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Y-balance normative data for female collegiate volleyball players

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ABSTRACT

Objective: The Lower Quarter Y Balance (YBT-LQ) Test performance varies depending on competitive level, sport, gender, and age; therefore, determining normative scores specific to a population may be helpful in identifying injury-risk thresholds and return-to-play criteria following an injury. The purpose of this study was to determine normative YBT-LQ scores by assessing a subset of female, Division I volleyball players.
Design: A descriptive analysis cohort study.
Participants: Ninety healthy (19.6 ± 1.2 y/o), collegiate female volleyball players.
Main outcome measures: YBT-LQ was measured in 3 distinct directions of anterior (ANT), posteromedial (PM) and posterolateral (PL) on both the dominant and non-dominant limbs. In addition, a one way ANOVA was performed to determine mean group differences of YBT-LQ dominant and non-dominant limb composite score across position.
Results: Baseline values for this population were 94.1 ± 6.6% on the dominant limb and 93.9 ± 6.2% on the non-dominant limb. There were no significant differences for YBT-LQ composite scores on dominant ($P = 0.867$) and non-dominant ($P = 0.989$) limbs between position.
Conclusions: This study identified normative YBT-LQ composite scores for healthy, female, collegiate volleyball players. Participants performed similarly despite their position.

1. Introduction

Female volleyball players are at risk for injury each time they step on the court, with an injury incidence of 1.7 ± 0.3 injuries per 1000 player hours (Aagaard & Jorgensen, 1996; Agel, Palmieri-Smith, Dick, Wojtys, & Marshall, 2007; Bahr & Bahr, 1997). The National Collegiate Athletic Association (NCAA) injury surveillance data, spanning 16 years, has shown that more than 55% of female collegiate volleyball injuries involve the lower extremity (Agel et al., 2007). These injuries can lead to a significant loss of playing time for the athlete (Aagaard & Jorgensen, 1996). The ankle is the most common site of injury in collegiate volleyball players during games and practices, with injury rates as high as 44.1% and 29.4%, respectively (Agel et al., 2007). While the ankle is the most common joint to be injured, knee injuries are second in prevalence among volleyball players accounting for 14.1% of game injuries and 7.8% of practice injuries (Agel et al., 2007). Knee injuries result in the greatest game or training time missed due to injury (Aagaard & Jorgensen, 1996). On average, an athlete with a knee injury is out for 34 days and may experience prolonged symptoms, averaging 88 days (Aagaard & Jorgensen, 1996). In contrast ankle injuries result in an average of 8 days missed and 41 days of symptoms (Aagaard & Jorgensen, 1996). A number of risk factors contribute to these injuries, including but not limited to any previous injuries, sex, biomechanical and anatomical factors, decreased muscle flexibility, and poor balance (Garrison, Bothwell, Cohen, & Conway, 2014; Hewett et al., 2005; Hrysomallis, 2007; Huston, Greenfield, & Wojtys, 2000; Joseph et al., 2011; Knapik, Bauman, Jones, Harris, & Vaughan, 1991; Plisky, Rauh, Kaminski, & Underwood, 2006; Verhagen, Van der Beek, Bouter, Bahr, & Van Mechelen, 2004; Witvrouw, Bellemans, Lysens, Danneels, & Cambier, 2001).

Clinicians often use an injury-screening tool associated with dynamic lower extremity (DLE) balance to evaluate risk of injury and return to sport criterion following an injury. Dynamic lower extremity balance is the ability to maintain stability of an individual's center of mass during movement (Butler, Southers, Gorman, Kiesel, & Plisky, 2012). Poor DLE balance performance has been previously associated with an increased risk for injury in a variety of populations (Bouillon & Baker, 2011; Bressel, Yonker, Kras, & Heath, 2007; Butler et al., 2012; Butler, Lehr, Fink, Kiesel,

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& Plisky, 2013; Butler, Queen, Beckman, Kiesel, & Plisky, 2013; Garrison et al., 2014; Gorman, Butler, Rauh, Kiesel, & Plisky, 2012; Herrington, Hatcher, Hatcher, & McNicholas, 2009; Olmsted, Carcia, Hertel, & Shultz, 2002; Plisky et al., 2006). The Star Excursion Balance Test (SEBT), a test of DLE balance, has previously been used to predict lower extremity injury in female high school basketball players (Plisky et al., 2006). An anterior reach difference of 4 centimeters (cm) or more or a composite score (normalized to leg length) less than or equal to 94% for female basketball players on the SEBT has been used as a predictor for increased risk of lower extremity injury (Plisky et al., 2006).

The Lower Quarter Y Balance Test (YBT-LQ) is a simplified and reliable derivative of the SEBT (Gribble, Hertel, & Plisky, 2012; Hyong & Kim, 2014; Plisky et al., 2006; Plisky, Gorman, Butler, Kiesel, Underwood, & Elkins, 2009), which is a measure of single leg balance and dynamic neuromuscular control, strength, flexibility, and proprioception (Clanton, Matheny, Jarvis, & Jeronimus, 2012; Lehr, Plisky, Butler, Fink, Kiesel, & Underwood, 2013). For effective clinical use, a dynamic balance test needs to capture the greatest amount of information in the shortest amount of time thus the YBT-LQ variation is an efficient tool to detect risk of lower extremity injury (Plisky et al., 2009; Smith, Chimera, & Warren, 2015). Using the YBT-LQ, it has been determined a college football player with a composite score of less than 89.6% is 3.5 times more likely to sustain a non-contact lower extremity injury (Butler, Lehr, et al., 2013). In addition, high school female athletes with YBT-LQ composite scores below 94% were 6.5 times more likely to experience a lower extremity injury (Plisky et al., 2006). YBT-LQ composite scores vary across sports and level of competition (Bressel et al., 2007; Butler et al., 2012; Butler, Lehr, et al., 2013; Garrison, Arnold, Macko, & Conway, 2013; Plisky et al., 2006). Differences in reach distances between high school (HS), college (COL), and professional (PRO) soccer players revealed the HS group had a greater anterior reach distance than the other 2 groups ($P = 0.03$). In contrast, the HS group had less reach distance in the posteromedial and posterolateral directions than the other groups ($P < 0.01$ for both). HS players (98.4 ± 1.1) tended to exhibit a lower composite reach score than COL (100.9.4 ± 0.9) and PRO (101.8 ± 1.2), but this difference was not significant ($P = 0.08$) (Butler et al., 2012). Previous research suggests that soccer players score higher on dynamic balance compared to basketball players when measured by normalized leg reach distances on the SEBT ($P = 0.04$) (Bressel et al., 2007). The literature also indicates that gymnasts and dancers have superior balance compared to soccer players as assessed through center of pressure (COP) sway index (Gerbino, Griffin, & Zurakowski, 2007; Matsuda, Demura, & Uchiyama, 2008).

Performance on the YBT-LQ test varies depending on competitive level (Butler et al., 2012), sport (Bressel et al., 2007; Butler, Lehr, et al., 2013; Garrison et al., 2013; Plisky et al., 2006), gender (Gorman et al., 2012), and age (Bouillon & Baker, 2011); therefore, determining normative scores specific to a population may be helpful in identifying injury-risk thresholds and return-to-play criteria following an injury. While there are known YBT-LQ values for soccer, baseball, basketball, and football athletes, there is presently no research available on volleyball players' performance on YBT-LQ; therefore, the aim of the current study is to determine these normative YBT-LQ scores by assessing a subset of female, Division I volleyball players.

2. Methods

2.1. Participants

Ninety female collegiate volleyball players volunteered to participate in this study from 8 different Division I universities. All subjects gave informed consent to participate and the rights of each person were protected. The Institutional Review Board of Texas Health Resources approved the research procedures. Subjects were considered for study participation if they were a female athlete between the ages of 18 and 25 years old and playing collegiate volleyball. Injured athletes that were unable to play or practice at the time of data collection were excluded from the study. Patients were enrolled into the study by an investigator at the facility once screened for the inclusion and exclusion criteria. Once the patient offered consent, objective measurements of YBT-LQ were taken.

2.2. Testing

The YBT-LQ was utilized as a measure of trunk and lower extremity function (Garrison et al., 2013). The YBT-LQ assesses range of motion (ROM), strength, and neuromuscular control of the lower extremity and was chosen to assess the participants' lower limb balance as numerous prior studies have demonstrated its utility as a clinical test to assess for lower limb balance deficits in the athletic population (Paterno, Myer, Ford, & Hewett, 2004; Plisky et al., 2006,

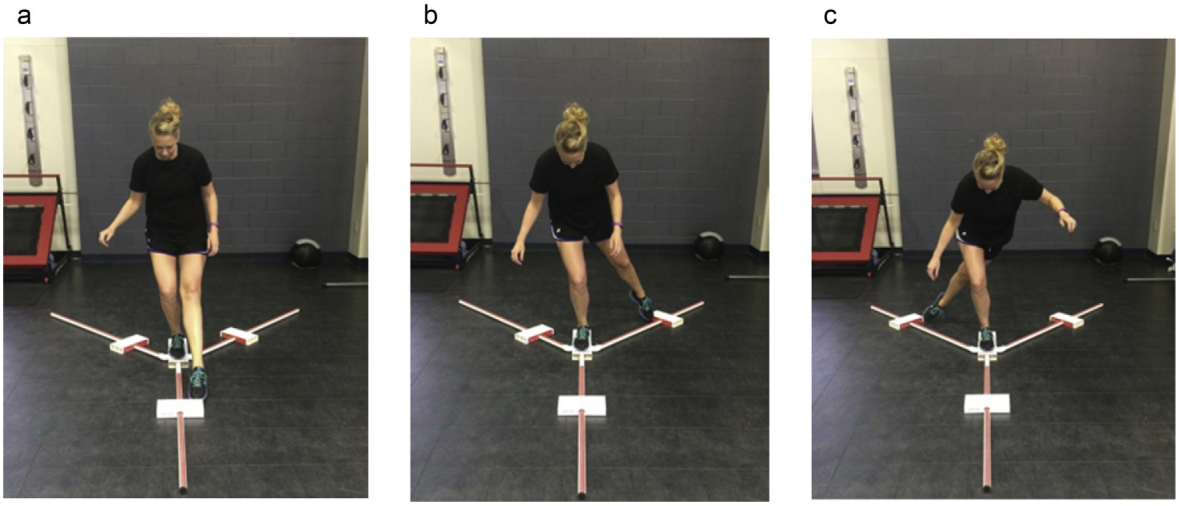

Fig. 1. a. Y-balance anterior reach, b. Y-balance posteromedial reach, c. Y-balance posterolateral reach.

Table 1
Demographics for DI female collegiate volleyball players.

Position	Number	Age (years)	Dominant arm R = right handed L = left handed	Height (m)	Weight (kg)
OH	26 (29%)	19.5 ± 1.2	R: 26 L: 0	1.81 ± 0.06	71.5 ± 5.5
RS	7 (7.8%)	19.7 ± 1.5	R: 2 L: 5	1.88 ± 0.04	75.9 ± 1.1
DS/L	18 (20%)	19.3 ± 1.3	R: 18 L: 0	1.68 ± 0.05	64.3 ± 5.4
S	15 (16.7%)	19.9 ± 1.2	R: 15 L: 0	1.75 ± 0.07	68.9 ± 9.6
MB	24 (26.7%)	19.7 ± 1.2	R: 24 L: 0	1.86 ± 0.04	73.2 ± 6.0
Total	90 (100%)	19.6 ± 1.2	R: 85 L: 5	1.79 ± 0.08	70.1 ± 7.1

2009; Sefton, Yarar, Hicks-Little, Berry, & Cordova, 2011). Measurements were taken in 3 distinct directions of anterior (ANT), posteromedial (PM) and posterolateral (PL) on both the dominant and non-dominant limbs. The dominant limb was determined as the lower extremity on which the athlete puts majority of weight on during hitting approach, which was the same side as the arm used to hit the ball. The participants were instructed in the YBT-LQ protocol, which has been previously described by using a combination of verbal cues and demonstration (Hannon, Garrison, & Conway, 2014; Plisky et al., 2009). The Y Balance Test Kit™ was utilized throughout the study. All participants wore shoes during testing and began on their dominant limbs. The participants were asked to perform single limb stance on the extremity while reaching outside their base of support to push a reach indicator box along the measurement pipe (Plisky et al., 2009). Elevation of the heel, toe or loss of balance resulting in a stepping strategy was recorded as a trial error indicating the trial should then be repeated. Subjects were allowed at least 3 practice trials in the ANT, PM and PL directions prior to recording the best of 3 formal trials in each plane. Three trials were completed on the dominant limb in the ANT (Fig. 1a) direction followed by 3 trials completed on the non-dominant limb (Plisky et al., 2009). This protocol was then replicated in the PM (Fig. 1b) and PL (Fig. 1c) directions. The maximal reach distance was recorded at the place where the most distal part of the foot reached based on the measurement pipe. The composite scores were calculated by adding the maximal reach distances (measured in cm) of the anterior, posteromedial, and posterolateral directions. The total was then divided by 3 times the participant's limb length, and multiplied by 100 to obtain a percentage (Plisky et al., 2006, 2009). Limb length was determined using the distance between the most prominent portion of the greater trochanter and the floor while the individual was in a standing position (Garrison et al., 2013). Composite YBT-LQ scores of the dominant and non-dominant limbs were computed for each of the athletes in this study. In addition, YBT-LQ anterior reach difference (ANT-Diff) was calculated by subtracting the non-dominant limb ANT from the dominant limb ANT (Dominant − Non-dominant).

2.3. Data analysis

A descriptive analysis was performed in order to determine the demographics for and establish baseline numbers for the group and each position. In addition, a one-way ANOVA was performed to determine mean group differences of YBT-LQ dominant and non-dominant limb composite scores across position.

Table 2
YBT-LQ composite scores for DI female collegiate volleyball players.

	Mean	Std. deviation	95% CI
Composite score Dominant leg	94.1%	±6.6	(92.7, 95.5)
Composite score Non-dominant leg	93.9%	±6.2	(92.6, 95.3)
Anterior difference (dominant − non-dominant)	−0.1 cm	±4.1	(−1.0, 0.8)

3. Results

Of the 90 participants, 24 were middle blockers (MB), 18 were defensive specialist or liberos (DS/L), 26 were outside hitters (OH), 7 were right side hitters (RS), and 15 were setters (S). Table 1 summarizes the demographic characteristics of the participants.

Baseline values for this population were 94.1 ± 6.6% on the dominant limb and 93.9 ± 6.2% on the non-dominant limb and the mean ANT-Diff was −0.1 ± 4.1 cm (Table 2). There were no significant differences for YBT-LQ composite scores on dominant ($P = 0.867$) and non-dominant ($P = 0.989$) limbs or ANT-Diff ($P = 0.13$) between positions (Table 3).

4. Discussion

This study reveals that healthy, female, collegiate volleyball players perform similarly to athletes in other sports on the YBT-LQ (dominant leg: 94.1% ± 6.6, non-dominant leg: 93.9% ± 6.2). Likewise, there was no significant difference in ANT-Diff by position in these healthy athletes. The composite scores and ANT-Diff for female, collegiate volleyball players determined by the current study may have clinical relevance, as previous research has focused on identifying cut-off scores that can predict injury in a variety of sports for both composite scores and ANT-Diff.

A review of the literature indicates that performance on the YBT-LQ varies by competition level, sport, gender, and age (Bressel et al., 2007; Butler et al., 2012; Butler, Lehr, et al., 2013; Garrison et al., 2013; Plisky et al., 2006). The results from the current study support the findings that composite scores vary by sport. Previously published research reveals that the mean YBT-LQ composite scores for soccer players ranged between 97 and 101% (American adolescent: 97.8% ± 6.2, high school: 98.4% ± 1.1, college: 100.9% ± 0.9, professional: 101.8% ± 1.2), basketball athletes scored 98–103% (females: 98.4% ± 8.2, males: 103.0% ± 8.0), and baseball players scored 95.8% ± 6.1 when normalized to leg length (Butler et al., 2012; Butler, Queen, et al., 2013; Garrison et al., 2013; Plisky et al., 2006).

A previously published prospective study demonstrated that a decrease in lower extremity balance is associated with a greater likelihood of lower extremity injury in female high school basketball players (Plisky et al., 2006). Females who had a composite score of less than 94% on the modified SEBT were 6.5 times more likely to incur an injury to the lower extremity during the subsequent

Table 3
Composite scores by position.

		Mean	Std. deviation	95% CI
Composite Dominant	OH	94.1%	7.1	(91.3, 97.0)
	RS	95.7%	7.3	(89.0, 102.6)
	S	94.7%	5.3	(89.7, 98.8)
	DS/L	94.2%	8.1	(92.1, 97.4)
	MB	92.9%	6.1	(90.4, 95.6)
Composite Non-Dominant	OH	94.0%	6.2	(91.6, 96.6)
	RS	94.9%	7.4	(88.0, 101.9)
	S	94.1%	5.6	(89.3, 97.7)
	DS/L	93.5%	7.5	(91.3, 96.9)
	MB	93.6%	6.0	(91.1, 96.2)
Anterior reach difference	OH	−1.5 cm	4.8	(−3.5, 0.4)
	RS	−2.0 cm	7.0	(−8.6, 4.4)
	S	0.8 cm	3.2	(−1.5, 2.5)
	DS/L	0.5 cm	3.6	(−0.8, 2.4)
	MB	0.9 cm	2.7	(−0.2, 2.1)

Table 4
Previously reported YBT-LQ composite scores.

Study	Sample description	Sample size	Age (years)	Gender	Healthy v. injured	Composite scores (%)
Butler, Queen, et al., 2013	Rwandan male adolescent soccer athletes	26	16.5 ± 1.2	Male	Healthy	105.6 ± 6.8
Butler, Queen, et al., 2013	American male adolescent soccer athletes	26	16.1 ± 0.9	Male	Healthy	97.8 ± 6.2
Butler et al., 2012	High school soccer athletes	38	15.6 ± 1.0	Male	Healthy	98.4 ± 1.1
Butler et al., 2012	College soccer athletes	37	18.8 ± 1.2	Male	Healthy	100.9 ± 0.9
Butler et al., 2012	Professional soccer athletes	44	26.2 ± 4.0	Male	Healthy	101.8 ± 1.2
Plisky et al., 2006	High school female basketball athletes	105	High school	Female	Healthy	98.4 ± 8.2
Plisky et al., 2006	High school male basketball athletes	130	High school	Male	Healthy	103.0 ± 8.0
Garrison et al., 2013	Baseball players with UCL tear	30	18.5 ± 1.9	Male	Injured	88.2 ± 7.9 (stance) 89.1 ± 6.7 (lead)
Garrison et al., 2013	Baseball players without UCL tear	30	19.0 ± 1.1	Male	Healthy	95.4 ± 6.4 (stance) 95.8 ± 6.1 (lead)
Gorman et al., 2012	Single sport high school athletes	92	15.9 ± 1.2	Male & Female	Healthy	97.1 ± 8.2
Gorman et al., 2012	Multisport high school athletes	92	15.4 ± 1.2	Male & Female	Healthy	97.1 ± 8.4
Hannon et al., 2014	Baseball players 3 months post surgery for UCL tear	33	18.5 ± 3.2	Male	Injured	94.9 ± 9.5 (stance) 93.6 ± 7.2 (lead)
Smith et al., 2015	Division I college athletes injured during sporting season	81	20.6 ± 1.6	Not reported	Injured	101.3 ± 7.8
Smith et al., 2015	Division I college athletes uninjured during sporting season	103	20.0 ± 1.4	Not reported	Healthy	101.2 ± 7.1
Hudson et al.	Female Division I collegiate volleyball athletes	90	19.6 ± 1.2	Female	Healthy	94.1 ± 6.6 (dominant) 93.9 ± 6.2 (non-dominant)

season. Likewise, when the results were compiled for both males and females, a composite reach score of less than 94% led to those athletes being 3 times more at risk for lower extremity injury during the following basketball season (Plisky et al., 2006). Butler, Lehr, et al. (2013) was the first study to investigate YBT performance and association with injury in college football players, identifying a significantly increased odds of injury with low composite scores and no association to injury with asymmetry in any reach direction. Butler, Lehr, et al. (2013) found composite score less than 89.6% to increase odds of injury by 3.5 times 95% CI [2.4, 5.4]. Plisky et al. (2006) and Butler, Lehr, et al. (2013) determined normalized composite scores using the same protocol as the current study, but injury data was not available for the volleyball players to determine injury cutoff scores. Smith et al. (2015) examined YBT composite scores and absolute differences in reach distance between sides in 184 Division I athletes from multiple sports. ROC curves determined ANT-Diff > 4 cm (sensitivity, 59%; specificity, 72%) as the optimal cutoff for predicting increased risk for noncontact injury.

The literature indicates that the interpretation of composite scores for the YBT-LQ requires norms and cut-offs specific to age, gender and sport. The YBT-LQ has been extensively studied across a variety of sports and athletes to include healthy, injured and normative data (Table 4). To our knowledge, the current study is the first to report normative data in a cohort of female Division I Collegiate volleyball players. The results of this study provide a clinical guideline for the YBT-LQ composite scores which clinicians can use when performing pre-performance screening or developing return to sport criterion following injury in female collegiate volleyball players. Additional research should be conducted in order to identify if dynamic balance performance is associated with lower extremity injuries in female volleyball players as well as to determine cut-off scores for injury risk.

The primary limitation of the current study was limited external validity due to the specific population examined. The current study only assessed female, collegiate volleyball players and future researchers should determine if similar results exist in males and youth volleyball players. This limitation is lessened because of the need for baseline data specific to volleyball players. A second limitation to external validity was the small sample size. Another limitation is a lack of injury history on the subjects included in the study. Prior research has suggested that patients with ACL injury or chronic ankle instability perform lower on standardized DLE balance tests, which was not controlled for in the current study and thus may impact the normative data (Herrington et al., 2009; Olmsted et al., 2002).

5. Conclusion

The results of this study provide normative YBT-LQ composite scores for healthy, female collegiate volleyball players. Participants performed similarly on both their dominant and non-dominant limbs despite their position. The descriptive information provided may serve as a guide for clinicians working with female collegiate volleyball players for both screening and rehabilitation.

Conflict of interest
None declared.

Ethical approval
This study protocol has been approved by the Institutional Review Board of Texas Health.

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