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ORIGINAL RESEARCH

CAN A SINGLE 6RM SQUAT SCORE PREDICT STRENGTH RATIOS IN FEMALE FOOTBALLERS?

Daniel P Marshall, Brendan J Burkett, Anthony G Boutagy and Mark R McKean

School of Health and Sport Science,
Faculty of Science, Health and Education,
University of Sunshine Coast, Queensland, Australia

Corresponding Author: M. R. McKean

Research Fellow – School of Health and Sport Science, Faculty of Science, Health, Education and Engineering, University of Sunshine Coast

Tel: +61 7 5456 5528, Fax: +61 7 5459 4600, Email: mmckean@usc.edu.au

ABSTRACT

Purpose: The purpose of this study was to determine if a single 6RM squat score can predict strength asymmetry in female football players. The influence joint range of motion of the hip and knee, injury history, training background and training frequency on this score was also determined.

Methods: Fifteen state-level female football athletes and fifteen recreational female strength athletes were assessed for joint range of motion at the hip and knee, and for 6RM strength of lower limb using standardised goniometric and strength measures.

Results: Scores for 6RM as follows: Back squat (Football – 51.7 kg, Strength – 60.9 kg), stationary lunge (L 30.0-36.7, R 29.5-36.5), single leg standing hamstring curl (L 13.4-14.7, R 13.3-15.1), and prone hamstring curl (Football – 32.0, Strength – 34.2). Results indicated common mean ratios existed between groups for the back squat to lunge and back squat to standing hamstring curl. Lunge scores had a strong correlation to the back squat scores suggesting the back squat may act as a predictor for the stationary lunge. Hamstring scores had a weak correlation to the back squat suggesting the back squat is a poor predictor of 6RM strength for hamstring exercises in females.

Conclusion: Both groups were found to have symmetry of right to left leg in all unilateral measures and the 6RM back squat may be used to determine lower limb strength in order to predict unilateral strength.

Key Words: Injury Prevention, Soccer, Lunge, Unilateral, Asymmetry, Strength Ratio

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INTRODUCTION

Football is played on a worldwide scale in over 200 countries with approximately 26 million females participating in competition from the ages of six to 45 [1]. Global participation rates have risen steeply in the past two decades with increased levels of interest in the United States of America (USA). The introduction of Title IX in 1972 making gender equality mandatory in education has helped the game spread, particularly at the varsity level, resulting in the establishment of a USA national league in 1995. This also coincided with the first women's World Cup in 1991 and the introduction of women's football as a recognised Olympic sport at the 1996 Atlanta Olympic Games.

Football requires athletes to perform a large range of coordinated non-contact lower limb movements such as kicking, jumping, sprinting, cutting and braking [2]. Although the skills required to play football are similar between genders, the physiological capacities of each gender may result in different game structures[3,4]. Furthermore, these physiological requirements may differ between amateur, semi-professional and professional players. The literature tends to focus on elite level players and findings garnered from these studies may not transfer to less skilled and experienced athletes due to the specific requirements that are associated with varying skill levels. A clear finding is strength capacity is important for performance in football players [2,5]. Developing maximal strength increases the force available to perform important actions of kicking, and specific movements of running, jumping, cutting and tackling [4]. Additionally, it is believed (although studies in this area are limited) that the physiological adaptations observed from strength training can reduce the risk of injury to the athlete due to stronger connective tissues and muscular structures that move the skeleton [5].

Football players have been reported as sustaining performance limiting, traumatic and even season or career ending injuries such as hamstring strains and tears, and anterior cruciate ligament (ACL) injury [6]. Non-contact injuries to the knee and hamstrings make up 70% of those documented by females in football [7]. Although comprehensive statistics on major injuries sustained are not readily available, the National Collegiate Athletic Association (NCAA) estimates that in just USA high schools alone, there are approximately one thousand ACL reconstructions on an annual basis.

Studies have shown that female football players have a higher risk of suffering both hamstring and anterior cruciate ligament (ACL) injury than male players and there is an effort to investigate the mechanisms that cause this phenomenon [3,8]. Suggested reasons from a conditioning perspective include decreased functional or conventional hamstring to quadriceps ratios [6,9], and muscular asymmetry [10,11]. Further to this, inadequate joint range of motion and prior injury can predispose the athlete to future injury, particularly where rehabilitation protocols have been inadequate [12,13]. Despite an extensive coverage of the hamstrings to quadriceps ratio in the literature, there is little agreement as to what is acceptable in both rehabilitation and performance environments. Furthermore, as the majority of research has been undertaken using specialised equipment, such as isokinetic dynamometers, the ability of these ratios to be utilised by strength coaches who train their athletes in common strength training environments is less than ideal. Consequently coaches from a variety of sports, including football, attest to using extensive pre-screening protocols during the pre-season to assist in adequately preparing athletes for sport [14-16].

The purpose of this study was to determine if a single 6RM squat score can predict strength asymmetry in female football players. The influence joint range of motion of the hip and knee, injury history, training background and training frequency on this score was also determined.

METHODS

Design

The cross sectional study of thirty female participants involved the performance of four exercises of the lower body generating 6RM scores of back squat, prone hamstring curl, single leg standing hamstring curl and stationary lunge.

Subsequent scores and ratios were analysed to determine the presence of lower body strength asymmetry and the effect that training background, injury history and joint range of motion had upon strength relationships of the hip and knee.

Participants

Fifteen state-level female footballers aged 26.3 (6.4) years, weighing 64.4 (10.5) kg, height 165.9 (6.9) cm; and fifteen recreational female strength athletes (who regularly performed lower body resistance training) aged 29.1 (4.5) years, weighing 63.59 (5.2) kg and height of 165.6 (4.4) cm volunteered for the study. No statistically significant differences for age, height, weight, and injury history were found between the two groups. Informed consent was obtained and all participants informed of the experimental risks according to guidelines of the University Human Research and Ethics Committee. All participants were free of musculoskeletal injury. The participant's dominant leg was determined based on which foot they preferred to kick a ball with. Participants were encouraged to follow similar nutritional and sleeping patterns prior to each of the two testing days. Participants also provided training and injury related information during the pre-exercise interview.

Procedures

All participants completed a brief screening questionnaire to ensure that they met the minimum age and strength training experience requirements. Bodyweight was recorded (Soehnle Professional, Exacta, Soehnle Professional GmbH & Co, Germany). Standing height measured using a Portable Stadiometer (Seca, 217, Seca Limited, England). Hip and knee joint range of motion assessed using a Physio-Med Ezi-Read 30cm Goniometer, following standardised procedures [17].

Strength testing was conducted under the supervision of an Australian Strength and Conditioning Association (ASCA) certified coach [18].The back squat exercise and stationary lunge were performed inside a power cage (Atlantis, C-109, Atlantis Incorporated, Canada). The safety bars positioned such that minimum squat depth of femur parallel to the ground was been achieved. The single leg standing hamstring curl was performed on an Atlantis standing leg curl machine (Atlantis, C-107, Atlantis Incorporated, Canada). The prone hamstring curl was performed on an Atlantis leg curl machine (Atlantis, PE-106, Atlantis Incorporated, Canada). The leg curl machines required no participant-specific calibration due to the unique self-aligning roller however participants were instructed on minimum performance criteria prior to the warm up phase of the testing.

On testing day one, participants performed the back squat and single leg standing hamstring curl exercises. On day two, (between 2 and 7 days later) participants performed the prone hamstring curl and stationary lunge exercises. Intra-day order of exercise was randomised[19]. Technique was carried out as per NSCA guidelines [20]. Repetition duration was controlled at two seconds eccentric and two seconds concentric per repetition [21]. Participants were verbally encouraged during each performance.

Back Squat. Participants were encouraged to assume a foot stance shoulder width apart and then descend to a depth of at least femur parallel to the ground.

Figure 1 – Top and bottom position of the back squat

Stationary Lunge. Participants performed the stationary lunge exercise by flexing the lead hip and knee and lower the back knee towards the ground.

Figure 2 - Top and bottom position of the stationary lunge

Standing Single Leg Hamstring Curl. Participants flexed the knee moving the roller behind their ankle until their tibia was at least parallel to the ground or no higher than approximately 110 degrees knee flexion.

Figure 3 - Start and finish position of the standing single leg hamstring curl

Prone Hamstring Curl. Participants moved the roller situated behind their ankles until it touched their gluteals, and then lowered the roller in a controlled fashion to knee extended position.

Figure 4 - Start and finish position of the prone hamstring curl

Six repetition-maximum (6RM) strength scores were chosen to match the repetition range primarily chosen by athletes in common strength training environments [22,23]. Participants advised their current estimated 6RM scores based on current training programs for each exercise as a means to determine starting point for the 6RM test. Participants performed warm up sets for each exercise by performing 6 repetitions progressively at 50%, 85% and 95% with two minutes between sets before commencing the first 6RM attempt. Rest of five minutes was provided between 6RM attempts sets to allow sufficient recovery [24].

STATISTICAL ANALYSES

All four lower limb strength exercise scores were recorded and analysed using SPSS 20.0 for Macintosh (SPSS, Inc. Chicago, USA). Although there were no significant anthropometric differences, data was analysed collectively and by mode of athletic performance; football or strength group. Pearson's moment correlation coefficient was used to examine the linear relationship between the four strength exercises. Less than 0.4 was considered weak, 0.4-0.7 moderate and greater than 0.7 was considered strong.

A one way analysis of variance was used to determine differences between the two athletic groups. Significance was set at $P < .05$ and data is presented as mean and 95% confidence interval profiles.

RESULTS

Training frequency, injury history and joint range of motion are shown in Table 1.

Training frequency was found to be significantly different ($P = .03$) between the groups. There were no statistically significant differences for lower limb injury however a small number of football players reported large blocks of time away from the sport due to injuries to the lower limbs.

Mean 6RM strength scores for the back squat, single leg standing hamstring curl prone hamstring curl and stationary lunge are shown in Table 2.

Table 1. Subject characteristics presented as mean (95%CI)

Variable	Soccer (n=15)	Strength (n=15)
Age (years)	26.3 (22.8,29.9)	29.1 (26.7,31.6)
Height (cm)	165.9 (164.1,167.7)	165.6 (164.5,166.7)
Weight (kg)	64.5 (58.6,70.3)	63.6 (60.7,66.5)
Training (days/week) *	3.0 (1.9,4.0)	5.4 (4.2,6.6)
Lower limb injury time (weeks)	15.9 (-1.7,33.4)	1.9 (-0.2,4.1)
Joint Range of Motion (deg)		
Hamstrings left	96.7 (91.5,101.9)	99.9 (92.1,107.6)
Hamstrings right	94.5 (88.2,100.9)	97.4 (89.6,105.2)
Quadriceps left	122.1 (114.9,129.4)	121.6 (117.0,126.2)
Quadriceps right	124.0 (116.5,131.5)	123.9 (120.0,127.8)
Hip flexor left	185.8 (181.2,190.4)	186.3 (182.3,189.8)
Hip flexor right	186.3 (181.7,190.8)	187.1 (183.4,190.9)

* Indicates significant difference between groups

Table 2. Strength scores 6RM presented as mean (95%CI)

Variable	Soccer	Strength
Squat 6RM (kg)	51.7 (42.8,60.5)	60.9 (52.7,69.0)
Single leg standing hamstring curl 6RM - left (kg)	13.4 (11.3,15.5)	14.7 (11.7,17.8)
Single leg standing hamstring curl 6RM - right (kg)	13.3 (11.2,15.5)	15.1 (12.0,18.3)
Stationary Lunge 6RM - left (kg) *	30.0 (25.1,34.8)	36.7 (32.4,41.1)
Stationary Lunge 6RM - right (kg) *	29.5 (23.9,35.1)	36.5 (32.3,40.7)
Prone Hamstring Curl 6RM (kg)	32.0 (28.8,35.3)	34.2 (30.6,37.8)

* Indicates significant difference between groups

The mean 6RM values for all of the strength exercises tested were higher in the strength training group; stationary lunge 25% (right) and 22% (left), squat (18%), standing hamstring curl 13% (right), 7% (left) and prone hamstring curl 7%. There were significant differences in strength scores between the two groups in the stationary lunge for both limbs (left P = .049, right P = .05). For the football group, the R^2 values were .63 (left) and .67 (right) indicating that the stationary lunge can account for 63% and 67% variance in the back squat respectively. For the strength group, the R^2 values were less significant at .59 (left) and .54 (right).

In addition, the stationary lunge-to-prone hamstring curl ratio for both limbs were found to be significantly different (left P = .026, right P = .022). Pearson's coefficient identified the back squat as showing moderate to strong correlation to the other three tested exercises in the strength training group (r = .43 to .77). Conversely, the football group had mostly weak correlations (r = .10 to .27), except for the stationary lunge (r = .78 to .81). The prone hamstring curl for the strength group had a moderate to strong correlation with the other tested exercises (r = .53 to .82)

There were no significant differences between groups for prior injury to the lower limb. In addition, there were no significant correlations between injury and anthropometric data, joint range of motion or side-to-side muscle imbalance. The football group reported 238 weeks of injury in comparison to just 29 weeks for the strength athletes. Of the 238 weeks of total time lost to injury, 200 weeks were because of an injury to the knee of three football players.

DISCUSSION

The purpose of this study was to firstly determine if a single 6RM squat score can predict strength asymmetry in female football players. Then determine the influence joint range of motion of the hip and knee, injury history, training background and training frequency has on this score.

The common aim of strength training is to increase musculoskeletal strength. For the strength athlete, the benefits of strength training are clear and

direct; the objective over time is to increase the weight moved for any particular exercise performed. For the football player, increased musculoskeletal strength has been shown, amongst other things, to reduce injury risk, particularly in the lower limbs [8]. Consequently, strength training is considered to be essential in the training regimen of football players [5]. Despite a small number of football players in the current study suffering long term injuries, the injury rates exhibited were similar to those reported in previous studies where strength training was used as an injury prevention strategy [8]. Additionally, there were no reported lower limb injury differences of significance to the strength training group supporting the concept that the act of strength training may contribute to reducing the risk of injury. Despite both groups having experience in the common strength training environment, the strength training group in this study achieved higher scores for the 6RM back squat, stationary lunge, prone hamstring curl and single leg standing hamstring curl. However, only strength scores for the stationary lunge were found to be significantly different.

Higher mean strength scores in the strength-training group may be more likely due to a significantly different training frequency, when compared to the football group. Amateur female football players during the regular season will generally perform football-specific activities once during the week, and once on the weekend. Given the mean strength scores of the strength athletes were higher across all exercises; the findings support increased strength training frequency as an important factor in developing muscular strength [25]. Strength gains are typically greater when strength training is performed 3 times per week, compared with once per week [26]. This was evident in the current study where a high strength training frequency of 5 days per week or more lead to greater levels of lower limb strength in females.

The mean 6RM back squat score difference of 9.2kg between the groups was not significant. Although this represented an 18% variance, the overlapping of the Confidence Intervals indicate that the many of the individuals from each group shared similar scores for the back squat. Although footballers train the squat movement, they may not necessarily do so for consistent strength gains, whereas strength athletes tend to train movements specifically to increase the weight moved for that exercise. Nesser et al reported 1RM back squat strength scores for National Collegiate Athletic Association (NCAA) Division 1 female football players of 75.8kg [27]. Using the National Strength and Conditioning Association (NSCA) repetition maximum conversion chart, the mean 6RM back squat strength scores in the current study can be converted to a 1RM score of 60kg for the football group [20]. This difference is most likely due to the fact that the current amateur group of football players have a different weekly training commitment to that of the NCAA players, who are semi-professional athletes. Additionally, these athletes completed 1RM training as part of their regular season training, indicating that they trained specifically for maximal strength improvements. In comparison the current state-level group typically work in the 6-12 repetition range for their strength training, which adheres with guidelines from recognised bodies such as the ACSM and strength training repetition guidelines laid out by authors such as Hoff and Helgerud [5,24].

Unilateral dominant movements, such as the lunge, have been reported as developing higher strength scores on the basis that repeated movements' leads to increased strength [22]. Football players in the current study did not achieve higher strength scores and this may be due in part to the limited range of motion of these movements in the sport when compared with the strength exercises used in this study. Leg strength symmetry was achieved for both groups with similar strength scores between limbs and no statistically significant difference. Ebben and colleagues tested recreational collegiate athletes and also found similar lunge scores between legs as in the current study [23]. In teenagers a difference of less than 15% was considered to be the norm for symmetry of strength and power [28,29]. Accordingly, both groups achieved muscular symmetry, with differences between legs being less than 3% which is well within this range and can be considered normal.

Strength ratios between the two groups were

similar, with the exception of the prone hamstring curl to stationary lunge ratio (football 1.16, strength 0.95). Given the significant differences in stationary lunge scores, this is understandable. The current study showed that football players have similar bilateral strength profiles to strength athletes, even though they may have different training goals such as balance and muscle symmetry [25]. Differences in the standing hamstring curl strength between dominant and non-dominant limbs were not significant with differences of -0.6% in the football group and 2.72% in the strength group. Although there are no similar free weight testing studies with which to compare these results, isokinetic testing has reported asymmetries in the hamstrings of elite level football players[6]. This suggests the competitive level of the athlete may contribute to the level of asymmetry. The increased time an athlete trains and plays their chosen sport may induce a higher level of sports specific adaptation leading to asymmetry at the elite level but not at the amateur level.

The current study identified two separate bilateral to unilateral ratios for the lower limbs. The first ratio was calculated for the knee flexors, using the back squat to single leg standing hamstring curl. In the current study, there were no significant differences found between groups or between limbs. Consequently, the ratio of back squat to single leg standing hamstring curl for all females in the current study was 26.5% (22.8% - 30.3%). The second ratio compared two compound movements, the back squat and the stationary lunge. In the current study, there were no significant differences found between groups or between limbs for this ratio 59.7% (55.0% - 64.4%). The upper and lower limits for both ratios represent less than 10% variation from the mean. Further research into other athletic populations would provide further knowledge as to whether the ratio found in the current study is common to all athletic women or just the groups in this study.

Correlation analysis showed a strong linear relationship between the back squat and the stationary lunge in both football and strength athletes. The current study reported similar R^2 values of .67 for the football players and 0.60 for the strength athletes, in comparison to elite karate athletes' ratio of 0.75 and 0.62 for collegiate athletes [22,23]. The slightly higher reported variance in the karate athletes may be explained by the reported emphasis on lunge type movements in karate athlete training [22].

The back squat had a weak correlation to the exercises that involved the hamstrings as the primary mover (R^2 range .01 – .28). This indicates that hamstring strength can only explain a small amount of variance in the squat scores between subjects. The results of the current study are supported by the findings of Ebben, who identified that no linear relationship existed between the back squat and strength exercises in NCAA Division I and III collegiate females where the hamstrings were the prime mover.[30].

While both groups exhibited small amounts of imbalance between dominant and non-dominant limbs, these imbalances were not found to be significant, nor were the between group differences significant. To the authors knowledge this was the first study to use the single leg standing hamstring curl and stationary lunge to assess unilateral strength effects between dominant and non-dominant legs, in female football players and strength athletes. There was also no evidence in the current study linking these minor differences with injury or loss of range of movement. No real differences were found between the two groups and this may be due to the amateur nature of the football group having not played at a high enough level with specific training to develop this. It has yet to be determined if the imbalance levels reported in this study would be similar for female athletes from different sporting backgrounds, but being the first study of this kind the data may be used as a reference point for both coaches and future research.

PRACTICAL APPLICATIONS

For the Strength and Conditioning Coach, being able to practically and effectively obtain information about an athlete's bilateral and unilateral strength profile may aid in effective resistance program design and subsequent identification of change that may link with injury. For the elite football player, testing numerous exercises to identify strength capacity as

well as muscle imbalance is time consuming and inefficient, particularly for an entire team. By quantifying these ratios of the lower limb, this study has shown that the exercise professional can use a 6RM squat test of bilateral strength, to establish unilateral strength levels and identify related ratios.

CONCLUSIONS

The findings of this study indicate that in amateur female footballers and strength athletes, two bilateral to unilateral ratios using 6RM strength scores of the bilateral back squat and unilateral stationary lunge and single leg standing hamstring curl exercises, may be effective measures of symmetry and strength. Having these ratios may aid the strength and exercise professional in taking the guesswork out of program and load prescription, ensuring their methods conform to best practice.

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