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Physical Performance Assessments of Strength and Power in Women Collegiate Athletes

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ABSTRACT

International Journal of Exercise Science 14(6): 984-993, 2021. Limited research exists on physical performance assessments for women collegiate athletes. The current cross-sectional study compared field-based tests of muscular strength and power and investigated their relationship. Sports included field hockey, volleyball, soccer, and softball. Tests of one repetition maximum (1-RM) back squat, 1-RM bench press, vertical jump, and standing long jump were administered. A one-way analysis of variance (ANOVA) assessed differences across sports. Bivariate Pearson correlation coefficients examined relationships among tests. It was hypothesized sports with a higher anaerobic nature (volleyball, softball) would outperform those with higher aerobic nature (field hockey, soccer). Softball had the highest 1-RM bench press and 1-RM back squat ($p < 0.001$) compared to field hockey, volleyball, and soccer. Further, softball had the highest vertical jump ($p < 0.001$) compared to field hockey and soccer, but did not differ from volleyball. There were no differences across sports for standing long jump. Correlations ($p < 0.001$) existed between 1-RM back squat and 1-RM bench press ($n = 663$, $r = 0.56$), and vertical jump and standing long jump ($n = 160$, $r = 0.64$). Results demonstrate strength and power differences among collegiate women's sports. Softball consistently outperformed others in bench press, back squat, and vertical jump, which may be due to the demand of power embedded in the nature of the sport. These data provide descriptive measures of physical performance assessments and may assist practitioners with goal setting and program design.

KEY WORDS: 1-RM; females; field tests; muscular strength; power

INTRODUCTION

The 1972 passage of Title IX prohibited sex discrimination in educational programs and activities within the United States. As a result, more opportunities for athletic participation by the National Collegiate Athletic Association (NCAA) became available for collegiate women, and since that time, growth in women's intercollegiate athletics has steadily continued. As of 2019, the total number of women's teams competing in NCAA sports outnumbered men's teams (23). Within the NCAA's division structure, the NCAA Division III has the greatest number of institutions with ~25% of the students participating as student-athletes (23). As athletic participation increases, so does the competitive nature of sport, which likely encourages coaches and athletes to seek optimal training strategies for enhanced sport performance. While evidence supports the benefits of strength and power in team sport athletes and standard assessments through which to measure physical performance (20, 37), limited research exists supporting physical performance testing of women collegiate athletes. In order to evaluate the effectiveness of training, practitioners must integrate routine assessments that are specific to the desired adaptations. Muscular strength and power underpin superior athletic performance and are critical points of emphasis in training to enhance performance while reducing the likelihood of injury (35).

Through development of muscular strength and power, athletes are better equipped to perform high intensity movements such as jumping, sprinting, and changing direction (37). Power, defined as the product of force x velocity, is predicated on a foundation of maximal strength that serves as a vehicle through which force producing qualities are developed (37). Force producing capabilities beneficially transfer to sport specific skills, such as swinging a bat or kicking a ball (35). In addition, the likelihood of injury is decreased by simply increasing strength and power, and thus, stability of the musculotendinous structures supporting the joints that are heavily stressed through intense training and competition (14). It is recommended that practitioners strive to induce neuromuscular adaptations conducive to greater strength and power, and closely monitor training through standard and timely assessments. Field-based assessments of physical performance overcome some of the limitations of lab-based testing procedures by providing a practical, cost effective, and time-efficient measure to assess training-induced adaptations.

The most common of maximal strength performance assessments is one repetition maximum (1-RM) testing of the barbell back squat and bench press for lower and upper body strength, respectively (20). In addition, vertical jump and standing long jump are popular field tests of lower body power (20). Considering the influence of force on power output, maximal squat strength has been shown to relate well to vertical jump performance (1, 26, 28, 34). Strength and power can be evaluated in absolute terms or in relative terms in order to normalize the data to bodyweight. Although relative strength and power more strongly relate to sport performance, considerations for absolute measures may benefit practitioners who lack the time and resources to collect valid and reliable anthropometric data. Further, neuromuscular performance can vary with sport, position, level of competition, and individual differences (i.e., sex, age, training status, genetics). Current literature supports the benefits of enhancing neuromuscular performance across an array of athletic populations (28, 35). Collegiate women athletes, in particular, demonstrate improved sport performance with increased strength and power (4, 8, 16, 24, 29). While evidence exists in identifying performance demands and assessments in NCAA DI collegiate women athletes, there is a lack of sufficiently powered studies with adequate sample sizes describing physical performance assessments in NCAA DIII women athletes. Thus, assessment of neuromuscular strength and power within NCAA DIII women athletes would assist with the establishment of descriptive measures and be of benefit to the strength and conditioning practitioner.

The purpose of the current cross-sectional study was to investigate absolute measures of strength and power assessments in NCAA DIII women athletes from four different sports. Specifically, this research aims to determine whether or not a significant relationship exists between strength-oriented tests and power-oriented tests of horizontal and vertical jumping ability. It was hypothesized that physical performance assessments would vary among sports depending upon the sport-specific physiological demands. Sports with a higher anaerobic nature were expected to display greater strength and power when compared to those with higher aerobic demands. Specifically, volleyball, and softball were hypothesized to outperform soccer and field hockey in strength and power.

METHODS

Participants
National Collegiate Athletic Association Division III women athletes from field hockey (FH, n = 394), softball (SB, n = 187), soccer (SOC n = 161), and volleyball (VB, n = 131) participated. All athletes were under the direction of a certified strength and conditioning specialist (CSCS) and were following sport-specific training regimens with neuromuscular demands particular to their sport. Further, as part of their training program, athletes were taught proper lifting technique and deemed proficient before being permitted to test. All athletes completed a medical history form and were cleared for intercollegiate athletic participation. An athlete was only excluded from participating if unable to meet the criteria. Risks and benefits were explained, and an institutionally approved consent form was signed prior to participation. This study was conducted according to the Declaration of Helsinki guidelines. All procedures involving human subjects were approved by the university's institutional review board for use of human subjects in research. Written consent was obtained from all subjects. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (22).

Protocol
Data were collected over a ten-year period as part of an organized testing program during the off-season training period. Each athlete performed selected tests over two non-consecutive days while experienced strength coaches supervised the standardized warm-up and tests according to pre-established protocols (19). Session 1 testing included vertical jump, standing long jump, and 1-RM back squat. Session 2 testing consisted 1-RM bench press and sport-specific testing, which was administered by the head sport coach. Volleyball did not perform standing long jump as it was deemed to lack sport-specificity.

Lower Body Power: Athletes performed a standardized supervised warm-up, which consisted of 5 minutes of light jogging followed by 10 minutes of dynamic whole-body stretches. The vertical jump and standing long jump tests were used as performance assessments of lower body power. For the vertical jump test, the Vertec (Sports Imports, Inc., Columbus, OH, USA) was used.

Athletes were instructed to use a countermovement of the body and arms. For the standing long jump, a marked mat (SBP Products, Montreal, Canada) was used. In an explosive movement with an arm swing, athletes propelled forward and landed on the mat. Distance was measured from the toes at the push-off to the location of the rearmost heel strike. For both the vertical jump and the standing long jump, if the third attempt was greater than the first two, another attempt was allowed until a decrease in jump height or distance was observed with no more than five maximum trials of either jump allowed. A 10-second rest separated each jump to reduce any potential impact from the previous jump (12).

Maximum Strength: Lower body strength was assessed approximately 10 minutes following completion of jumping tests. For back squat and bench press testing, subjects performed an incremental warm up based upon their previously completed test results. Testing was conducted using standard weight lifting power racks for the bench press and back squat (Power Lift, Jefferson, IA, USA). Athletes took a timed rest of 3 minutes between maximal attempts. After 2 failures, testing was stopped, and the best lift was recorded. Squat depth, for all testing, was visually assessed by certified strength and conditioning specialists (CSCS) and supplemented with auditory signaling from a safety squat beeper (Bigger, Faster, Stronger, Salt Lake City, UT, USA) to ensure that each athlete squatted to the desired depth of 90° knee flexion.

Statistical Analysis

Descriptive statistics (mean ± SD) were computed for physical performance assessments. A one-way analysis of variance (ANOVA) was used to assess differences in tests across sports. Post-hoc analysis using Bonferroni Correction was performed to determine differences among the sports. Further, Bivariate (Pearson) correlation coefficients (r) and effect sizes reported as Eta squared ($\eta 2$) were calculated to determine significant relationships among variables of interest. The magnitudes of correlations (weak: 0.1, moderate: 0.3, strong: > 0.5) and effect sizes (small: 0.01, medium: 0.05, large: 0.14) were defined according to Cohen (5). All statistical procedures were conducted using the Statistical Package for the Social Sciences (SPSS version 25; IBM Corp, Armonk, NY) was used for data analysis ($p < 0.05$).

RESULTS

Physical performance assessments are presented in Table 1. Softball had greater values for bench press, back squat, and vertical jump than field hockey or soccer. Softball also performed better than volleyball on 1-RM tests of bench press and back squat. Further, field hockey had a greater 1-RM back squat than soccer, but soccer had a higher vertical jump. No difference across sports existed for standing long jump.

Table 1. Physical performance assessment results.

	Field Hockey	Softball	Soccer	Volleyball	Effect Size (η^2)	Power
Bench Press (kg)	43.9 ± 7.4 (*n* = 335)	46.1 ± 9.5[a] (*n* = 184)	42.9 ± 7.9 (*n* = 161)	42.7 ± 7.5 (*n* = 124)	0.023	0.97
Back Squat (kg)	78.4 ± 16.44 (*n* = 328)	83.8 ± 17.9[b] (*n* = 187)	72.5 ± 13.9 (*n* = 151)	76.1 ± 14.0[c] (*n* = 91)	0.053	1.0
Vertical Jump (cm)	44.1 ± 6.5 (*n* = 394)	52.5 ± 4.5[d] (*n* = 27)	46.2 ± 6.3[e] (*n* = 106)	50.8 ± 7.2[d] (*n* = 131)	0.162	1.0
Standing Long Jump (cm)	174.4 ± 16.5 (*n* = 224)	191.4 ± 11.9 (*n* = 13)	178.1 ± 16.5 (*n* = 62)	N/A	0.013	0.41

Values are mean ± SD; Order of significant differences ($p < 0.05$) for each assessment: 1-RM BP: [a]SB > FH, SOC, VB; 1-RM BS: [b]SB > FH, [c]VB > SOC; VJ: [d]SB, VB > [e]SOC > FH; SLJ: FH, SOC, SB.

Significant positive correlations existed between standing long jump and vertical jump (r = 0.636, $p < 0.001$), 1-RM bench press and 1-RM back squat (r = 0.563, $p < 0.001$), and 1-RM bench press and standing long jump (r = 0.354, p = 0.002). No relationship existed between 1-RM back squat and vertical jump, or 1-RM back squat and standing long jump (Table. 2).

Table 2. Correlations among physical performance assessments.

	1-RM BP	1-RM BS	VJ	SLJ
1-RM BP	1	0.563* $p < 0.001$ *n* = 663	0.155 *n* = 193	0.354* p = 0.002 *n* = 77
1-RM BS		1	0.083 *n* = 191	0.229 *n* = 69
VJ			1	0.636* $p < 0.001$ *n* = 160
SLJ				1

BP: bench press; BS: back squat; VJ: vertical jump; SLJ: standing long jump.

DISCUSSION

In support of the original hypothesis, softball athletes displayed greater upper body strength (1-RM bench press) and lower body strength (1-RM back squat) than field hockey, soccer, and volleyball athletes. Further, lower body power (vertical jump) was greater for softball compared to field hockey and soccer athletes. This is not surprising, as strength and power are two integral components of softball performance (36). In fact, previous research with baseball athletes has reported lower body strength and power (1-RM back squat, vertical jump, respectively) and upper body strength (1-RM bench press) correlate to bat swing velocity, home runs, total bases, and stolen bases (7, 11, 21, 33). In addition, vertical jump has been reported as the best predictor of defensive fielding performance (17). Softball athletes are likely to express higher levels of strength and power, particularly because maximal performance relies upon athletes' ability to throw, hit, field, and sprint. As might be expected, previous results from a small sample (*n* = 14) of NCAA DI softball athletes reported greater upper body strength than the DIII athletes in the current study (51.1 ± 7.5 kg vs 46.1 ± 9.5 kg) (29).

Volleyball is a primarily anaerobic sport requiring a large volume of vertical jumps that can reach upwards of 5,000 jumps per week with 50% performed at maximal or near maximal intensity (32). It was expected that volleyball athletes would demonstrate high lower body strength and power. In support of our hypothesis, volleyball displayed greater lower body strength than soccer, and outperformed soccer and field hockey in vertical jump. Volleyball is characterized as having a large demand of upper body movements (i.e., spiking, blocking, setting, bumping). Despite this, upper body strength of volleyball athletes was lower than softball and did not differ from soccer or field hockey. These findings were surprising due to the minimal upper body requirements of soccer and the considerably different upper body requirement of field hockey. It is worthy to consider the inclusion of upper body power testing (i.e., overhead medicine ball throw) with upper body strength testing for a more comprehensive understanding of volleyball athlete needs relative to sport-specific performance. Previously reported data in women collegiate volleyball athletes vary, with published physical performance assessments reported from small samples of NCAA DI athletes. The 1-RM bench press ranged from 38.6 ± 3.9 kg (*n* = 8) (8) to 47.0 ± 8.0 kg (*n* = 14) (11); 1-RM back squat ranged from 61.8 ± 10.5 kg (*n* = 8) (8) to 89.5 ± 14.3 kg (*n* = 76) (4); and vertical jump ranged from 42.4 ± 4.2 cm (*n* = 8) (8) to 60.9 ± 7.8 cm (*n* = 76) (4). Interestingly, the DIII volleyball athletes in the current study performed within the aforementioned ranges for the NCAA DI athletes on all measures.

In contrast to the more anaerobic-focused demands of softball and volleyball, performance in soccer and field hockey is strongly influenced by both aerobic and anaerobic metabolism, which may explain the discrepancy in assessment results among sports (6, 13, 30). In competitive matches, NCAA DI women soccer and elite women field hockey athletes cover distances of 6.6-9.5 km with approximately 2.7-4.5% of distance covered by high intensity movement (10, 31). In comparison to other anaerobic sports, these athletes need a higher oxidative capacity to be more resistant to fatigue. The onset of fatigue may reduce force producing capabilities and thus, expression of strength and power (38). Therefore, it was expected that these athletes would show reduced strength and power compared to the more anaerobic-focused sports of softball and volleyball.

While soccer and field hockey appear to share similar physical profiles (i.e., field dimensions, game duration, positions) (9), upper body strength and power may be more important for field hockey due to the higher demands of energy transfer to the upper extremities for skill movements such as stickhandling and shooting (3). Further, soccer athletes had the lowest 1-RM back squat of the four sports tested yet had significantly greater lower body power than field hockey. This may be a result of the mechanical demands of soccer (i.e., heading the ball) being more specific to vertical jump testing procedures whereas field hockey athletes are rarely, if ever, required to jump. Neeser and Lee tested 16 NCAA DI women soccer players and reported greater lower body strength (75.8 ± 14.0 kg) but comparable upper body strength (41.5 ± 6.4 kg) to the DIII soccer athletes of the current study, supporting the supposition of minimal demands for upper body strength in soccer (24). Further, the soccer athletes in the current study had a lower vertical jump (43.4 ± 5.1 cm) than previously reported in DI soccer players (range: 51.0 ± 6.00 – 53.1 ± 9.4; n = 16-19) (16, 24). Limited research has reported physical performance assessments in field hockey athletes, making comparison difficult. More assessments are needed across all divisions in women collegiate athletes with larger sample sizes to allow for more thorough interpretation of results.

There were established relationships between physical performance assessments. The 1-RM bench press had a significant positive relationship with 1-RM back squat and standing long jump, while vertical jump exhibited a positive relationship with standing long jump. Interestingly, 1-RM back squat was not significantly correlated with vertical jump or standing long jump, aligning with previous findings that absolute measures of lower body strength are not necessarily related to explosive lower body movements such as jumping (1, 26). Anderson, Lockie, and Dawes reported no relationship between absolute lower-body strength and vertical jump in 17 NCAA DII women's soccer athletes (1). However, when expressed in relative terms lower-body strength had a significant positive relationship with vertical jump (26). In contrast, ten high-level, college-aged Australian softball athletes displayed no relationship between relative lower-body strength and vertical jump (25). Both vertical jump and standing long jump may be influenced by mechanical factors such as arm swing, which can increase performance up to 28% and 21%, respectively (2, 15). Further, kinematic variables (i.e., depth and joint angles) of a countermovement may influence kinetic outputs and performance in vertical jumping according to the force-velocity relationship (18, 27).

The current study is not without limitations. Although the sample size is much larger than what is typically reported in research with women collegiate athletes, no measures of height or body mass were available at the time of testing precluding the ability to express data in relative terms. In addition, general training information was not accounted for as training phase and individual training age can influence performance. Further, while the practical assessment strategies used enabled accessible, valid, and reliable data, the selected vertical jump testing method cannot provide additional information on potentially confounding variables, such as kinetics or kinematics. In the current study, vertical jump had a large effect size accounting for the largest percent variance ($\eta^2 = 0.162$) of all assessments. In comparison, other tests demonstrated a small effect, indicating that vertical jump may be a more sensitive assessment to denote differences among the sports examined.

In summary, the current study provides data for an understudied area, physical performance assessments in a large sample of women collegiate athletes. When comparing across sport, significant differences were observed in lower body strength, upper body strength, and lower body power, likely due to differences in physiological demands of the sports. In addition, results support relationships among various assessments. For practitioners involved in coaching and training of collegiate athletes, the data presented may be used as an assistive tool for goal setting, exercise prescription, training programs, and player evaluations.

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