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ORIGINAL ARTICLE

Lower and upper quarter y-balance test in recreationally active healthy adults: test-retest reliability, gender differences and inter-limb asymmetries

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Abstract

Y-balance test for lower limbs (LQYBT) and upper limbs (UQYBT) are frequently used to assess dynamic single-leg balance. In this study, we aimed to examine the test-retest reliability of both tests, to compare scores on the dominant and nondominant sides and report on the magnitude of asymmetry, as well as assess any gender differences. A sample of 30 healthy, recreationally active individuals (15 men and 15 women; age, 22.83 ± 8.78 years; height, 175.46 ± 8.29 cm; body mass 72.08 kg ± 12.60 kg) completed the LQYBT und UQYBT measurements twice 12 to 14 days. Reliability was assessed using the intraclass correlation coefficient (ICC) (absolute agreement, two-way random), paired-samples t-test, and typical error (expressed as coefficient of variation, CV). Both tests showed moderate to good relative reliability (ICC = 0.62 – 0.85) and acceptable absolute reliability (CV = 3.54 – 7.20 %), with a possible learning effect for certain reach directions. Men tended to score better than women, but statistically significant differences were confirmed in only 3 of 12 comparisons. Differences between dominant and non-dominant sides were mostly very small and statistically significant in only 2 of 6 comparisons. Mean asymmetry scores were in the range of ~3-6%. These results contribute to the evidence on the utility of LQYBT and UQYBT testing in healthy adults.

Keywords: balance test · postural control · sport injury · testing methods

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Introduction

Testing motor abilities is one of the essential tasks for professionals in sports and health sciences and contributes to successful work with athletes and the general population. Balance is one of the most important motor abilities and has been associated with athletic performance and injury risk (Hrysomallis, 2007, 2011). In the elderly, balance and postural control are related to risk of falls (Melzer et al., 2010) and quality of life (Dunsky, 2019). Static balance is usually defined as the ability to the body's center of mass withing the base of support with minimal movement, whereas dynamic balance refers to the ability to perform a task while maintaining a stable position (Bressel et al., 2007; Winter et al., 1990). In an unpredictable sport environment, the ability to maintain a stable position is critical not only for successful skill execution, but also for reducing the risk of injury (Butler et al., 2013; Plisky et al., 2006; Zazulak et al., 2008). There is a wide range of methods and tests for assessing balance, ranging from more complex laboratory measurements of center of pressure or center of mass movement to simple field tests that can be performed without specialized equipment.

The Y-Balance Test (YBT) is a slightly modified version of the Star Excursion Balance Test developed to improve practicality and commercial accessibility (Chimera et al., 2015; Plisky et al., 2021). It is used to assess injury risk and can be used for both upper and lower extremities. The Lower Quarter Y-Balance Test (LQYBT) has been thoroughly researched, and its protocol is based on studies conducted with the SEBT. In the YBT, a single-leg reach is performed in the anterior, posterolateral, and posteromedial directions while keeping the other leg at the starting position. The maximum distance achieved in each direction is measured in centimeters. Although commercial test kits are available, the test can also be performed with only three measuring tapes. Its simplicity and affordability are among its greatest advantages compared to some laboratory procedures, such as instrumented posturography (Kattilakoski et al., 2023).

Less is known about the upper quarter version of the Y-balance test (UQYBT). It is known that the test is repeatable at a single visit (Gorman et al., 2012) and is valid and reliable in healthy adolescents (Xu et al., 2023). However, less is known about reliability in the general adult population, and further research is needed to determine whether LQYBT and UQYBT have similar reliability. In addition, there does not appear to be a difference between genders for the UQYBT (Gorman et al., 2012), but this contradicts the results for the lower extremity version (Plisky et al., 2021). Therefore, further research is needed regarding possible gender differences. Westrick et al., (2012) reported that there is no difference in symmetry between the dominant and non-dominant limb in UQYBT. This means that the performance of the non-injured limb can serve as a meaningful reference measure when testing the injured limb, regardless of limb dominance, allowing independent evaluation of each upper limb. In the context of injury, Edwards et al., (2022) used the UQYBT to tracked the return to sport after shoulder surgery. However, it is important to note that the magnitude of asymmetry can vary significantly between different measurement tasks and the desired percentage of asymmetry cannot be generalized across different, albeit related, tests (Bishop et al., 2021). In addition to further investigation of the reliability of the UQYBT through future research, it is also worthwhile to investigate the magnitudes of asymmetry in the uninjured population, as understanding normal values is essential for interpreting results in injured individuals.

The aim of this study was to contribute to the knowledge on the usefulness of the LQYBT and, in particular, the UQYBT in the general population. Specifically, we aimed to a) examine the test-retest reliability of both tests, b) compare scores on the dominant and nondominant sides and report on the magnitude of asymmetry in the uninjured population, and c) assess any gender differences. By addressing these research objectives, we can gain a better understanding of the practical application of the LQYBT and UQYBT and their potential for assessing upper extremity function. In addition, this study will contribute to the existing body of knowledge on balance assessment and provide insight into the potential differences between upper and lower extremity Y-balance tests.

Method

Participants

We enrolled 30 healthy, recreationally active individuals (15 men and 15 women; age, 22.83 ± 8.78 years; height, 175.46 ± 8.29 cm; body mass 72.08 kg ± 12.60 kg). Individuals who reported lower limb musculoskeletal injuries in the past 6 months, low back pain, neurological disorders, or other conditions that could negatively affect their health were excluded from the study. Before the measurements, participants were informed of the details of the protocol and signed an informed consent form to participate in the study. Participants were asked not to engage in resistance exercise 48 hours before the measurement and to maintain their usual dietary habits. The study procedures were approved by the National Medical Ethics Committee of the Republic of Slovenia (approval number: 0120-690/2017/8).

Study design

We used a combination of cross-sectional (objectives b-c) and test-retest (objective a) study designs. Measurements were taken in one session lasting ~40 minutes, and participants repeated measurements at the same time of day with an interval of 12 to 14 days between visits. The measurements were done around noon or in the afternoon. Of the 30 participants, 21 participated in the second measurement (10 men and 11 women). Participants performed a standard warm-up workout consisting of 10 minutes of light aerobic activity, 5 minutes of dynamic stretching, 2 sets of 10 squats, 3 sets of 5 push-ups, and 10 jumps with countermovement.

Procedures

After the warm-up, participants performed LQYBT and UQYBT in random order, with practice measurements before each version (6 and 3 trials for the lower and upper limb versions, respectively). In each version, they performed reaches in all three directions sequentially (without rest). Each set was followed by a one-minute rest, and the test was repeated with the other arm/leg, with a 2-minute rest between each. A 5-minute rest was taken between the two versions of the test. The results were analyzed as percentage of the length of the arm or leg (normalized value [cm] = (baseline value [cm] × 100%)/length of arm/leg [cm]). The length of the arm for normalization was measured from the C7 vertebra to the longest finger of the hand, with the shoulder at a 90° angle (Gorman et al., 2012). The length of the leg for normalization was measured from the superior iliac spine to the tip of the toe. These measurements were performed prior to warm-up with a tape measure. Inter-limb asymmetries between the left and right legs were calculated as the difference between the sides, divided by the mean value and multiplied by 100 %.

We used a standardized instrument specifically designed to perform the Y test and followed procedures consistent with previous studies (Gorman et al., 2012). In the upper limb version, the participant was positioned perpendicular to the instrument and performed reaches in the medial, superolateral, and inferolateral directions. The feet were no more than 20 cm apart. In the lower limb version, the hands were extended anteriorly, posteromedially, and posterolaterally.

Statistical analysis

Descriptive statistics are reported as mean and standard deviation. Normality of data distribution was tested using the Shapiro-Wilk test. Reliability was assessed using the intraclass correlation coefficient (ICC) (absolute agreement, two-way random), paired-samples t test, and typical error (expressed as coefficient of variation, CV). Relative reliability according to ICC was interpreted as > 0.9 (excellent), 0.9-0.75 (good), 0.75- 0.50 (moderate), and < 0.5 (poor) (Koo & Li, 2016) and CV < 10% was considered to indicate acceptable absolute reliability. The comparison between genders is performed with independent samples t-test, and the comparison between sides is performed with paired t-tests. Effect size is expressed with Cohen's d, which is interpreted as negligible (< 0.2), small (0.2-0.5), medium (0.5-0.8), and high (> 0.8). Asymmetry scores are compared for all tests and directions using repeated-measures analysis of variance and Bonferroni-corrected post-hoc t tests. Statistically significant effects and associations are accepted at $\alpha < 0.05$.

Results

Reliability

Table 2 shows contains the test-retest reliability of the measurements between visits. Relative repeatability was good for all directions regardless of body side for the LQYBT (ICC = 0.76 75 to 0.85). For the UQYBT, reliability was moderate to good; it was slightly worse, especially for the medial reach on the nondominant hand (ICC = 0.62). Absolute repeatability was acceptable for all directions on both legs (CV = 3.54 to 5.91%) and both arms (CV = 4.85 to 7.20%). For the LQYBT, a statistically significant systematic error was present for reaching in the posteromedial direction on both legs (p = 0.009 and 0.022), and on the nondominant leg also for reaching posteromedially posterolaterally (p = 0.004). On the UQYBT, a statistically significant systematic error was present when reaching superolaterally on the non-dominant arm (p = 0.019). In all cases, reach increased on the second visit compared to the first.

Table 1. Descriptive statistics

Limb / Test	Direction	Mean±SD	MIN/MAX
	Anterior	64.4±7.3	49.4/78.0
Lower quarter y-balance test – non-dominant	Posterolateral	103.9±9.7	80.0/123.2
	Posteromedial	99.6±11.5	72.7/120.7
	Anterior	63.0±7.1	50.5/76.5
Lower quarter y-balance test – dominant	Posterolateral	104.6±11.1	75.2/125.5
	Posteromedial	104.1±12.2	77.7/143.3
	Medial	96.5±9.3	73.7/117.8
Upper quarter y-balance test – non-dominant	Superolateral	76.0±9.5	53.4/92.0
	Inferolateral	92.9±13.2	72.3/127.8
	Medial	97.4±9.3	74.6/119.0
Upper quarter y-balance test – dominant	Superolateral	77.5±8.8	55.2/98.5
	Inferolateral	93.4±11.4	74.7/126.7

Table 2. Reliability of the measurements

Limb / Test	Direction	Visit 1	Visit 2	Relative reliability		
		Mean±SD	Mean±SD	ICC	95% CI	
	Anterior	64.4±7.3	65.3±8.1	0.76	0.50	0.89
Lower quarter y-balance test – non-dominant	Posterolateral	103.9±9.7	108.8±8.5	0.85	0.66	0.93
	Posteromedial	99.8±11.6	105.9±7.6	0.75	0.47	0.88
	Anterior	63.0±7.1	65.3±8.1	0.79	0.55	0.90
Lower quarter y-balance test – dominant	Posterolateral	104.6±11.1	108.8±8.5	0.80	0.58	0.91
	Posteromedial	102.7±9.9	106.3±8.1	0.83	0.62	0.92
	Medial	95.8±8.5	97.3±6.0	0.62	0.25	0.82
Upper quarter y-balance test – non-dominant	Superolateral	76.0±9.5	81.7±11.7	0.78	0.54	0.90
	Inferolateral	92.9±13.2	96.5±12.9	0.74	0.47	0.88
	Medial	97.0±9.1	98.1±9.5	0.75	0.48	0.88
Upper quarter y-balance test – dominant	Superolateral	77.5±8.8	81.9±11.6	0.74	0.46	0.87
	Inferolateral	93.4±11.4	95.7±14.9	0.78	0.54	0.90

Table 2. Reliability of the measurements (continued)

Limb / Test	Direction	Absolute reliability			Systematic error	
		CV	95% CI		Difference	p
	Anterior	5.91	4.52	8.53	0.85	0.852
Lower quarter y-balance test – non-dominant	Posterolateral	3.54	2.71	5.11	4.83	0.004
	Posteromedial	5.15	3.92	7.52	6.07	0.009
	Anterior	5.54	4.24	8.00	2.30	0.097
Lower quarter y-balance test – dominant	Posterolateral	4.35	3.33	6.28	4.19	0.022
	Posteromedial	3.77	2.87	5.51	3.57	0.390
	Medial	4.95	3.76	7.23	1.53	0.694
Upper quarter y-balance test – non-dominant	Superolateral	6.38	4.88	9.22	5.76	0.019
	Inferolateral	7.20	5.51	10.40	3.61	0.148
	Medial	4.85	3.69	7.08	1.08	0.671
Upper quarter y-balance test – dominant	Superolateral	6.64	5.08	9.59	4.40	0.150
	Inferolateral	6.58	5.03	9.50	2.38	0.227

Gender

Table 3 shows the analysis of differences between men and women. Statistically significant differences with a high effect size occurred for posterolateral reach for both legs ($p = 0.004$ and 0.006; $d = 1.17$ and 1.11). There were also differences in medial reach in the UQYBT, but only for the nondominant hand ($p = 0.023$; $d = 0.89$). In all cases, males had higher scores than females.

Table 3. Gender differences

Limb / Test	Direction	Men	Women	t-test		
		Mean±SD	Mean±SD	Diff.	p	d
Lower quarter y-balance test – non-dominant	Anterior	63.7±8.0	65.1±6.7	-1.4	0.601	0.19
	Posterolateral	108.9±8.0	99.0±8.9	9.9	0.004	1.17
	Posteromedial	103.6±9.8	95.6±12.0	8.0	0.054	0.74
Lower quarter y-balance test – dominant	Anterior	62.7±8.0	63.2±6.2	-0.6	0.833	0.08
	Posterolateral	109.9±8.1	99.2±11.3	10.7	0.006	1.11
	Posteromedial	107.7±7.2	100.4±15.2	7.4	0.100	0.66
Upper quarter y-balance test – non-dominant	Medial	100.3±7.5	92.7±9.6	7.6	0.023	0.89
	Superolateral	76.3±8.5	75.6±10.6	0.7	0.854	0.07
	Inferolateral	94.2±16.1	91.6±10.0	2.6	0.593	0.20
Upper quarter y-balance test – dominant	Medial	100.5±8.2	94.4±9.5	6.1	0.069	0.69
	Superolateral	78.5±7.6	76.6±10.0	2.0	0.553	0.22
	Inferolateral	94.8±12.9	91.9±9.9	2.9	0.489	0.26

Side comparisons and asymmetries

Table 4 shows the analysis of the differences between the nondominant and dominant limb. In LQYBT, the anterior reach was statistically significantly better on the nondominant side ($p = 0.003$), but the difference was very small ($d = 0.20$). Posteromedial reach was statistically significantly better on the dominant leg ($p = 0.009$), with an equally small effect size ($d = 0.31$). For UQYBT, there were no statistically significant differences between the dominant and non-dominant sides ($p \geq 0.147$).

Table 4. Side differences

Test	Direction	Non-dominant	Dominant	t-test		
		Mean±SD	Mean±SD	Diff.	p	d
Lower quarter y-balance test	Anterior	64.4±7.3	63.0±7.1	1.45	0.003	0.20
	Posterolateral	103.9±9.7	104.6±11.1	-0.64	0.455	0.06
	Posteromedial	99.6±11.5	102.9±9.8	-3.32	0.009	0.31
Upper quarter y-balance test	Medial	96.5±9.3	97.4±9.3	-0.92	0.245	0.10
	Superolateral	76.0±9.5	77.5±8.8	-1.59	0.147	0.17
	Inferolateral	92.9±13.2	93.4±11.4	-0.46	0.677	0.04

Table 5. Mean asymmetry scores

Test	Direction	Mean±SD	MIN/MAX	Within test F	Within test p	Overall F	Overall p
Lower quarter y-balance test	Anterior	3.68±2.37	0.30/9.76	4.31	0.018	3.02	0.013
	Posterolateral	3.37±2.93	0.16/10.79				
	Posteromedial	6.35±6.37	0.61/26.32				
Upper quarter y-balance test	Medial	3.02±3.17	0.20/11.43	3.73	0.018		
	Superolateral	5.86±5.58	0.23/17.69				
	Inferolateral	5.02±4.21	0.41/19.82				

Table 5 shows the values of inter-limb asymmetries (mean and range). Analysis of variance for repeated measures (all 6 tests included) showed that the magnitude of asymmetries differed between test directions (F = 3.02; p = 0.013). Post-hoc tests showed no difference between tests, which is more likely due to the large number of comparisons (effect of Bonferroni correction). A repeated-measures analysis of variance performed only for the LQYBT tests also showed statistically significant differences in the magnitude of the asymmetries (F = 4.31; p = 0.018), with post-hoc tests again failing to reach significance, but according to descriptive statistics showing greater asymmetry in the posteromedial direction compared to the other two directions. Similarly, a repeated-measures analysis of variance performed for the UQYBT tests only revealed statistically significant differences in the magnitude of the asymmetries (F = 3.73; p = 0.018), with post-hoc tests also failing to reach significance, but according to descriptive statistics showing less asymmetry in the medial direction compared to the other two directions (Table 5).

Discussion

This study examined test-retest reliability, gender differences, and asymmetries in LQYBT and UQYBT tests. Both tests showed moderate to good relative reliability and acceptable absolute reliability, with a possible learning effect for certain reach directions. Men tended to score better than women, but statistically significant differences were confirmed in only 3 of 12 comparisons. Differences between sides were mostly very small and statistically significant in only 2 of 6 comparisons. Mean asymmetry scores were in the range of ~3-6%. These results contribute to the evidence on the utility of LQYBT and UQYBT testing in healthy adults.

Our results showed mostly good test-retest reliability and acceptable absolute reliability for all variables. For UQYBT, reliability was moderate to good, consistent with a previous study by Gorman et al., (2012) who reported that the direction of movement with the highest test-retest reliability was superolateral (0.92 to 0.99), while the inferolateral direction had the lowest test-retest reliability (0.80 to 0.96). However, the reliability in our study for the medial reach on the non-dominant hand was slightly lower (ICC = 0.62). The repeatability of the LQYBT tended to be slightly better than that of the UQYBT. Velarde-Sotres et al., (2021) reported that the modified version of the UQYBT test (using custom-made, inexpensive alternative accessories) was also repeatable between the first and second week of testing (mean scores: 81.63 ± 23.57 cm vs. 77.90 ± 22 .92 cm). We observed statistically significant systematic bias in specific directions in both lower and upper extremities, indicating a consistent trend of improving scores at retesting. Overall, we can conclude that the results show good test-retest reliability, but additional familiarization attempts may be needed to completely eliminate the learning effect.

We observed statistically significant differences between men and women in posterolateral reach for both lower extremities in the LQYBT test and differences in medial reach in the UQYBT test, but only for the non-dominant hand. In all cases, males scored higher than females, suggesting some gender differences on the LQYBT and UQYBT tests. However, the results in the literature are inconsistent. For instance, Gorman et al., (2012) did not find any gender differences for the UQYBT, while Plisky et al., (2009) reported significant differences for the LQYBT test. Butler et al., (2014) reported no gender differences in a reach direction or an overall reach score for UQYBT in their study. Schwiertz et al., (2021) found differences only in the right hand in the inferolateral in favor of boys compared to girls for the UQYBT, while Butler et al., (2014) found that female swimmers performed worse than male swimmers on the UQYBT test, but found no gender differences in inter-limb asymmetries. The variance in outcomes across different studies, as well as the observed minor differences in our own research, could be attributed to multiple factors. Sample characteristics, athletic backgrounds, and training programs can play a significant role in these discrepancies. It is also crucial to acknowledge that functional performance is influenced not just by gender, but also by individual variability, technique, and training experience. While our study focused primarily on functional performance in LQYBT and UQYBT tests, it is conceivable that the nervous system plays a role in these differences. Motor coordination, reflexes, and sensory perception, all regulated by the nervous system, might influence the observed gender difference. Delving deeper into specific neural mechanisms responsible for these differences would necessitate further research. In light of these discussions, we believe that further research with larger samples is essential to elucidate the mechanisms underpinning gender differences and ascertain their practical implications for training and performance optimization. We recommend that when available, coaches take into account gender-and sport-specific normative values for better training outcomes.

In the LQYBT test, the anterior reach was statistically significantly better on the nondominant side, but the difference was very small. Posteromedial reach was statistically significantly better on the dominant leg, but again the effect size was similarly small. There were no statistically significant differences between the dominant and nondominant sides in the UQYBT test. These results suggest the presence of asymmetries between the dominant and nondominant sides in the LQYBT test, but not in the UQYBT test. However, the effect sizes were very small and statistical significance was not always reached. Previous studies have also presented mixed results on this topic. Some studies report no bilateral differences in any reaching direction or between the dominant and nondominant sides, while others have observed significant differences (Butler et al., 2014; Gorman et al., 2012; Schwiertz et al., 2021; Westrick et al., 2012; Xu et al., 2023). For example, Bauer et al., (2021) found significant side differences in handball players where the dominance of one side used for passing, dribbling, and shooting was evident. These asymmetries exceeded the suggested threshold of ≥7.75%, indicating a potential increased risk of injury. Ruffe et al., (2019) observed that in male runners, a difference in posteromedial reach in the LQYBT test of ≥4.0 cm was associated with a higher likelihood of a running-related injury, whereas a difference in side-to-side reach in the UQYBT test of ≥4.0 cm was associated with hip/thigh/knee injuries. However, no such associations were found in female runners, either in the lower or upper body. The conflicting results highlight the complexity of asymmetries and their association with injury risk in different populations and activities. Further research is needed to better understand the underlying factors contributing to these asymmetries and their implications for injury prevention and performance optimization.

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