Brumitt J, Patterson C, Dudley R, et al. Correlations Between Preseason Functional Test Scores and Game Performance in Female Collegiate Volleyball Players. *IJSPT*. 2022;17(5):896-906.

Original Research

Correlations Between Preseason Functional Test Scores and Game Performance in Female Collegiate Volleyball Players

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Keywords: y-balance test, single-leg hop, standing long jump, lower extremity functional test

https://doi.org/10.26603/001c.36805

International Journal of Sports Physical Therapy

Vol. 17, Issue 5, 2022

Background

Functional tests (FT) are assessment tools that attempt to evaluate balance, flexibility, strength, power, speed, or agility through performance of gross motor skills. FT are frequently administered by coaches or sports medicine professionals to evaluate athletic ability, to predict performance, to identify athletes at risk for injury, or to evaluate an athlete's ability to return to sport after injury. Functional tests which can provide accurate or predictive information regarding athletic ability would be advantageous to coaching staffs or medical professionals.

Purpose

The primary purpose of this study was to identify correlations between preseason FT scores and in-season game statistics in a cohort of female collegiate level volleyball (VB) players. A secondary purpose was to present FT descriptive data for this cohort based on level of competition, player position, and starter status.

Study Design

prospective cohort; correlational

Methods

One hundred and thirty-one female collegiate VB players representing three levels of competition completed four FT [standing long jump (SLJ), single-leg hop (SLH), lower extremity functional test (LEFT), and the Y-Balance Test - Lower Quarter (YBT-LQ)] at the start of the preseason. Player statistics were collected from team records at the completion of the season.

Results

Starters performed significantly better on all tests. There were moderate negative correlations between LEFT scores and game statistics for liberos, defensive specialists, and outside hitters. There were moderate positive correlations between YBT-LQ composite scores and game statistics for liberos, defensive specialists, hitters, and middle blockers. There were also low to moderate level positive correlations between SLJ and SLH scores and game performance for outside hitters. There were low to moderate level positive correlations between SLH scores and game performance for middle blockers and opposite side hitters.

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Conclusions

The results of this study indicate that there are low to moderate correlations between some preseason functional test scores and some game statistics. The SLJ, SLH, LEFT, and YBT-LQ tests may help coaches with talent identification and/or may influence training strategies.

Level of Evidence

3

INTRODUCTION

Functional tests (FT) are assessment tools that attempt to evaluate measures of balance, flexibility, strength, power, speed, or agility through performance of gross motor skills.[1,2] FT are inexpensive alternatives to laboratory based measures and are frequently administered by strength coaches or sports medicine professionals to evaluate athletic ability, to predict performance, to identify athletes at risk for injury, or to evaluate an athlete's ability to return to sport after injury.[3–10] These tests are performed during the off-season or at the start of the preseason to identify deficits that may be addressed by training programs.

There are numerous examples in the literature that illustrate correlations between test scores and game performance.[11–16] Coaches may use this information when evaluating talent and/or it may influence training strategies. However, some of the aforementioned studies utilized tests that may not be available in all collegiate settings. The advantage of utilizing FT, instead of high-tech options like a motion capture lab or isokinetic machines, are that they are quick to perform, require minimal equipment, are less expensive than other tests, and that they can be administered and interpreted by all professionals.[1,2]

Correlations between FT scores and player demographics or game performance has been reported in collegiate and professional volleyball (VB) players.[11,12,14–16] Sattler et al. evaluated performance of the squat jump (SJ), countermovement jump (CMJ), block jump (BJ), and the attack jump (AJ) in a cohort of high-level adult male and female volleyball players from Slovenia.[14,15] They reported male outside hitters had significantly greater SJ and CMJ than male setters and significantly greater AJ performance than male liberos.[14,15] However, there was no difference in test performance between female VB players.[15] Boldt et al. reported significant correlations between body fat and t-test agility drill performance ($r = 0.544$) and fat free mass and standing long jump performance ($r = 0.538$) in National Collegiate Athletic Association (NCAA) Division III (D III) female VB players.[11] Bunn et al. reported significant positive correlations between 1) broad jump (aka standing long jump) scores and block assists/set for setters and kills/set, errors/set, block assists/set, and block solos/set for middle blockers and 2) T-drill test scores with digs/set for setters in NCAA Division I female VB players.[12]

There have been only a few studies reporting correlations between preseason FT scores and performance measures in female collegiate level VB players.[11,12] Evaluating potential relationships between FT scores and game performance in female collegiate VB players may help coaches with talent identification and/or may influence training strategies per player position. The primary purpose of this study was to identify correlations between preseason FT scores and in-season game statistics in a cohort of female collegiate level VB players. It was hypothesized that there would be positive correlations between preseason test performance and game statistics per each test. A secondary purpose was to present FT descriptive data for this cohort based on level of competition, player position, and starter status.

METHODS

PARTICIPANTS

Female collegiate level VB players were recruited from nine teams over a three-year period (2015-2017). A total of 131 VB players, representing three levels of competition, completed all tests: NCAA D II (n = 32), NCAA D III (n = 74), NAIA (n = 25). Each athlete completed the informed consent document prior to testing. This study was approved by George Fox University's (Newberg, OR) and Azusa Pacific University's (Azusa, CA) Institutional Review Boards.

PROCEDURES

Female collegiate level VB players were recruited from university or college programs from the Portland, OR and Azusa, CA regions. This study was part of a larger prospective cohort study. Athletes were tested at the start of the preseason with an athlete completing each test during one testing session. Each athlete completed the Y-Balance Test – Lower Quarter (YBT-LQ), the standing long jump (SLJ), the single-leg hop (SLH; performed bilaterally), and the lower extremity functional test (LEFT) in that order. The testing sequence was designed to have athletes perform the dynamic balance test first, followed by the lower extremity tests for lower body power (i.e., SLJ and SLH), and finally the most fatiguing test, the LEFT, was performed last.[1,2,7]

Age and anthropometric data were collected from each athlete prior to performing the FT. Height was collected using a cloth measuring tape affixed to a wall. Body mass was measured when the athlete stood on a force plate (model BP 600600; AMTI, Watertown, MA). Specific athletic information (e.g., player position and starter status) and game statistics were collected from team records at the completion of the season. Next, each athlete completed a five-minute dynamic warm-up.[4] Athletes performed the following movements in a hallway adjacent to the lab: forward walking, backward walking, heel walking, tip toe walking, marching, and hip flexion with opposite arm reach.[4] Each athlete also performed three submaximal effort SLJ as part of the dynamic warm-up.[4]

Y-BALANCE TEST - LOWER QUARTER PROTOCOL

The YBT-LQ test was performed by each athlete first. Each athlete received test instruction and performed six warm-up trials per lower extremity.[17] After the warm-up trials each athlete performed the test in the anterior direction completing three trials on the right (i.e., right LE weight-bearing) followed by performing three trials on the left.[17] After the anterior trials were completed athletes performed three trials per lower extremity (right side followed by the left side) in the posteromedial direction followed by the posterolateral direction.[17] A trial was repeated if the athlete performed the test with a technique error.[17] The mean score for the three trials in each reach direction was used for subsequent statistical analyses. YBT-LQ reach measures were normalized to the athlete's limb length. After completing the YBT-LQ test an investigator measured limb length bilaterally from the anterior superior iliac spine to the distal aspect of the medial malleolus.[17] The formula to normalize reach distance is: ([reach distance / limb length] x 100).[17] A composite reach score, which is a measure representing reach scores into each direction of the "Y" was also calculated: ([mean anterior reach + mean posteromedial reach + mean posterolateral reach] / [limb length x 3]) x 100.[17] Group mean individual and composite scores were used for data analysis. The YBT-LQ has excellent intrarater reliability (0.85-0.91) and interrater reliability (0.99-1.00).[17]

STANDING LONG JUMP

An athlete stood with her feet approximately shoulder width apart behind a line of tape affixed to the floor.[4,5,7] A cloth measuring tape, oriented perpendicular to the line of tape (i.e., the starting point), was used for measuring the distance jumped and hopped.[4,5,7] Each athlete performed three maximal effort SLJ with hands clasped behind the back during testing.[4,5,7] Jump distance was measured from the starting line to the rearmost heel. A 30 second rest break was provided to each athlete between trials.[18] If the athlete used her arms during the SLJ or if she failed to stick the landing a trial was repeated.[7] The mean of three SLJ was used for data analyses. Mean scores were normalized as a percentage of the athlete's height (% ht.). The test-retest reliability for the SLJ is excellent ranging from 0.91 to 0.98.[2,19–23]

SINGLE-LEG HOP

Each athlete performed six SLH; three per lower extremity. To perform the test the athlete would stand on one leg, behind the starting line, with her hands clasped behind her back.[4,5,7] A coin flip was performed to determine which lower extremity was hopped off first with each successive trial alternating between legs. Athletes were provided with a 30 second rest break between trials.[18] A SLH trial was repeated if an athlete failed to stick landing, landed with the wrong leg, or if she used her arms during the test.[4,5,7] The distance hopped was measured from the rear of the landing foot heel to the starting line. The mean of three SLH, per side, was used for data analysis. Mean scores were normalized as a percentage of an athlete's height (% ht.). The SLH has excellent test-retest reliability ranging from 0.93 to 0.96.[2,19,24,25]

LOWER EXTREMITY FUNCTIONAL TEST (LEFT)

The final test performed by each athlete was the LEFT. The LEFT, an agility drill, is performed over a diamond shape course.[7] The dimensions of the LEFT is 9.14 meters (m) [30 feet] in the north-south direction and 3.05 m [10 feet] in the west-east direction.[7] Strips of tape in the shape of equilateral triangles (0.305 m) were affixed to the floor at the end of each axis. Prior to starting the test, the athlete stood at the southern triangle and received test instruction. Athletes were instructed to run to the northern triangle and back followed by running backwards from the southern triangle to the northern triangle and back.[7,26] As the athlete neared completion of the backwards run, the tester provided verbal instructions as to the subsequent agility drill and the direction of movement through the course.[7,26] The LEFT consists of the following drills, performed counter-clockwise and clockwise (except for the forward and backward runs) in this order: forward run, backward run, side shuffles, cariocas, Figure 8s, 45◦ cuts (plant outside foot), 90◦ cuts (plant outside foot), crossover 90◦ cuts (plant inside foot), forward run, and the backward run.[7] The tester used a stopwatch to record the time (seconds) it took the athlete to complete the test. Each athlete only performed the LEFT once. The ICCs for the LEFT is 0.95-0.97.[27]

STATISTICAL ANALYSIS

Shapiro-Wilk test was performed to assess normality of data. Each functional test demonstrated a normal distribution (SLJ $p = 0.153$, R SLH $p = 0.446$, L SLH $p = 0.958$, LEFT $p = 0.458$, R YBT-LQ composite $p = 0.159$, L YBT-LQ composite = 0.750). Descriptive statistics (mean ± SD) were calculated for age, anthropometric measures, and FT measures (note: descriptive data for the YBT-LQ has been previously reported and is therefore not reported in this study).[28] Independent t-tests were used to compare mean functional test scores per player movement categorization (i.e., based on player positions)[28] and starter status. Player movement categorization was based on positional requirements related to the frequency of vertical jumping during sport.[28] One group (n = 80) consisted of athletes who frequently perform vertical jumps during a game: outside hitters, middle blockers, and opposite side hitters. The other group (n = 51) consisted of liberos, defensive specialists, and setters. One-way analysis of variance (ANOVA) was performed to assess mean differences for age, anthropometric, and FT measures between athletes per level of competition. ANOVA was also performed to compare FT measures between athletes based on player position. A post-hoc Bonferroni test was performed after ANOVA to identify significant differences between subcategories within a group. Pearson product moment correlations were calculated to identify correlations between functional test scores and in-season game statistics (kills/set, assists/set, service ace/set, digs/set, blocks/set, points/set). A sample size of 26 per group analysis (i.e., correlations between player position and preseason test scores) was calculated using G*Power

Table 1. Demographic Information and Functional Performance Test Scores (Mean ± SD) Per Level of Competition

Variable	Totals (n = 131)	NCAA D II (n = 32)	NCAA D III (n = 74)	NAIA (n = 25)	p-value
Age (years)	19.3 ± 1.1	19.3 ± 0.9	19.1 ± 1.1	19.8 ± 1.2	0.032[a]
Height (m)	1.74 ± 0.08	1.76 ± 0.07	1.73 ± 0.08	1.75± 0.09	0.200
Body mass (kg)	70.84 ± 9.69	71.15 ± 9.12	70.46 ± 9.41	71.58 ± 11.44	0.866
BMI (kg/m^2)	23.4 ± 3.0	23.0 ± 2.5	23.6 ± 3.2	23.4 ± 2.8	0.595
SLJ (% ht.)	0.81 ± 0.1	0.84 ± 0.1	0.81 ± 0.1	0.79 ± 0.1	0.228
(R) SLH (% ht.)	0.65 ± 0.1	0.66 ± 0.1	0.64 ± 0.1	0.65 ± 0.1	0.740
(L) SLH (% ht.)	0.63 ± 0.1	0.67 ± 0.1	0.61 ± 0.1	0.64 ± 0.1	0.127
LEFT (sec)	111.5 ± 11.8	105.8 ± 17.4	112.6 ± 8.9	115.3 ± 7.7	0.004[b,c]

NCAA = National Collegiate Athletic Association; D II = Division II; D III = Division III; NAIA = National Athletic Intercollegiate Association; SLJ = standing long jump; SLH = single leg hop; LEFT = lower extremity functional test; % ht. = refers to jump or hop distances normalized as a percentage of one's height
[a]Significant difference between NAIA and D III; p-value = 0.026
[b]Significant difference between D II and D III; p-value = 0.017
[c]Significant difference between D II and NAIA; p-value = 0.007

with alpha set at 0.05, power at 0.8, and an effect size of 0.5. Correlation (*r*) scores were stratified by magnitude: low (⩽ 0.35); moderate (0.36 -0.67); strong (0.68-1.0).[29,30] Statistical analysis was performed using SPSS Statistics 25.0 (IBM, Chicago, IL, USA) with alpha level set at 0.05.

RESULTS

Mean age, anthropometric measures, and FT scores for the entire sample and per level of competition are presented in Table 1. The mean age was 19.3 ± 1.1 years; mean height was 1.74 ± 0.08 m; mean weight was 70.84 ± 9.69 kg; mean body mass index was 23.4 ± 3.0 kg/m^2 (Table 1). There were no significant differences in demographic information between groups except for age; NAIA athletes were significantly older than D III athletes. Mean scores for the FT were: SLJ (% ht.) 0.81 ± 0.1; (R) SLH (% ht.) 0.65 ± 0.1; (L) SLH (% ht.) 0.63 ± 0.1; and LEFT 111.5 ± 11.8 sec (note: mean YBT-LQ for this population was previously reported[28]). There was only one difference in FT performance based on level of competition; D II VB players completed the LEFT significantly faster than D III and NAIA athletes.

Table 2 presents correlation statistics between preseason FT scores and in-season game statistics for all participants. There was a low statistically significant positive correlation between SLJ performance and digs/set (*r* = 0.225; p = 0.01). Right SLH performance had low statistically significant positive correlations with kills/set (*r* = 0.205; p = 0.019) and points/set (*r* = 0.187; p = 0.032). Left SLH performance had low statistically significant positive correlations with kills/set (*r* = 0.272; p = 0.002), digs/set (*r* = 0.209; p = 0.017), and points/set (*r* = 0.266; p = 0.002). There were low statistically significant negative correlations between LEFT scores and kills/set (*r* = -0.191; p = 0.029), digs/set (*r* = -0.249; p = 0.004), and points/set (*r* = -0.182; p = 0.037). Preseason YBT-LQ performance was positively correlated to some game statistics and negatively correlated with others. There were numerous low to moderate statistically significant positive correlations between individual and composite YBT-LQ scores and service ace/set and digs/set. There were numerous low to moderate significant negative correlations between YBT-LQ measures and kills/set, blocks/set, and points/set.

Table 3a presents correlation statistics between preseason SLJ, SLH, and LEFT measures and in-season game statistics per player positions. There were statistically significant moderate negative correlations between LEFT performance and assists/set (*r* = -0.469; p = 0.028) and digs/set (*r* = -0.449; p = 0.036) in liberos and defensive specialists. There were statistically significant moderate positive correlations between SLH performance and kills/set ([R] *r* = 0.519; p = 0.008; [L] 0.410; p = 0.042) and points/set ([R] *r* = 0.539; p = 0.005; [L] *r* = 0.400; p = 0.047] in setters. There were several low and moderate positive correlations between SLJ and SLH performance for kills/set, assist/set, digs/set, and points/set in outside hitters. Outside hitters also demonstrated several moderate negative correlations between performance and LEFT scores. SLH performance with the left lower extremity had low and moderate level correlations with kills/set (*r* = 0.308; p = 0.05), service ace/set (*r* = 0.358, p = 0.022) and points/set (*r* = 0.322; p = 0.04) in MB and OPP.

Table 3b presents correlation statistics between preseason YBT-LQ measures and in-season game statistics per player positions. There were some statistically significant negative correlations between YBT-LQ scores and game performance in liberos, defensive specialists, and setters. There was a moderate negative correlation between (L) posteromedial reach and assists per set (*r* = -0.433; p = 0.044) in liberos/defensive specialists. There were two moderate negative correlations between YBT scores and game statistics in setters: (L) posteromedial reach and assists/set (r = -0.468; p = 0.018) and (R) posterolateral and digs/set (*r* = -0.431; p = 0.032). There were however two significant moderate positive correlations observed in the libero/defensive specialist grouping. Composite score performance was moderately correlated with digs/set ([R] composite *r* = 0.506; p = 0.016; [L] composite *r* = 0.538; p = 0.010). There were several positive low and moderate correlations between individual reach measures and performance in out-

Table 2. Pearson Product Moment Correlations (*r*) between In-Season Statistics and Preseason Functional Test Scores

	Kills/Set	Assists/Set	Service Ace/Set	Digs/Set	Blocks/Set	Points/Set
SLJ	0.165	-0.012	0.118	0.225ǂ	-0.053	0.135
(R) SLH	0.205ǂ	-0.002	0.074	0.165	0.043	0.187ǂ
(L) SLH	0.272ǂ	-0.082	0.168	0.209ǂ	0.061	0.266ǂ
LEFT	-0.191ǂ	-0.010	-0.137	-0.249ǂ	0.000	-0.182ǂ
Y-Balance LQ						
(R) Anterior	0.007	-0.052	0.118	0.199[j]	-0.121	0.000
(R) Posteromedial	0.012	-0.095	0.154	0.169	-0.173ǂ	0.000
(R) Posterolateral	-0.109	-0.066	0.132	0.197ǂ	-0.205ǂ	-0.109
(R) Composite	-0.231ǂ	0.082	0.241ǂ	0.402ǂ	-0.434ǂ	-0.232ǂ
(L) Anterior	0.111	-0.110	0.131	0.187ǂ	-0.008	0.113
(L) Posteromedial	0.040	-0.093	0.159	0.179ǂ	-0.136	0.036
(L) Posterolateral	-0.033	-0.077	0.181ǂ	0.266ǂ	-0.135	-0.034
(L) Composite	-0.202ǂ	0.073	0.274ǂ	0.450ǂ	-0.406ǂ	-0.199ǂ

ǂp-value < 0.05; SLJ = standing long jump; SLH = single leg hop; LEFT = lower extremity functional test; (R) = right; (L) = left

side hitters. There were also numerous low to moderate statistically significant correlations between reach scores and performance in MB and OPP; however, of the 22 statistically significant correlations 12 of them were negative correlations.

The secondary purpose of this study was to present FT descriptive data for this cohort based on player position, starter status, and player movement categorization. There were no significant differences in functional test scores when comparing athletes per individual positions (Table 4). [Note: in Table 4 L and DS were combined into one category and MB and OPP were combined into one category. These combinations were performed for two reasons: some athletes were identified in team statistics as playing more than one position and combining similar positions helped to create larger sample sizes per group]. There was a significant difference for each functional test based on starter status (SLJ p = 0.000; [R] SLH p = 0.002; [L] p = 0.002; LEFT p = 0.018) (Table 4).

There were no significant differences in preseason FT scores when comparing athletes based on movement categorization (i.e., grouping athletes based on performing frequent vertical movements during sport versus lateral movements) (Table 5). One group consisted of athletes who frequently perform vertical movements during VB (e.g., hitting, blocking): outside hitters (OH), middle blockers (MB), opposite side hitters (OPP). The other group consisted of athletes who frequently perform horizontal movements during VB (e.g., digging, defense): libero (L), setter (S), defensive specialist (DS).

DISCUSSION

This is the first study to report mean scores for several frequently utilized FT for a cohort of female collegiate level VB players and correlations between preseason test scores and in-season game statistics. The data presented in this study has applications for head coaches, strength coaches, and sports medicine professionals.

JUMP AND HOP TESTS

There was no difference in SLJ or SLH scores between athletes based on level of competition. There was however a significant difference in SLJ and SLH measures based on starter status with starters jumping and hopping significantly farther than their nonstarter counterparts. This data has applications for head coaches and strength coaches. First, SLJ and SLH measures can be used by coaches to evaluate aspects of an athlete's lower extremity power.[1,2,31–36] Many smaller universities (i.e., non-Division I institutions) lack expensive equipment (e.g., isokinetic machines) to test their athletes; the SLJ and SLH tests may be used as clinical correlates for quantifying lower extremity power.[1,2,31–36]

There were several low to moderate level positive correlations between jump or hop performance and game statistics (Table 2). The jump and hop tests appear to have the greatest value when evaluating VB athletes per position (Table 3a). For example, there were several low to moderate correlations between game statistics and SLJ or SLH performance by outside hitters. Outside hitters are involved in the offensive attack and thus are frequently performing vertical jumps throughout the game. Having greater lower extremity power is advantageous for their position.[33]

There were also low and moderate level correlations between (L) SLH power and game performance in middle blockers and opposite side hitters. Middle blockers and opposite side hitters play in the front line and are responsible for blocking and attacking. The correlations between (L) SLH and game stats illustrates the importance of lower extremity power, especially in the left lower extremity which

Table 3a. Pearson Product Moment Correlations (*r*) between Preseason Functional Test [SLJ, SLH, LEFT] Scores and In-Season Game Statistics per Player Position

Position and Statistics	SLJ	(R) SLH	(L) SLH	LEFT
Liberos and Defensive Specialists (n = 22)				
Kills/Set	-0.144	-0.142	-0.209	0.371
Assists/Set	0.407	0.122	0.051	-0.469ǂ
Service Ace/Set	0.255	0.015	0.080	-0.403
Digs/Set	0.301	0.096	0.184	-0.449ǂ
Blocks/Set	-0.135	-0.018	-0.083	0.329
Points/Set	-0.129	-0.120	-0.186	0.336
Setters (n = 25)				
Kills/Set	0.356	0.519ǂ	0.410ǂ	0.015
Assists/Set	-0.070	0.069	-0.004	-0.035
Service Ace/Set	0.101	0.228	0.038	0.235
Digs/Set	-0.113	-0.032	-0.077	0.138
Blocks/Set	0.023	0.152	0.140	0.080
Points/Set	0.313	0.539ǂ	0.400ǂ	0.135
Outside Hitters (n = 43)				
Kills/Set	0.260	0.353ǂ	0.416ǂ	-0.365ǂ
Assists/Set	0.261	0.323ǂ	0.363ǂ	-0.264
Service Ace/Set	0.047	0.253	0.238	-0.443ǂ
Digs/Set	0.373ǂ	0.467ǂ	0.459ǂ	-0.465ǂ
Blocks/Set	0.148	0.278	0.222	-0.177
Points/Set	0.202	0.297	0.381ǂ	-0.391ǂ
Middle Blockers and Opposite Side Hitters (n = 41)				
Kills/Set	0.122	0.075	0.308ǂ	-0.081
Assists/Set	0.011	-0.043	-0.014	-0.183
Service Ace/Set	0.276	0.144	0.358ǂ	-0.231
Digs/Set	0.144	0.085	0.129	-0.256
Blocks/Set	-0.133	-0.025	0.006	-0.022
Points/Set	0.127	0.089	0.322ǂ	-0.113

ǂp-value < 0.05; SLJ = standing long jump; SLH = single leg hop; (R) = right; (L) = left; LEFT = lower extremity functional test

is often used as the primary take-off leg during the vertical jump in athletes who are right-side dominant when hitting.

LOWER EXTREMITY FUNCTIONAL TEST

Starters were significantly faster at completing the LEFT course than their nonstarter counterparts. There was a negative correlation between many game statistics and LEFT performance (measured in seconds). In other words, completing the course faster (i.e., athletes with a lower LEFT score) correlated with better game performance. To complete the LEFT quickly one must be able to rapidly change direction in response to verbal cues.[7] There were moderate negative correlations (i.e., faster performance of the LEFT correlated with better game performance) for liberos, defensive specialists, and outside hitters (Table 3a). These athletes must possess agility to respond to unpredictable ball play.

Y BALANCE TEST - LOWER QUARTER

There were both positive and negative correlations between preseason scores and game performance when evaluating the general population of athletes in this study (Table 2). Negative correlations represent opposite relationships between test performance and game statistics. It is not recommended to select athletes based on these negative correlations nor to "detrain" athletes. The YBT-LQ does not appear to be a useful test for measuring athletic ability for all VB athletes due to the low correlations with many per-

Table 3b. Pearson Product Moment Correlations between Lower Quarter Y-Balance Test [YBT-LQ] Scores and In-Season Game Statistics per Player Position

Position(s) and YBT-LQ	Kills/ Set	Assists/ Set	Service Ace/ Set	Digs/ Set	Blocks/ Set	Points/ Set
Liberos and Defensive Specialists (n = 22)						
(R) Anterior	-0.153	-0.347	-0.010	0.118	-0.087	-0.144
(R) Posteromedial	0.168	-0.334	-0.037	0.063	0.180	0.179
(R) Posterolateral	0.093	-0.305	-0.112	0.036	0.122	0.094
(L) Anterior	-0.188	-0.370	-0.043	0.035	-0.141	-0.191
(L) Posteromedial	-0.176	-0.433ǂ	-0.100	0.006	0.288	0.203
(L) Posterolateral	-0.063	-0.295	-0.068	0.127	0.125	0.074
(R) Composite	-0.295	0.070	0.327	0.506ǂ	-0.306	-0.277
(L) Composite	-0.339	0.018	0.343	0.538ǂ	-0.315	-0.314
Setters (n = 25)						
(R) Anterior	0.224	0.013	0.063	-0.140	-0.015	0.197
(R) Posteromedial	0.002	-0.345	0.127	-0.349	-0.201	0.058
(R) Posterolateral	-0.224	-0.391	-0.041	-0.431ǂ	-0.389	-0.217
(L) Anterior	0.354	-0.103	0.225	-0.100	0.101	0.383
(L) Posteromedial	-0.114	-0.335	0.176	-0.344	-0.241	-0.028
(L) Posterolateral	-0.157	-0.468ǂ	0.062	-0.355	-0.313	-0.114
(R) Composite	-0.063	-0.122	0.054	-0.195	-0.326	-0.069
(L) Composite	-0.055	-0.180	0.165	-0.164	-0.300	-0.016
Outside Hitters (n = 43)						
(R) Anterior	0.269	0.294	0.232	0.458ǂ	0.008	0.256
(R) Posteromedial	0.275	0.343ǂ	0.265	0.359ǂ	0.174	0.256
(R) Posterolateral	0.217	0.338ǂ	0.153	0.331ǂ	0.137	0.206
(L) Anterior	0.425ǂ	0.175	0.256	0.454ǂ	0.226	0.421ǂ
(L) Posteromedial	0.313ǂ	0.290	0.249	0.418ǂ	0.217	0.312ǂ
(L) Posterolateral	0.279	0.324ǂ	0.195	0.428ǂ	0.209	0.248
(R) Composite	0.168	0.446ǂ	0.270	0.469ǂ	-0.052	0.188
(L) Composite	0.249	0.393ǂ	0.301ǂ	0.537ǂ	0.038	0.273
Middle Blockers and Opposite Side Hitters (n = 41)						
(R) Anterior	-0.261	0.119	0.154	0.107	-0.273	-0.248
(R) Posteromedial	-0.172	0.220	0.212	0.205	-0.439ǂ	-0.183
(R) Posterolateral	-0.371ǂ	0.331ǂ	0.302	0.381ǂ	-0.534ǂ	-0.364ǂ
(L) Anterior	-0.097	0.182	0.120	0.116	-0.099	-0.079
(L) Posteromedial	-0.042	0.247	0.231	0.237	-0.425ǂ	-0.071
(L) Posterolateral	-0.156	0.374ǂ	0.365ǂ	0.362ǂ	-0.368ǂ	-0.143
(R) Composite	-0.435ǂ	0.329ǂ	0.294	0.422ǂ	-0.673ǂ	-0.443ǂ
(L) Composite	-0.374ǂ	0.398ǂ	0.316ǂ	0.465ǂ	-0.636ǂ	-0.384ǂ

ǂp-value < 0.05; (R) = right; (L) = left

Table 4. Comparison of Functional Performance Test Scores (Mean ± SD) Per Player Position and Starter Status

Category	(N)	Standing Long Jump (% ht.)	(R) Single-Leg Hop (% ht.)	(L) Single-Leg Hop (% ht.)	Lower Extremity Functional Test (sec)
Player Position					
Libero and Defensive Specialist	22	0.83 (0.1)	0.65 (0.1)	0.67 (0.1)	111.7 (7.5)
Setter	25	0.80 (0.1)	0.64 (0.1)	0.59 (0.2)	113.0 (16.2)
Outside Hitter	43	0.83 (0.1)	0.68 (0.1)	0.64 (0.1)	108.3 (13.4)
Middle Blocker and Opposite Hitter	41	0.79 (0.1)	0.63 (0.1)	0.62 (0.1)	113.7 (7.7)
Totals	131	0.81 (0.1)	0.65 (0.1)	0.63 (0.1)	111.5 (11.8)
p-value		0.142	0.265	0.174	0.165
Starter					
Yes	49	0.86 (0.1)	0.69 (0.1)	0.68 (0.1)	108.3 (12.4)
No	82	0.78 (0.1)	0.63 (0.1)	0.60 (0.1)	113.3 (11.0)
p-value		0.000	0.002	0.002	0.018

Table 5. Functional Performance Test Scores (Mean ± SD) Per Player Movement Categorization

Functional Test	L/DS/S (n = 51)	OH/MB/Opp (N = 80)	p-value
Standing Long Jump (% ht.)	0.81 (0.11)	0.81 (0.10)	0.817
(R) Single-Leg Hop (% ht.)	0.65 (0.12)	0.65 (0.12)	0.813
(L) Single-Leg Hop (% ht.)	0.62 (0.14)	0.63 (0.13)	0.588
LEFT (seconds)	111.5 (12.3)	111.4 (11.6)	0.968

LEFT = lower extremity functional test; L = libero; DS = defensive specialist; S = setter; OH = outside hitter; MB = middle blocker; Opp = opposite side hitter

formance measures. Of interest though is the finding of a moderate positive correlation between digs/set and (R) or (L) composite scores in the entire population (Table 2). The composite score is often considered a measure of dynamic balance taking into account each of the three arms of the "Y". When evaluating correlations based on player position there was a moderate positive correlation between digs/set and composite scores in liberos/defensive specialists (Table 3b). These athletes frequently have to lunge in horizontal or diagonal positions to make a play on the ball. There were also low to moderate positive correlations between YBT-LQ reach measures and composite scores and digs/set in outside hitters (Table 3b). Many outside hitters are also required to play in the back row; and possessing greater dynamic balance as measured by the YBT-LQ may be advantageous for their defensive assignments. Administering the YBT-LQ may provide strength coaches with actionable information that could influence training programs for liberos, defensive specialists, and outside hitters. Other VB players, setters, middle blockers, and opposite side hitters, may not benefit from YBT-LQ testing. For example, there were many correlations, both positive and negative, between YBT-LQ scores and game performance in middle blockers and opposite side hitters (Table 3b). The inconsistency in correlations challenges a professional's ability to interpret the meaning of the scores for this group of athletes.

FUNCTIONAL TESTS MAY ALSO ALLOW COACHES TO SCREEN FOR ATHLETES AT-RISK FOR INJURY

Utilization of FT that can both discriminate injury risk and that can provide the coaching staff with information about one's athletic ability would be advantageous. The tests administered in this study, the standing long jump (SLJ), the single-leg hop (SLH), the lower extremity functional test (LEFT), and the Lower Quarter Y Balance Test (YBT-LQ), have shown promise as tests to identify female collegiate athletes who are at an increased risk for injury.[3,4,6,37,38] Female Division III collegiate athletes, representing athletes from eight sports (including VB), were nine times more likely to experience a noncontact time-loss injury to the thigh or knee if they had lower standing long jump (SLJ $\leq$ 79% ht.), single-leg hop (SLH $\leq$ 64% each side), and slower extremity functional test (LEFT $\geq$ 118 sec) scores.[4] Female Division III collegiate level VB players with lower SLJ (< 80% height), lower bilateral SLH (< 70% height per side) and side-to-side asymmetry during SLH > 10% were four times more likely to experience a noncontact time-loss injury to the lower quadrant region (i.e., low back and lower extremities).[6] In a separate cohort, female collegiate level VB players were three times more likely to experience a noncontact time-loss injury to the lower quadrant region if SLJ distance was < 80% height, both SLH scores were < 70% height, and the athlete had a prior history of injury.[37] Asymmetrical YBT-LQ reach scores in the anterior direction was associated with a two times greater risk of a noncontact lower extremity injury in a sample of Division I athletes.[38]

VALUE OF TESTS FOR REHABILITATION PROFESSIONALS

The descriptive data presented in this study, as well as previously reported LEFT and YBT-LQ data, may be of use to sports medicine professionals.[26,28] Injury to the lower quadrant region (i.e., low back and lower extremities) is high with over 70 percent of all time-loss injuries occurring in this region.[39] The most common lower quadrant injuries during volleyball games are ankle ligament sprains, internal derangement of the knee, and low back strains.[39] The most common lower quadrant injuries sustained during volleyball practice are ankle ligament sprains, strains of the upper leg, and low back strains.[39] The SLJ, SLH, LEFT, and YBT-LQ tests are frequently used to evaluate deficits due to injury and to track an athlete's recovery.[7,8,40] The descriptive data from this study can provide scores specific to the female collegiate VB player population therefore improving a clinician's ability to make decisions about return to play.

For example, one return to sport testing algorithm recommends that most female athletes should complete the LEFT in 120 seconds or less prior to returning to sport.[8] The results from this study (e.g., mean LEFT score of 111 sec) may influence sports medicine professionals to require collegiate level VB players to complete the LEFT faster than previously published data [8] prior to resuming sport.

STRENGTHS AND LIMITATIONS

The strengths of this study include the large sample size recruited and the collection of FT data at the start of the athlete's season. A potential limitation of this study is that the researchers did not perform an *a priori* reliability study for leg length measurements. The leg length measurements are used to normalize reach measures during YBT-LQ testing. However, Plisky et al did report this procedure had an excellent reliability of 0.99.[41] Another potential limitation for this study is the sample sizes recruited per level of competition. The highest percentage of athletes were recruited from Division III schools. Collecting data from additional athletes who compete for Division II or NAIA schools may have allowed for evaluating correlations based on level of competition. Also, this study did not recruit VB players from either Division I or community college levels. While there are likely similarities in test performance between the sample in this study and athletes from the Division I or community college levels, coaches and clinicians should use caution when applying normative data to those groups.

CONCLUSION

The results of this study indicate that there are low to moderate correlations between some preseason functional test scores and some game statistics. Scores, particularly those that demonstrated moderate correlations, can be used by a coach/strength coach for talent identification and to inform training program design. The descriptive data presented in this study may help sports medicine professionals when evaluating measures of functional performance during a course of rehabilitation.

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The authors have no conflicts of interest to declare.

Submitted: April 12, 2021 CDT, Accepted: April 24, 2022 CDT

REFERENCES

1. Manske R, Reiman M. Functional performance testing for power and return to sports. *Sports Health*. 2013;5(3):244-250. doi:10.1177/1941738113479925

2. Reiman M, Manske R. *Functional Testing in Human Performance*. Human Kinetics; 2009.

3. Butler RJ, Lehr ME, Fink ML, Kiesel KB, Plisky PJ. Dynamic balance performance and noncontact lower extremity injury in college football players: an initial study. *Sports Health*. 2013;5(5):417-422. doi:10.1177/1941738113498703

4. Brumitt J, Heiderscheit BC, Manske RC, et al. Lower extremity functional tests and risk of injury in division iii collegiate athletes. *Int J Sports Phys Ther*. 2013;8(3):216-227.

5. Brumitt J, Heiderscheit BC, Manske RC, Niemuth PE, Mattocks A, Rauh MJ. Preseason functional test scores are associated with future sports injury in female collegiate athletes. *J Strength Cond Res*. 2018;32(6):1692-1701. doi:10.1519/jsc.0000000000002243

6. Brumitt J, Mattocks A, Loew J, Lentz P. Preseason functional performance test measures are associated with injury in female college volleyball players. *J Sport Rehabil*. 2020;29(3):320-325. doi:10.1123/jsr.2018-0179

7. Davies GJ, Zillmer DA. Functional progression of a patient through a rehabilitation program. *Orthop Phys Ther Clin N Am*. 2000;9(2):103-117.

8. Davies GJ, McCarty E, Provencher M, Manske RC. ACL return to sport guidelines and criteria. *Curr Rev Musculoskelet Med*. 2017;10(3):307-314. doi:10.1007/s12178-017-9420-9

9. Lehr ME, Plisky PJ, Butler RJ, Fink ML, Kiesel KB, Underwood FB. Field-expedient screening and injury risk algorithm categories as predictors of noncontact lower extremity injury. *Scand J Med Sci Sports*. 2013;23(4):e225-e232. doi:10.1111/sms.12062

10. Myer GD, Paterno MV, Ford KR, Quatman CE, Hewett TE. Rehabilitation after anterior cruciate ligament reconstruction: criteria-based progression through the return-to-sport phase. *J Orthop Sports Phys Ther*. 2006;36(6):385-402. doi:10.2519/jospt.2006.2222

11. Boldt M, Gregory D, Jaffe D, et al. Relationship between body composition and performance measures in NCAA division III women's volleyball players. *J Strength Cond Res*. 2011;25(Suppl 1):S79-S80.

12. Bunn JA, Ryan GA, Button GR, Zhang S. Evaluation of strength and conditioning measures with game success in division I collegiate volleyball: a retrospective study. *J Strength Cond Res*. 2020;34(1):183-191. doi:10.1519/jsc.0000000000002181

13. McGill SM, Andersen JT, Horne AD. Predicting performance and injury resilience from movement quality and fitness scores in a basketball team over 2 years. *J Strength Cond Res*. 2012;26(7):1731-1739. doi:10.1519/jsc.0b013e3182576a76

14. Sattler T, Sekulic D, Hadzic V, et al. Vertical jumping tests in volleyball: reliability, validity, and playing-position specifics. *J Strength Cond Res*. 2012;26(6):1532-1538.

15. Sattler T, Hadžić V, Dervišević E, Markovic G. Vertical jump performance of professional male and female volleyball players: effects of playing position and competition level. *J Strength Cond Res*. 2015;29(6):1486-1493. doi:10.1519/jsc.0000000000000781

16. Schaal M, Ransdell LB, Simonson SR, Gao Y. Physiologic performance test differences in female volleyball athletes by competition level and player position. *J Strength Cond Res*. 2013;27(7):1841-1850. doi:10.1519/jsc.0b013e31827361c4

17. Plisky PJ, Gorman PP, Butler RJ, et al. The reliability of an instrumented device for measuring components of the star excursion balance test. *N Am J Sports Phys Ther*. 2009;4(2):92-99.

18. Greenberger HB, Paterno MV. Relationship of knee extensor strength and hopping test performance in the assessment of lower extremity function. *J Orthop Sports Phys Ther*. 1995;22(5):202-206. doi:10.2519/jospt.1995.22.5.202

19. Brumitt J, Heiderscheit BC, Manske RC, et al. Off-season training habits and preseason functional test measures of division iii collegiate athletes: a descriptive report. *Int J Sports Phys Ther*. 2014;9(4):447-455.

20. Markovic G, Dizdar D, Jukic I, et al. Reliability and factorial validity of squat and countermovement jump tests. *J Strength Cond Res*. 2004;18(3):551-555.

21. Koch AJ, O'Bryant HS, Stone ME, et al. Effect of warm-up on the standing broad jump in trained and untrained men and women. *J Strength Cond Res*. 2003;17(4):710-714.

22. Manske RC, Smith B, Wyatt F. Test retest reliability of lower extremity functional tests after a closed kinetic chain isokinetic testing bout. *J Sport Rehabil*. 2003;12(2):119-132. doi:10.1123/jsr.12.2.119

23. Unger CL, Wooden MMJ. Effect of foot intrinsic muscle strength training on jump performance. *J Strength Cond Res*. 2000;14(4):373-378.

24. Ross MD, Langford B, Whelan PJ. Test-retest reliability of 4 single-leg horizontal hop tests. *J Strength Cond Res*. 2002;16(4):617-622.

25. Bremander AB, Dahl LL, Roos EM. Validity and reliability of functional performance tests in meniscectomized patients with or without knee osteoarthritis. *Scand J Med Sci Sports*. 2007;17(2):120-127.

26. Brumitt J, Wilson V, Ellis N, Petersen J, Zita CJ, Reyes J. Preseason lower extremity functional test scores are not associated with lower quadrant injury – a validation study with normative data on 395 division iii athletes. *Intl J Sports Phys Ther*. 2018;13(3):410-421. doi:10.26603/ijspt20180410

27. Tabor MA, Davies GJ, Kernozek TW, Negrete RJ, Hudson V. A multicenter study of the test-retest reliability of the lower extremity functional test. *J Sport Rehabil*. 2002;11(3):190-201. doi:10.1123/jsr.11.3.190

28. Brumitt J, Patterson C, Dudley R, Sorenson E, Hill G, Peterson C. Comparison of lower quarter y-balance test scores for female collegiate volleyball players based on competition level, position, and starter status. *Intl J Sports Phys Ther*. 2019;14(3):415-423. doi:10.26603/ijspt20190415

29. Mason RO, Lind DA, Marchal WG. *Statistics: An Introduction*. Harcourt Brace Jovanovich, Inc; 1983.

30. Weber JC, Lamb DR. *Statistics and Research in Physical Education*. CV Mosby Co; 1970.

31. Almuzaini KS, Fleck SJ. Modificationn of the standing long jump test enhances ability to predict anaerobic performance. *J Strength Cond Res*. 2008;22(4):1265-1272. doi:10.1519/jsc.0b013e3181739838

32. Mann JB, Bird M, Signorile JF, Brechue WF, Mayhew JL. Prediction of anaerobic power from standing long jump in NCAA division IA football players. *J Strength Cond Res*. 2021;35(6):1542-1546. doi:10.1519/jsc.0000000000004043

33. Ikeda Y, Sasaki Y, Hamano R. Factors influencing spike jump height in female college volleyball players. *J Strength Cond Res*. 2018;32(1):267-273. doi:10.1519/jsc.0000000000002191

34. Kockum B, Heijne AILM. Hop performance and leg muscle power in athletes: reliability of a test battery. *Phys Ther Sport*. 2015;16(3):222-227. doi:10.1016/j.ptsp.2014.09.002

35. Sullivan SW, Fleet NA, Brooks VA, Bido J, Nwachukwu BU, Brubaker PH. Comparison of different functional tests for leg power and normative bilateral asymmetry index in healthy collegiate athletes. *Open Access J Sports Med*. 2021;12:119-128. doi:10.2147/oajsm.s315162

36. Lopes TJA, Simic M, Alves D de S, et al. Physical performance measures of flexibility, hip strength, lower limb power, and trunk endurance in healthy navy cadets: normative data and differences between sex and limb dominance. *J Strength Cond Res*. 2021;35(2):458-464. doi:10.1519/jsc.0000000000002365

37. Patterson CS, Dudley RI, Sorenson E, Brumitt J. Preseason functional tests discriminate injury risk in female collegiate volleyball players. *Phys Ther Sport*. Published online 2021.

38. Smith CA, Chimera NJ, Warren M. Association of y balance test reach asymmetry and injury in division I athletes. *Med Sci Sports Exerc*. 2015;47(1):136-141. doi:10.1249/mss.0000000000000380

39. Agel J, Palmieri-Smith RM, Dick R, et al. Descriptive epidemiology of collegiate women's volleyball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. *J Athl Train*. 2007;42(2):295-302.

40. Garrison JC, Bothwell JM, Wolf G, et al. Y balance test anterior reach symmetry at three months is related to single leg functional performance at time of return to sports following anterior cruciate ligament reconstruction. *Int J Sports Phys Ther*. 2015;10(5):602-611.

41. Plisky PJ, Rauh MJ, Kaminski TW, Underwood FB. Star excursion balance test as a predictor of lower extremity injury in high school basketball players. *J Orthop Sports Phys Ther*. 2006;36(12):911-919. doi:10.2519/jospt.2006.2244