International Journal of EXERCISE SCIENCE

Original Research

Correlation between Lower-body Strength and Performance Tests among Female NCAA Division II Softball Players

ELIZABETH L. ALFARO†[1], JOCAROL E. SHIELDS†[1], JAVIER A. ZARAGOZA†[1,2], MARCEL LOPES DOS SANTOS†[1], J. JAY DAWES‡[1], and DOUGLAS B. SMITH‡[1]

[1]School of Kinesiology, Applied Health, and Recreation, Oklahoma State University, Stillwater, OK, USA; [2]Human Performance Lab, School of Exercise & Sport Science, University of Mary Hardin-Baylor, Belton, TX, USA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 17(4): 212-219, 2024. Softball is a sport that requires speed, agility, and lower-body power to be successful. Accordingly, strength and conditioning programs have focused on improving speed and lower-body power, which are beneficial to players performing softball-related tasks. The purpose of this study was to determine the correlation between absolute and relative lower-body strength to performance measures among female collegiate softball players. Archived data collected during pre-season performance testing for twenty-one (n = 21) NCAA Division II collegiate softball players was used for this analysis. Measurements included countermovement jump (CMJ), broad jump (BJ), linear speed (LS), 505 test for change of direction speed (COD), and shuttle runs. Absolute lower body strength (ALBS) was measured using a 3-repetition maximum hex-bar deadlift (HBDL) and body weight was used to calculate relative lower body strength (RLBS) of each player. Pearson's correlation coefficients were used to relate measures of lower body strength to each performance test. Significant ($p \leq 0.05$) large to moderate correlations were discovered between RLBS and COD (505L: r = -0.59, 505R: r = -.63), 300 yard (yd) shuttle run time (trial 1: r = -0.47, trial 2: -0.50), and lower-body power (CMJ: r = 0.48, BJ: r = 0.52). ALBS was correlated only to the BJ (r = 0.43). The results suggest that relative strength is related more with COD, shuttle run, and lower-body power when compared to absolute strength. Therefore, strength and conditioning professionals should consider measures of RLBS when administering softball specific tests for developing and implementing a successful strength program in collegiate softball.

KEY WORDS: Agility, power, sprint, speed, vertical jump, women

INTRODUCTION

Softball is a sport that requires lower-body power and multidirectional speed in order to be successful. Offensively speaking, these physical qualities are paramount in terms of generating power when batting, as well as when running bases (4). From a defensive perspective, these attributes may also help improve a player's fielding range, which is useful in preventing the opposition from scoring (4). Consequently, improving both speed and power are of significant importance in many strength and conditioning programs aimed at improving softball performance (4, 7, 8). However, further research is needed to determine the influence of relative and absolute strength on measures of lower- body power and speed within collegiate softball players. A better understanding of strength among collegiate softball players is related to power and speed development may be useful to strength and conditioning coaches when developing a periodized training program for improving softball performance.

Previous research has examined the correlations between lower-body strength, power, and speed among female athletes (4, 5, 8, 9, 12, 15). One study (12) found significant correlations between lower-body strength (absolute and relative) to measures of power and change of direction speed among a group of ten (n = 10) NCAA Division II female volleyball players. Similarly, another study (1) investigated the relationship between lower-body strength and predictors of athletic performance among a group of seventeen (n = 17) NCAA Division II female soccer players. Their results suggested that absolute and relative strength improve power, agility, and speed performance. To our knowledge, only one study has investigated the relationship between relative strength on measures of lower-body power, vertical jump height, linear speed, and change of direction (COD) ability among softball players (7). The authors reported significant correlations between relative lower-body strength (1RM back squat/body mass) to speed and COD ability (r = -0.73 — 0.85). However, this study did not investigate relationships between absolute strength and lower-body power, speed, and COD ability. Having a better understanding of how these variables may affect performance may be useful in the development of strength and conditioning programs within this population.

The purpose of this study was to investigate the correlation between absolute and relative lower-body strength to lower-body power [countermovement jump (CMJ) and broad jump (BJ)], linear speed, shuttle runs, and COD ability among a group of NCAA Division II collegiate softball players. The researchers hypothesized that both absolute and relative lower body strength would be significantly correlated with CMJ, BJ, linear speed, shuttle runs, and COD in Division II collegiate softball players. The results of this study may be helpful to strength and conditioning professionals when designing and implementing strength programs in collegiate softball. Additionally, a better understanding of how lower-body strength relates to softball specific tests could potentially assist practitioners in developing a year-round periodization plan to enhance on field performance.

METHODS

Participants

A power analysis conducted with G*Power 3.1.9.7 (Universität Kiel, Germany) determined that 84 participants were needed in the present study for a power of 0.80, with an effect size of 0.3 and an a = 0.05. While this recommendation is statistically appropriate, this exceeds the total number of individuals available on the team analyzed. While this may list some statistical inferences, it is common practice, and necessary, within studies utilizing collegiate athletes (1,5,8,9,12) to gain greater insights into performance within this populations. Archived data for twenty-one (*n* = 21) NCAA Division II collegiate softball players (age = 20 ± 1 years, height = 166.6 ± 6.3 cm, and body mass = 66.2 ± 11.1 kg) was used for this study. Data was collected by the university's athletic performance staff as part of the team's normal pre-season testing procedures. Consequently, the tests performed in this testing battery were dictated by the coaching staff and not the investigators. Written informed consent was distributed and obtained at the beginning of the academic year via the university's athletic department. Prior to the commencement of this analysis, a university institutional ethics committee approved the use of this archival data for analysis (IRB#: ED-19-117-STW). The study was in accordance with the procedures of the Helsinki Declaration. Additionally, research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (6).

Protocol

Archived data collected during pre-season performance testing was utilized for this investigation. The testing took place over two days during practice time, with 48 hours between sessions. On the first day, anthropometric variables (height and body mass), lower body power (CMJ and BJ), COD, linear speed, and 300 yd shuttle runs were completed outdoors on grass. Lower body strength was determined on the second day in the university weight room using a 3RM hex bar deadlift (HBDL) assessment to estimate the players' one-repetition maximum (1RM). Each session included a ten-minute standardized warm-up consisting of sport-specific dynamic stretching and light running activities. Afterward, players were given full instructions on how to perform each assessment. Subjects were allowed two practice trials prior to each performance-based assessment. Assessments were completed in the following order:

Height and Body Mass: At the start of the testing session, height (cm) and weight (kg) were measured using a doctor's beam scale (Cardinal, St Lois, Missouri) and a portable stadiometer (SECA).

Countermovement Jump Height: CMJ was measured using a jump mat (Just Jump, Pro Biotics Inc., Huntsville, AL, USA). Players were asked to stand on the center of the mat with their arms extended above their heads. When ready, players performed a maximal effort vertical jump using a countermovement arm-swing. Players were given three attempts with a minimum of 10 seconds (s) allowed between jumps to minimize the impact of fatigue on subsequent attempts (1). The player's best jump was recorded as their final score.

Broad Jump Distance: The BJ was performed three times, with the best jump recorded as the player's final score. Players stood at the starting line with their feet hip to shoulder- width apart. When ready, players performed a maximal effort horizontal jump using a countermovement arm-swing. Players were allowed a minimum of 30 seconds between jumps. The distance between the start line and the player's back heel was recorded, with the maximum distance between trials being used for analysis.

505 Test: This test was used to assess the player's change of direction speed (COD). Players were required to build up to full speed over a 10 meter (m) distance and upon passing the electronic

timing system (TC-System, Brower Timing Systems, Draper, UT, USA), sprint 5 m, make a 180-degree turn, and then sprint 5 m back through the timing gate to complete the test. Players were instructed to perform two trials cutting off each leg (i.e., two trials with left leg lead and two trials with right leg lead). The order in which they performed these trials was randomized, with some players performing a left leg cut, before a right and vice versa. The best score from each side was recorded to the nearest 0.10 sec.

Linear Speed: To assess linear speed, players were required to sprint 60ft (18.28m) as fast as possible. Split times at the 30ft (9.14m) and 60ft (18.28m) markers were recorded using an electronic timing system (TC-System, Brower Timing Systems, Draper, UT, USA). The best of three trials was recorded to the nearest 0.10 sec.

300 yard (yd) shuttle run: The 300 yd (274.32m) shuttle was utilized to measure anaerobic capacity. Players performed this test twice, with five minutes of rest between trials. Both times were recorded to the nearest 0.10 sec. using a stopwatch. The testing procedures have previously been detailed (11). Players began on the starting line and on the "go" signal, sprinted 25yds (22.86m), to the second marked line, then rapidly turned and sprinted back to the starting line. This process was completed for six continuous rounds without stopping. Both times were used for analysis to determine if there was a relationship between RLBS and fatigue between 300m bouts.

Lower-body Strength: Absolute lower-body strength (ALBS) was measured using a 3RM hex bar deadlift (HBDL) test. Each player performed warm up sets with progressively heavier loads as described in a previous study (1): 5 repetitions at 30% of their one-repetition maximum (1RM), 8 repetitions at 50% 1RM, 6 repetitions at 60% 1RM, 5 repetitions at 70% 1RM, and 3 repetitions at 80% 1RM, resting 3 min between each trial. Once the final 3RM was performed, it was converted via previously established equations to a predicted 1RM for the individual's absolute strength measure (1). If a player failed prior to achieving a 3RM but were able to perform a 1-2 RM, this attempt was used to either determine or estimate the 1RM. Since the purpose of the 3RM was to estimate the 1RM, this method was employed to minimize the stress on the athletes, while still obtaining accurate strength data for analysis. Relative lower- body strength (RLBS) was calculated for each player by dividing kilograms lifted by body mass.

Statistical Analysis

Data was analyzed using IBM SPSS statistics (Version 24.0, IBM Corporation, New York, NY, USA). Descriptive statistics (mean ± SD) was calculated for each variable. Data sets were tested for normality using the Shapiro-Wilk test. Pearson's correlation coefficients were used to correlate the absolute and relative lower-body strength measures of the hex bar deadlift (HBDL) to performance tests. Statistical analysis was set at $p < 0.05$ level. As recommended by Hopkins (3), the strength of each correlation value are as follows: 0 to 0.30 or 0 to -0.30 was low; 0.31 to 0.49 or -0.31 to -0.49 was moderate; 0.50 to 0.69 or -0.50 to -0.69 was large; 0.70 to 0.89 or -0.70 to -0.89 was very large; and 0.90 to 1.0 or -0.90 to -1.0 was near perfect.

RESULTS

Abbreviations used in this section are provided in Table 1. Descriptive statistics for all performance measures are shown in Table 2 as mean ± standard deviation (SD). Correlations for absolute and relative lower-body strength in relation to measures of performance are shown in Table 3. The statistical analysis revealed significant correlations between RLBS and all performance measures ($p \leq 0.05$, $p \leq 0.01$) except for linear speed while ALBS had only one significant correlation with BJ ($p \leq 0.05$).

Table 1. Abbreviations used in results.

Variable	Abbreviation
Countermovement Jump	CMJ
Broad Jump	BJ
505 Test (right/left)	505 (R/L)
Linear Speed (30ft/60ft)	LS (30/60)
Absolute Lower-body Strength	ALBS
Relative Lower-body Strength	RLBS

Table 2. Descriptive Statistics for performance measures.

Variable	Mean ± SD
CMJ (cm)	48.2 ± 5.4
BJ (cm)	197.1 ± 20.4
505R (s)	2.5 ± 0.2
505L (s)	2.5 ± 0.1
LS 30 (s)	2 ± 0.1
LS 60 (s)	3.4 ± 0.2
Shuttle 1 (s)	71.4 ± 5.8
Shuttle 2 (s)	80.3 ± 6.0
ALBS (kg)	80.3 ± 20.0
RLBS (HBDL kg/BM kg)	1.24 ± 0.3

Table 3. Correlation analysis between strength and performance measures.

	CMJ	BJ	505R	505L	LS 30	LS 60	Shuttle 1	Shuttle 2
ALBS	**.196**	**.434***	**-.396**	**-.321**	**-.111**	**-.052**	**-.107**	**-.085**
p	.39	.05	.08	.16	.63	.82	.64	.71
95% CI	[-.26, .58]	[.003, .73]	[-.71, .04]	[-.66, .13]	[-.52, .34]	[-.47, .39]	[-.52, .34]	[-.50, .36]
RLBS	**.483***	**.518***	**-.626****	**-.590****	**-.379**	**-.362**	**-.466***	**-.500***
p	.03	.02	.002	.005	.09	.12	.03	.02
95% CI	[.07, .76]	[.11, .78]	[-.83, -.27]	[-.81, -.21]	[-.70, .06]	[-.69, .08]	[-.75, -.04]	[-.76, -.09]

Note. ** Significant at the 0.01 level (2-tailed); * Significant at the 0.05 level (2-tailed)

DISCUSSION

The purpose of this study was to identify correlations between absolute lower-body strength (ALBS) and relative lower-body strength (RLBS) to measures of lower-body power (CMJ and BJ), COD, linear speed, and shuttle runs among NCAA Division II softball players. The primary findings of this study revealed no significant correlations between ALBS and any measure of athletic performance except for a moderate correlation with BJ. In contrast, for RLBS, there was a significant negative correlation with COD and no significant correlation between RLBS and linear speed. However, there was a moderate to large correlation between RLBS and shuttle runs, and a moderate to large correlation between RLBS and lower-body power. These results suggest that improving RLBS, by decreasing body weight or increasing strength, may support improvements in COD, shuttle runs, and lower-body power. As such, this study provides valuable evidence to strength and conditioning professionals to make potential adjustments when training in order to optimize performance in softball.

The ability to change direction rapidly and efficiently is necessary in softball (4, 7). Previously, only one study has noted the correlation between RLBS, COD, and linear speed in softball players. In the current study, large, negative correlations were seen between RLBS and 505R (r = -0.63) and 505L (r =-0.59). This is similar to findings from a previous study (8) which longitudinally tracked the correlation between RLBS and COD and identified very large, negative correlations (r = -0.73 — -0.85). Although not specific to softball players, other data suggest similar correlations in collegiate female athletes (1, 12). No correlation between RLBS and linear speed was identified in this current study. This contrasts with a previous study with softball players that found significant, very large, negative correlations with RLBS and linear speed (r = -0.80 — -0.87) (8). This could be attributed to differences in RLBS and/or linear speed times, and/or testing procedures (e.g., running towards a base versus no base could elicit motivational differences). Similar to COD, other studies show correlations between RLBS and linear speed (1, 8). Recommendations for improving RLBS to improve linear speed have included resistance strength/power training, neuromuscular training, and interval training (10, 13, 14).

It has been noted that RLBS may play a significant role in the ability for a player to perform maximal effort jumps (2, 6, 13, 14). As such, some research has sought to identify correlations between RLBS and measures of power through jump assessments. In fact, previous research (1) has identified large correlations between RLBS and vertical jump (r = 0.54). However, other findings have found dissimilar results (8, 12). The current study adds to the existing body of literature showing significant, moderate to large correlations between RLBS and CMJ (r = 0.48) and BJ (r = 0.52).

Another less common attribute in softball is anaerobic endurance with COD ability (e.g., shuttle run). In sports where the shuttle run is routine and practical, similar correlations exist (13, 14). Turner and colleagues reported that greater RLBS may improve a soccer player's ability to control his/her body during acceleration and deceleration, such as sprinting and turning, thus suggesting that it may provide greater acceleration, acceptance of the high forces, and reduce risks for injury. To the knowledge of the authors, this is the first study examining the correlation

between 300 yd shuttle run performance and RLBS in softball players of any level. Tasks that may require similar attributes include runners caught between bases or defensive fielders quickly transitioning to bunting situations. In this study, RLBS was moderate to largely correlated with shuttle run performance (shuttle 1: r = -0.47, shuttle 2: r = -0.50). The correlation may be explained by the training regimen completed by the team, to which researchers did not have access. If a player consistently trains or tests a specific way, adaptations will be made specific to that type of training or test, regardless of the game demands.
As with all research, this current study is not without limitations. While the sample size in this study is larger than in previous investigations (8, 12), it is still relatively small. Consequently, correlations between certain variables may have reached significance with a larger sample size. Furthermore, this study was limited to one NCAA Division II softball team. Indeed, future studies should investigate these correlations among players at different playing levels and should consider collecting data across multiple seasons to increase the sample size. Factors such as the level of player, training experience, and age must be considered when determining the strength of the relationship between variables.

The present study sought to determine the correlation between ALBS and RLBS to performance measurements of lower-body power, COD, linear sprint, and shuttle runs. Based on our findings, it is plausible to suggest that lower body strength plays a vital role in softball-specific performance measures. Furthermore, relative lower body strength significantly relates to more measures of power, speed, and agility than lower body absolute strength. Importantly, this information provides tangible support to strength professionals and coaches for the examination and emphasis of lower body strength training in collegiate athletics. Specifically in sports, which are comprised of velocity driven or dynamic movement components. Future research should include a longitudinal tracking of correlations among players throughout the course of an entire season (pre-season, in-season, off-season) to determine if the results will remain the same or change.

REFERENCES

1. Andersen E, Lockie RG, Dawes JJ. Relationship of absolute and relative lower-body strength to predictors of athletic performance in collegiate women soccer players. Sports (Basel) 6(4): 106, 2018.

2. Hedrick A. Training for high level performance in women's collegiate volleyball: Part I training requirements. Strength Cond J 29(6): 50–53, 2007.

3. Hopkins WG. A new view of statistics. Internet Society for Sports Science. Retrieved from: https://www.sportsci.org/resource/stats/; 2000.

4. Magrini M, Dawes JJ, Spaniol F, Roberts A. Speed and agility training for baseball/softball. Strength Cond J 40(1): 68-74, 2018.

5. Marques MC, Tillaar RV, Vescovi JD, Gonzalez-Badillo JJ. Changes in strength and power performance in elite senior female professional volleyball players during the in-season: a case study. J Strength Cond Res 22(4): 1147-1155, 2008.

6. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. Int J Exerc Sci 12(1): 1-8, 2019.

7. Nimphius S. Developing strength and power for fastpitch softball. NSCA Perform Train J 4(1): 17-20, 2005.

8. Nimphius S, McGuigan MR, Newton RU. Relationship between strength, power, speed, and change of direction performance of female softball players. J Strength Cond Res 24(4): 885–895, 2010.

9. Pereira LA, Nimphius S, Kobal R, Kitamura K, Turisco LAL, Orsi RC, Cal Abad CC, Loturco I. Relationship between change of direction, speed, and power in male and female national olympic team handball athletes. J Strength Cond Res 32(10): 2987–2994, 2018.

10. Peterson MD, Alvar BA, Rhea MR. The contribution of maximal force production to explosive movement among young collegiate athletes. J Strength Cond Res 20(4): 867–873, 2006.

11. Sporis G, Ruzic L, Leko G. The anaerobic endurance of elite soccer players improved after a high-intensity training intervention in the 8-week conditioning program. J Strength Cond Res 22(2): 559–566, 2008.

12. Tramel W, Lockie RG, Lindsay KG, Dawes JJ. Associations between absolute and relative lower body strength to measures of power and change of direction speed in division II female volleyball players. Sports (Basel) 7(7): 160, 2019.

13. Turner E, Munro AG, Comfort P. Female soccer: Part 1—a needs analysis. Strength Cond J 35(1): 51-57, 2013.

14. Turner E, Munro AG, Comfort P. Female soccer: Part 2—training considerations and recommendations. Strength Cond J 35(1): 58–65, 2013.

15. Vescovi JD, McGuigan MR. Relationships between sprinting, agility, and jump ability in female athletes. J Sport Sci 26(1): 97-107, 2008.