraclass correlation coefficient; LL = leg length; PL = posterolateral; PM = posteromedial; SEM = standard error of measurement.

Table 4
Minimal detectable change (MDC_{95%}) by grade.

	6 th	7 th	8 th	9 th	10 th	11 th
Left leg stance						
AT (% LL)	10.02	6.22	10.31	11.80	12.55	5.65
PM (% LL)	12.01	6.14	11.95	12.82	9.27	10.24
PL (% LL)	8.91	7.52	13.34	11.24	9.02	10.33
CS (% L)	5.86	4.95	7.87	8.11	7.29	4.90
Right leg stance						
AT (% LL)	8.59	13.67	12.35	10.03	8.72	8.92
PM (% LL)	13.66	15.30	11.20	16.10	10.98	6.97
PL (% LL)	11.50	8.85	13.80	15.29	9.24	11.64
CS (% LL)	7.46	8.72	8.22	10.86	7.07	6.38

AT = anterior; CS = composite score; LL = leg length; PL = posterolateral; PM = posteromedial.

corresponding SEM values ranged from 3.30 to 5.90%. Further, Calatayud et al. [9] studied primary school children and observed ICC values for the three reach directions ranging from 0.51 to 0.93 that are indicative of "moderate-to-good" to "excellent" reliability. The additionally reported SEM values ranged from 3.03 to 12.32%. Lastly, Faigenbaum et al. [8] detected ICC values for the three reach directions in children that ranged from "poor" to "excellent" (i.e., 0.38 to 0.80). Our findings and the results of the aforementioned studies imply that the YBT-LQ is a reproducible test for the assessment of dynamic balance performance, especially in adolescents. Of note, we detected the largest ICC / lowest SEM values for the CS in both legs. This finding is most likely based on the higher number of data points compared to the measurements of each leg individually. In order to calculate the CS, three (i.e., AT, PM, PL) instead of only one reach direction were used for calculations. Thus, practitioners are advised to use the CS to evaluate dynamic balance performance in healthy adolescents because this parameter showed the most reliable results.

The minimal amount of change score outside of measurement error that may reflect true change (MDC_{95%}) ranged between 4.90 and 16.10%. Compared to other studies, our values are close to those (7.68 to 13.70%) reported by Linek et al. [10] and better than those (8.4 to 34.2%) stated by Calatayud et al. [9]. The differences between our values and those of Linek et al. [10] compared to Calatayud et al. [9] might be based on the investigated cohort. Our study as well as the study by Linek and colleagues [10] used adolescents while Calatayud and colleagues [9] investigated children. The latter might show worse capabilities to reliably perform the YBT-LQ compared to adolescents. From a practical perspective, our obtained MDC_{95%} values ranging from 4.90 to 16.10% suggest that this is the minimum amount of change needed to exist between pre- and post-testing YBT-LQ performance scores for a change to be practically significant. In this regard, several studies [3,18,19] showed training-related changes that were in this range. For example, Muehlbauer et al. [18] investigated the impact of four weeks of inline skating exercise on YBT-LQ performance in healthy students aged 11 to 12 years. The authors reported significant improvements of 17 to 48% for the intervention compared to the control group.

5. Conclusions

Our findings of predominately "excellent" ICC scores (relative reliability), and rather low SEM values (absolute reliability), indicate that the YBT-LQ is a reproducible test for the assessment of dynamic balance in healthy female and male adolescents from grade 6 to 11. The obtained MDC_{95%} values ranging from 4.90 to 16.10% represent the minimal threshold that is needed to detect clinically relevant effects between repeated measurements of the YBT-LQ performance.

Conflict of interest

None of the authors has any conflicts of interest.

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