

LOWER-LIMB EXPLOSIVE POWER AND PHYSICAL MATCH PERFORMANCE
IN COLLEGIATE FEMALE SOCCER PLAYERS

By

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Abstract

LOWER-LIMB EXPLOSIVE POWER AND PHYSICAL MATCH PERFORMANCE IN COLLEGIATE FEMALE SOCCER PLAYERS

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The purpose was to determine the relationship between two measures of lower-limb explosive power (LLEP) and establish the relationship between these measures and physical match performance (PMP) in Division II female collegiate soccer players (N = 24). Countermovement jump (CMJ) height (using a switch mat) and a 5-jump test (5JT) for distance were measured. PMP was measured by the Yo-yo intermittent recovery test level 1 (YYIRTL1). Hypotheses were: 1) 5JT would significantly relate to CMJ, and 2) the relationship between 5JT and YYIRTL1 would be stronger than the relationship between CMJ and YYIRTL1. Scores on the 5JT (910.0 ± 59.7 cm) and CMJ (39.7 ± 4.3 cm) were related ($r = .71, p < .05$). No significant relationship was found for 5JT or CMJ with YYIRTL1 ($r = .20, p > .05$; $r = .11, p > .05$, respectively). 5JT is a valid measure of LLEP in female soccer players. The sex of the athlete, limitations in measurement methods for LLEP, the location of participants on the spectrum of performance and/or restriction of range in values may explain findings of the current study relevant to existing literature. Also, validation of YYIRTL1 is based on high-intensity running in a match, and the contribution of LLEP to this may be small. Alternatively, powerful participants, who are less resistant to fatigue, may have performed poorly on YYIRTL1

due to its fatiguing nature. The 5JT validly measures LLEP in soccer; LLEP does not explain variance in PMP in Division II female soccer players.

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Chapter One

Introduction/Literature Review

Soccer is comprised of intermittent activity where players are required to turn and change direction at varying intensities, which requires well-developed aerobic and anaerobic mechanisms (Bangsbo, Norregaard, & Torsoe, 1991; Drust, Reilly, & Rienzi, 1998; Hoff, Gran, & Helgerud, 2002). Specifically, Drust et al. stated that the ratio of low to high-intensity work rate in soccer is 7:1, suggesting that the energy demands of soccer are largely aerobic in nature. The high-intensity (i.e., anaerobic) sprint-type activities in soccer are relatively short in terms of distance (22.4 m) and time (3.7 s), and occur throughout the game on average once every 90 s (Reilly & Thomas, 1976).

What makes athletes successful in soccer is, in part, due to how they perform, physically, during a match. This is exclusive of how the athlete performs technically, tactically and psychologically. Overall, the athletes who maintain endurance to cover a lot of ground for a long time period (Reilly & Thomas, 1976) and who possess explosive anaerobic qualities for turning (Withers, Maricic, Wasilewski, & Kelly, 1982), accelerating, sprinting, and jumping and who have a high power output in single actions such as kicking, theoretically, will be successful in their PMP (PMP) (Wisloff, Castagna, Helgerud, & Hoff, 2004).

No perfect measure of PMP exists. If there is a good test of PMP, the test must be sport-specific (e.g., specific to the movement patterns during competition) (Bangsbo,

Mohr, Poulsen, Perez-Gomez, & Krusturp, 2006; Spencer, Bishop, Dawson, & Goodman, 2005). Once a good sport-specific test is identified, then the factors and/or physiological correlates to performance in that test can be assessed. Many different tests have been used in soccer players to objectively assess PMP to indicate how an athlete might perform, monitor performance over time, and/or identify needs for training (Bangsbo, Iaia, & Krusturp, 2008; Buchheit, 2008; Rampinini et al., 2007b).

Field tests for assessment of PMP in soccer include, but are not limited to, the Interval Field test (Bangsbo & Lindquist, 1992), the Bangsbo Sprint test (BST)(Bangsbo, 1994a), and Yo-yo tests (Bangsbo et al., 2008). The Interval Field test (Bangsbo & Lindquist) consists of activities at high and low intensities. The high-intensity activities include locomotion patterns such as sidestepping, backwards and forward running, while the low-intensity patterns include jogging and stopping. Testing of 20 male elite soccer players by Bangsbo and Lindquist (1992) revealed that the Interval Field Test can be used to determine long-term intermittent exercise performance (as measured on a treadmill) ($r = .83, p < .05$), however, the Interval Field Test was not related to match activities including match distance ($r = .38, p > .05$) and high-intensity distance during a match ($r = .23, p > .05$) (Bangsbo & Lindquist). Therefore, there is not sufficient evidence that the Interval Field Test is a valid measure of match performance for soccer players.

The BST (Bangsbo, 1994a), another test which has been used to assess PMP, requires the participants run seven maximal sprints of 34.2 m each, each followed by 25 s of active recovery. Bangsbo (1994a) incorporated a turn in the middle of the run, which forced the participants to change direction, making the test applicable to the

multidirectional nature of the sport of soccer. Wragg, Maxwell, and Doust (2000) cross-validated the BST with the Maximal Anaerobic Running Test (MART), which had previously received strong support as a measure of anaerobic performance, since its intermittent nature reflects movement-patterns in many running-based sports. Energetics of the tests were not related; a low correlation was found between scores on the BST (sprint time) and MART (total running time) ($r = -.30, p = .52$). The authors noted that there is a lack of benchmark tests that can be used to validate sprint tests; hence it is difficult to establish criterion validity. The authors noted that all tests are indirect; as they measure external work as opposed to physiological strain (Wragg et al., 2000). Nonetheless, BST was not a convincing test for prediction of PMP nor was it reliable.

Yo-yo tests have become popular field tests for assessing ability to repeatedly perform high-intensity activity, due to their practicality and specificity to team sports (Bangsbo, et al., 2008). These tests range in duration from 2 min to 20 min and consist of two 20-m shuttle runs at rapidly increasing speeds, controlled by audio beeps from a compact disc. Each successful run of 40 m (2 x 20 m) comprises the completion of the shuttle (Bangsbo, 1994a). The score on the Yo-yo tests is taken as the amount of successful bouts completed multiplied by 40 m for a total distance covered. Yo-yo tests have been suggested as the best way to assess PMP in soccer (Bangsbo et al., 1991; Krustup, Mohr, Ellingsgaard, & Bangsbo, 2005; Mohr, Krustup, & Bangsbo, 2001) as they have been related to sport-specific activities of soccer (Krustup et al., 2003; Krustup et al., 2005).

There are three different types of Yo-yo tests. They are: Yo-yo endurance test (YYET), Yo-yo intermittent endurance test (YYIET), and Yo-yo intermittent recovery test (YYIRT) (Bangsbo et al., 2006). The YYET captures a person's ability to work continuously over a longer period of time, similar to a work performed by a distance runner (Bangsbo et al., 2006). The YYIET captures the ability of an athlete to perform intervals with only a short recovery over a prolonged period of time, similar to the nature of interval sports (Bangsbo et al., 2006). The YYIRT captures the players' ability to recover from high-intensity exercise, as it is a critical component of performance in a soccer match. The YYIRT is the test of choice for the present investigation because it mimics the nature of soccer in the run-pivot-run-recover-stop-run model and 10-s recovery between bouts, which makes it true to the game of soccer where stopping and starting are prevalent. The other Yo-yo tests have limited to no recovery time (Bangsbo et al., 2006).

The YYIRT has two levels (L1 and L2), which differ in terms of starting speed; the YYIRTL1 has a slower starting speed. For an elite trained male soccer player, the YYIRTL1 represents the ability to tax the aerobic system, whereas YYIRTL2 represents the ability to tax both the aerobic system and the anaerobic system (Bangsbo et al., 2008). That said, according to Bangsbo et al. (2008), the YYIRTL1 captures the contribution of both aerobic and anaerobic systems of someone who is sub-elite.

A key validation study of the YYIRTL1 was reported by Krusturup et al. (2003) using 54 elite level male soccer players. Researchers collected physiological data on these males before, during, and after the YYIRTL1 by performing heart rate monitoring,

taking blood samples, and doing invasive muscle biopsies at rest and exhaustion.

Additionally, individual VO_2max and peak heart rate (HR_{peak}) data were collected from the participants in a laboratory setting and 12 participants were recorded via VHS for computerized recordings of locomotion during a match. The locomotion was later divided into subcategories: standing, walking, low-intensity running (jogging), and high-intensity running (sprinting) (Krustrup et al., 2003).

Krustrup et al. (2003) found that the amount of high-intensity running during match performance was significantly correlated to performance in the YYIRTL1 ($r = .71, p < .05$). Furthermore, “a significant correlation was observed between YYIRTL1 test performance and time to fatigue in an incremental running test ($r = .79, p < .05$), as well as VO_2max ($r = .71, p < .05$).” (Krustrup et al., 2003, p.700). Physiological measures indicated that the aerobic energy system was highly taxed toward the end of the test. Lastly, Krustrup et al. (2003) found high test-retest reliability for the YYIRTL1; there was no difference in performance in the first and second YYIRTL1 tests performed within 1 week of each other (1867 ± 72 versus 1880 ± 89 m; $N = 13$).

Bangsbo et al. (2008) makes a case for the reliability and validity of the Yo-yo tests (both L1 and L2), citing evidence of higher scores among higher-level players, which has been shown in both male and female players (Castagna, Impellizzeri, Chamari, Carlomagno, & Rampinini, 2006; Kirkendall, 2000; Kirkendall, Leonard, & Garret, 2004; Krustrup & Bangsbo, 2001; Krustrup et al., 2005; Mohr, Krustrup, & Bangsbo, 2003; Rampinini et al., 2007b). Scores on the Yo-yo differ by position in the expected manner (Krustrup et al., 2003, 2005; Mohr et al., 2003). Also, the Yo-yo tests can detect changes

in the ability of the athletes to perform high-intensity activity throughout the season (Bangsbo et al., 2006; Krstrup et al., 2006).

Krstrup et al. (2005) validated the YYIRTL1 as a measure of PMP in elite female players. Krstrup et al. studied the best female players from the Danish soccer league using time-motion analysis and found that YYIRTL1 relates to aerobic and anaerobic capacities in elite female soccer players. YYIRTL1 scores correlated with individuals total distance covered during a match ($r = .56, p < .05$) and high-intensity running ($r = .76, p < .05$) as well as the amount of high-intensity running during later periods of the halves when the athletes could potentially show signs of fatigue ($r = .83, p < .01$). VO_2 max, Interval Treadmill Test performance, and lactate levels also were significantly related to YYIRTL1. Krstrup et al. concluded that “YYIRTL1 is a good predictor of elite female soccer player’s ability to perform high-intensity running throughout competitive matches” (Krstrup, 2005, p. 1245) and that the YYIRTL1 can be used as an indicator of PMP.

The primary way that the YYIRTL1 was validated was as a measure of the amount of high-intensity running during a match in elite female players. Krstrup et al. (2005) found that the relationship of high-intensity running to YYIRTL1 scores was $r = .76$. High-intensity running was defined as running from 15-25 km/h. It is important to note that high-intensity running is a broad term, as it encompasses 15 km/h to 25-km/h speeds (Krstrup et al., 2005), and the amount of sprinting (≈ 25 km/h) is only a portion of the total high-intensity running.

In summary, although it is difficult to precisely assess PMP, the YYIRTL1 test has been related to high-intensity running during a competition in one study (Krustrup et al., 2003) of elite-male players, another study (Krustrup & Bangsbo, 2001) of top class soccer referees, as well as in a study of elite-level female players (Krustrup et al., 2005). Given that PMP can be objectively measured using a Yo-yo test, an important question is what are the fitness and/or physiological components that contribute to (i.e., determinants of) performance in this test and ultimately to PMP in soccer. As previously mentioned, soccer requires both aerobic and anaerobic components.

The demand for aerobic endurance in soccer performance explains, in large part, the athletes' physical capacity during optimal conditions (i.e., exempt from tactical limitations, quality of opponent, and lack of motivation) (Bangsbo, 1994b; Bangsbo et al., 2006; White, Emery, & Kane, 1988). Aerobic capacity is challenged toward the end of a match performance due to fatigue (Mohr et al., 2003; Reilly & Thomas, 1976). Aerobic endurance, however, may help to reduce signs of fatigue (Helgerud, Engen, Wisloff, & Hoff, 2001; Reilly & Thomas), which in turn will contribute to PMP, including distance covered, level of work intensity, number of sprints, and number of involvements with the ball.

While endurance capabilities are undoubtedly important, soccer performance is also dependent upon high-intensity work, including sprints, tackles and shots on goal (Chamari et al. 2008; Hoff & Helgerud, 2004). High-intensity capacities, in turn, are dependent upon muscle strength and power (Castagna et al., 2006; Hoff & Helgerud, 2004; Reilly, 1994; Wisloff, Helgerud, & Hoff, 1998). Wisloff et al. (2004) found that

strength was significantly related to 10 m and 30-m sprint-time and jump height in elite male players. Furthermore, Hoff and Helgerud strength trained elite male soccer players and showed improvements in power as well as improvements in running economy. This led Castagna et al. (2006) to conceptualize that anaerobic components influence PMP.

Castagna et al. (2006) stated that while continuous shuttle run tests have been correlated with aerobic factors such as $VO_2\text{max}$ (Krustrup et al., 2003; Leger & Lambert, 1982; Paliczka, Nichols, & Boreham, 1987; Ramsbottom, Brewer, & Williams, 1988; Williford, Scharff-Olsen, Duey, Pugh, & Barkdale, 1999), nobody had examined the influence of lower limb power in a progressive shuttle run test like the Yo-yo. Castagna et al. (2006), therefore, made the study of this relationship a purpose of their research. Castagna et al. hypothesized “that lower-limb explosive strength may positively affect performance in progressive, multistage, high-intensity field tests such as YYETL2 and YYIRL1 which involve extensive, continuous and intermittent, shuttle running, respectively” (p. 321).

Castagna et al. (2006) had 24 amateur male soccer players perform YYIRTL1 tests until exhaustion. Total distance covered was recorded. Participants also performed a countermovement jump (CMJ) using a force platform; the mean jump height and peak power (CMJPP) were determined for this test. The best 3 jumps of 5 were recorded and analyzed. Each of the athletes also performed an incremental treadmill test to measure $VO_2\text{max}$, the VO_2 at the ventilatory threshold ($VTVO_2$), the velocity at ventilatory threshold (vVT), and peak treadmill velocity (PTV). The correlations between the YYIRTL1 scores and the parameters tested are shown in Table 1.

Table 1

Correlations with YYIRTL1 in amateur male players.

Variable	<i>r</i> =
VO ₂ max	.46
VTVO ₂	.39
VVT	.69*
PVT	.71*
CMJ	.50*
CMJPP	.57*

Note. Correlations are expressed as the relationship between the parameter and YYIRTL1. * Significant correlations at $p < .05$. Table is adapted from Castagna et al. (2006).

The finding that explosive power (i.e., CMJ and CMJPP) was significantly related to YYIRTL1 performance supports the idea that LLEP has some influence on performance in high-intensity shuttle intermittent exercise (Castagna et al., 2006). Vertical jump (VJ) height can be measured using various methods, commonly VJ height is performed as a countermovement jump (CMJ). In this paper it will be noted if CMJ is measured otherwise. CMJ is often used to calculate LLEP (Canavan & Vescovi, 2004; Carlock et al., 2004; Markovic, Dizdar, Jukic, & Cardinale, 2004) and has been reported as competitive-level dependent in soccer players (Wisloff et al., 1998). Arnason et al. (2004) found that CMJ (expressed as team average jump height) was related to ranking of

Icelandic top division teams. Wisloff, et al. (2004) have shown VJ performance was significantly related to short sprint performance in elite male soccer players. However, not all researchers have found the relationships among power tests and PMP.

Rampinini et al. (2007a) sought to determine whether three practical field tests (incremental field test to exhaustion, squat jump [SJ] and repeated-sprint ability test) were indicators of PMP in elite-level male professional players. Rampinini et al. (2007a) measured PMP using a match-analysis image recognition system which captured parameters such as total distance, high-intensity running distance, very high-intensity running and sprint distance. SJ was measured using switch mat in which height was estimated from flight time. The jump was performed without a countermovement and hence was actually a squat jump. While repeated sprint ability and peak speed on an incremental run test were found to significantly relate to PMP, no significant relationship was found between SJ performance and PMP variables (correlation coefficients were not reported).

Rampinini et al. (2007a) noted that their findings go along with those of Cometti, Maffiuletti, Pousson, Chatard, and Maffulli (2001), who found that a group of amateur players had greater vertical jump values than Division II professional players. Also, Wisloff et al. (1998) found no difference in VJ between the first and last team of the Norwegian National Championship. However, Rosh et al. (2000) found VJ performance in top-level and third division players compared with local team players; however, amateur players had lower VJ than top-level and third division players. Therefore and in summary, there are discrepancies regarding the question of whether LLEP, at least when

measured using VJ, explains soccer performance because team average jump heights are inconsistent with levels and standings. Furthermore, it appears that no one has examined the relationship of VJ to soccer performance in women or in collegiate-level players.

Recently researchers have used a more practical alternative to the VJ for estimating LLEP; the 5-jump test (5JT) has been used to measure power in selected populations of athletes (Bouhlel, E., Bouhlel, H., Chelly, & Tabka, 2006; Chtara et al., 2008; Paavolainen, Hakkinen, Hamalainen, Nummela, & Rusko, 1999; Slattery, Wallace, Murphy, & Coutts, 2006; Spurrs, Murphy, & Watsford, 2003), including soccer players (Rohr, 1992; Spinks, C., Murphy, Spinks, W., & Lockie, 2007). The 5JT measures horizontal stretch-shortening cycle capabilities in the distance traveled using lower limb actions similar to those of the sprint step usually performed by soccer players (Spinks et al.). The 5JT consists of 5 consecutive steps with joined feet position at the start and end of the jumps. This 5JT was previously shown to be reliable in elite male soccer players with an interclass correlation of .91 for measures taken one week apart (Spinks et al.). The 5JT is practical because it uses no sophisticated materials.

Most recently, Chamari et al. (2008) used the 5JT to assess lower limb explosive power in elite male soccer players. The 5JT scores were then related to laboratory jump tests for explosive power. The laboratory tests consisted of a squat jump and a CMJ using a force plate as well as extension and flexion using an isokinetic dynamometer. Chamari et al. found that the 5JT, when expressed as a value relative to leg length and as a value scaled to weight, was significantly related to the lab-based measures of LLEP. Chamari et al. suggested that 5JT “may be regarded as an explosive strength diagnostic tool under

field conditions in elite soccer players” (p. 944). The question remains as to if the 5JT test is a practical means of evaluating LLEP in collegiate female soccer players and if it relates to PMP.

In summary, PMP in soccer can be validly measured by-way-of the YYIRTL1 (Bangsbo & Lindquist, 1992; Castagna et al., 2006; Krusturup & Bangsbo, 2001; Krusturup et al., 2003, 2005, 2006; Mohr et al., 2003), and it reflects high-intensity activity similar to what occurs in a match. Castagna et al. added the idea that LLEP, specifically measured using the CMJ, relates to PMP using YYIRTL1 (Castagna, et al.). Chamari et al. established that the 5JT, a field test, can provide a means for assessment of lower limb explosive power in soccer players (Krusturup et al., 2005).

Significance/Statement of the Problem

With the exception of the study validating YYIRTL1 as a measure of PMP in elite female soccer players (Krusturup et al., 2005), all of this cited research has been done using males as participants. It is not known if 5JT relates to lab measures of CMJ performance in female Division II level collegiate players. That is, is the 5JT a practical measure of LLEP in female collegiate soccer players? It is also not known whether LLEP (measured using 5JT and/or CMJ) relates to PMP in female collegiate Division II players. 5JT and CMJ are usually expressed in absolute terms as the overall distance covered (i.e. in cm). The purpose of this research is to determine the relationship between 5JT and CMJ and to determine which measure of LLEP best relates to PMP in this group of athletes.

Substantive Hypotheses

The 5JT performance will significantly relate to CMJ performance. Also, the relationship between 5JT performance and YYIRT performance will be stronger than the relationship between CMJ performance and YYIRT performance.

Assumptions

The thesis will determine correlations based on the assumptions that all athletes performed to the best of their abilities.

Practical Applications

The college soccer season is short, especially the pre-season (before competition) period, which are just a few short weeks. Time is of the essence while evaluating fitness of athletes, therefore, field tests present themselves as practical and specific alternatives to lab-based tests which are expensive, require a lot of time and are not sport specific. Information from the current study may help guide coaches to prescribe training in the specific capacity to which improves match performance. In the big picture, those prescribed training programs (for improvement in power) may be monitored.

Chapter Two

Methods

Participants

Twenty-five collegiate Division II female soccer players from Humboldt State University (Arcata, CA) volunteered for the study. The participants were tested during pre-season and participants completed an informed consent to participate in the study (Appendix A). Information regarding age, playing position, years of playing experience at collegiate level, and medical history were collected prior to participation via questionnaire (Appendix B). Participants were screened for inclusion and exclusion criteria and any participants who indicated on the questionnaire that they had a musculoskeletal injury that could have become worse by participation in strenuous activity, felt they could not or should not participate in strenuous activity (due to doctors orders or could be unable to manage previous health issues such as asthma, or high blood pressure) or pregnant were excluded from the study. No specific medical information related to previous injuries was obtained; therefore, performance on LLEP may have been influenced by previous injury. A calibrated scale (Health-o-Meter, Illinois) measured weight to the nearest 0.25 kg (at 10:00 am), and height to the nearest 0.5 cm. Participants were all wearing the same practice gear, including a short-sleeved t-shirt, shorts and were barefooted so that heights would not be misrepresented by shoe heights and weights would be taken with the same amount of clothing per participant.

Immediately after weight is measured, standing and seated height were measured according to procedures slightly modified from those used in the National Health and Nutrition Examination Survey (NHANES) using a stadiometer (Health o Meter, Illinois). Procedures for collection of standing height included standing on the stadiometer platform with the participants back to the backboard. The participants stood so that the posterior of the heels, buttocks, shoulder blades and head touched the backboard. Participants were positioned by the principal investigator into the correct Frankfort plane. A deep breath was taken the level on the stadiometer was lowered to the participant's height, at which point the participant was asked to relax (Appendix G).

Using the same stadiometer, seated height was obtained via measurement from the buttocks to the top of the head (placed in Frankfort plane). Sitting on a box of a known height which was adjacent to a fixed stadiometer. Participants were instructed to take a deep breath and sit up as tall as possible without moving out of the Frankfort plane until the measurement was determined. Seated height (inclusive of box height) was recorded by subtracting the known height of the box from the seated height measure to obtain the measure of the participant's seated height. Measures of lower limb length (subtracting seated height from standing height) was assessed and used for data analysis. Full procedures are in Appendix H and data collection form for all three measurements is in Appendix I.

Experimental Design

Three different tests were done in order to determine if the 5JT is a practical measure of lower limb explosive power and to assess the relationships between both 5JT and CMJ scores and soccer performance. These tests are the YYIRTL1, 5JT and CMJ using a switch mat. The YYIRTL1 was performed on the first day of tryouts as part of the assessment done by the soccer coach during the first day of practice (August 11, 2008) at 9:00 am. Two weeks prior to the YYIRTL1 test, the participants performed the 5JT and CMJ tests between (9:00 am and 11:00 am). Participants then were retested in both jump tests 24 hrs after initial testing in order to obtain objectivity (a different investigator assessed the athletes and comparisons will be made among the results), reliability coefficients for this population of women using Cronbach's alpha coefficient.

Participants were asked (in their team meeting with their coach) not to participate in any strenuous activity 24-hours prior to participation in YYIRTL1. Prior activity was not controlled for in the jump tests because participants were in the middle of preseason training which required strenuous activity on a daily basis; however, all athletes participated in the same training sessions. Prior intense activity during training may have caused the athletes to perform the jump tests with a less than optimal level of motivation. Participants were read instructions for each test prior to participation (Appendices C, E and F). Prior to testing, participants were encouraged to give their maximal effort; however, during testing session for each athlete, no encouragement was given (in order for test conditions to be consistent across participants). All tests were performed on artificial turf in which the athletes were accustomed to.

Yo-yo Test (YYIRTL1)

The YYIRTL1 test was validated by Krstrup et al. (2005) for female soccer players and was used to assess PMP. The testing protocol for the YYIRT was similar to that as suggested by Krstrup et al. (2003). Participants wore soccer shoes (molded and turf), practice shorts and a t-shirt. Immediately prior to the Yo-yo test, the participants warmed up with the coach for 6 minutes by jogging for about 3 min followed by an increase in speed up to about 75-80% of max speed, using the 20-m markers set out. The tests total time lasted 5 min to 9 min. Participants ran in individual running lanes marked by cones having a width of 2 m and a length of 20 m. A cone placed 5 m behind the finish line marked the distance in which participants completed an active recovery.

The YYIRTL1 consisted of 40 m (2 x 20-m shuttles) controlled by audio beeps projected from a portable stereo (Memorex, Model #MP3112-01), which played the Yo-yo test CD (Bangsbo 1994a, www.bangsbosport.com). After each 40-m run, players performed an active recovery in which they walked or jogged slowly around the 5-m mark behind the start marker and then returned to the start line within 10 s. Participants then briefly stopped and waited for the start signal of the next shuttle (Figure 1). The speed of each 2 x 20-m shuttle progressively increased until exhaustion. The YYIRTL1 consisted of one to four running bouts between 5-13 km/h (0-160 m) and another 8 bouts at 13.5-14 km/h (160-440 m); thereafter, it continued stepwise at 0.5-km/h speed increments at every 8 running bouts (i.e., after 760, 1080, 1400, 1720 m, etc.) (Krstrup et al., 2003) (Figure 2).

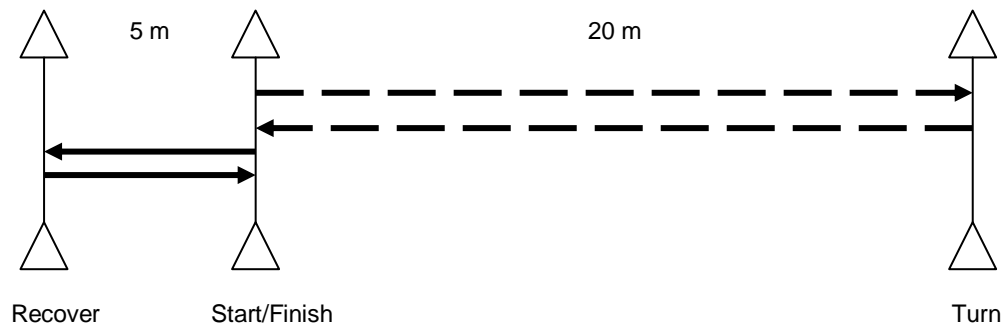


Figure 1. YYIRTL1 design showing 2 x 20-m shuttle and the 2 x 5-m recovery zone.

When a participant failed to reach the finish line by the time of the beep for that level the participant was warned verbally of the infraction by the principal investigator. The test was terminated when the athlete could not keep up with the pace of beeps on two separate occasions (not necessarily two in a row) or the participant stopped voluntarily. The total number of successfully completed bouts (including the bout which contained the first infraction) was recorded. The total distance was calculated by multiplying the total number of completed bouts by 40 m. Total distance was then used as the measure of performance. The active recovery distance covered did not count in the total distance (Krustrup et al., 2006).

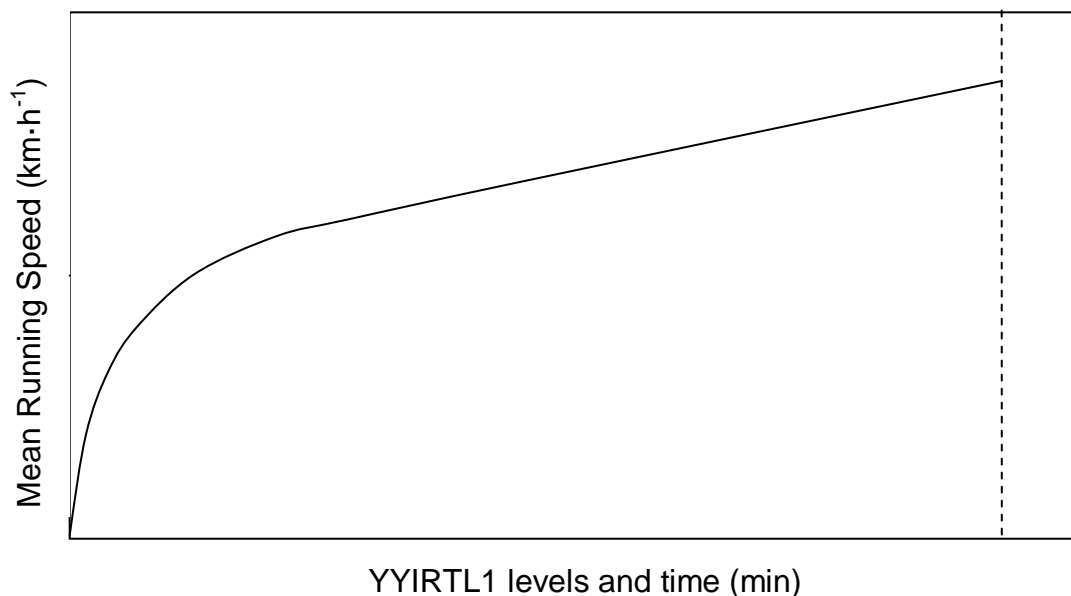


Figure 2. Schematic representation of the YYIRTL1.

For the YYIRTL1, participants were randomly split into two groups (A and B), containing 12 and 13 participants, respectively. Group A ran first and those in Group B were each assigned one player from Group A to monitor when crossing the finish line and to insure that the principal investigator was aware of any infractions. All participants were read instructions at the same time; including criteria for crossing the finish line (Appendix C), and were able to ask questions regarding protocol. The participants then viewed a 2-min demonstration provided by the principle investigator. Since participants in Group A performed first, they were be allowed to warm up and practice the first 2 min of the test in their assigned running lanes to get accustomed to the running pattern and

increases in speed. Participants in Group B were provided this same opportunity when it was their turn.

Criteria for each successful shuttle included crossing the finish line with a body part including head to toe; hands and arms did not count. When the monitors observed an infraction they alert the principal investigator and the participant verbally by saying “warning”, followed by the name of the participant. The principal investigator wrote a mark on the data sheet (Appendix D) on the level in which the infraction occurred. When a participant accumulated two infractions, the principal investigator said the name of the participant aloud followed by “you are done”. The principal investigator noted on the data sheet exactly the level the participant could not complete (were she was terminated from the test). The level of the last successfully completed shuttle was recorded as total distance covered in meters. Groups switched roles after all participants from Group A were finished with the test.

LLEP performance

The criterion measure of LLEP is a vertical jump, ideally measured using a force platform (Adams & Beam, 2008), however other measures can be done to predict power from jump height and body mass (Adams & Beam, 2008; Brown & Weir, 2001; Sayers, Harackiewicz, Harman, Frykman, & Rosenstein, 1999). Markovic et al. (2004) reported that using a switch mat to record flight time of a CMJ, and then converting the flight time to jump height, can be used to predict lower limb power. Markovic et al. found that a CMJ with predicted power was the most reliable and valid test of five different tests used

to estimate LLEP in physically active men. Slinde, Suber, C., Suber, L., Edwen, and Svantesson (2008) found an intra-class correlation coefficient of .88 for repeated CMJ tests done in 13 normally trained, but non-elite, women using a switch mat. CMJ therefore, can be used as a validated measure of LLEP in the current study.

As the purpose of this study is to explore LLEP contributions to PMP in female soccer players, the most appropriate measures for obtaining LLEP measures were considered. Chamari et al. (2008) proposed that for a measure of LLEP, a horizontal stretch-shortening 5JT is a more soccer specific test. Therefore, the 5JT, as well as the more validated CMJ, was used to evaluate the contribution of lower limb power to PMP in the participants in the current study.

Jump test design

5JT and CMJ were assessed during the same practice session. Participants were randomly assigned for YYIRTL1 (into Group A and Group B). In order to control for order effects in the jump tests, Group A and Group B was then randomly split further into Group A1, A2 and Group B1, B2. Group A1 and group B1 performed CMJ before the 5JT; the opposite applied for groups A2 and B2. Participants wore shorts, a t-shirt and were barefooted for the CMJ, but all participants wore their preferred soccer shoe for the 5JT. Prior to the jumps, participants performed a standardized warm-up including 10-min jogging and 5-min dynamic coordinated motions. Participants observed demonstrations for each of the jumps at the specific station, and were provided 5 min to practice jumping techniques at less than maximal effort (Castagna et al., 2006). No static passive stretching

occurred during warm up (Church, Wiggins, Moode, & Christ, 2001; Knudson, Bennett, Corn, Leick, & Smith, 2001; Kokkonen, Nelson, & Cornwell, 1998; Nelson, Guillory, Cornwell, & Kokkonen, 2001). Three minutes rest periods were provided before the actual first jump was administered. Work to rest ratio was 1:13 all participants order remained consistent therefore all participants had approximately the same rest time between jumps (~3 min). As individuals of each group finish their respective test, they then went to the other test and wait for investigator instructions.

5-Jump Test (5JT)

The following protocol for 5JT is adapted from research by Chamari et al. (2008). The participant stood with feet joined with toes at a fixed starting point. The participant jumped forward with one leg of her choice and continued jumping with alternate legs until each leg had performed 2 steps. At the end of the 4 consecutive steps the participant must have landed with both feet on the ground. Prior to performance, participants viewed an image of what is expected in the jump (Figure 3). Participants also viewed a demonstration by the investigator. The distance from front edge to the rear edge of their feet at the end of the last jump was spotted and recorded. It is of interest to include into the total jump distance the full length of the foot of the athletes as it is then the true distance traveled. Both distances (heel of foot and front edge of foot) on the last jump was accounted for. In the case that the athlete fell backward at landing the test was required to rest and then perform again. The investigator paid close attention to the final landing position, as the athlete was not able to hold that position and total jump distance

(to the nearest cm) was measured with a tape measure from the fixed starting location to the back edge of the feet at the final position. Total distance was recorded. The participant performed 3 trials of 5JT for greatest distance (Slattery et al., 2006; Paavolainen et al., 1999) and had ~3 min of recovery between the trials.

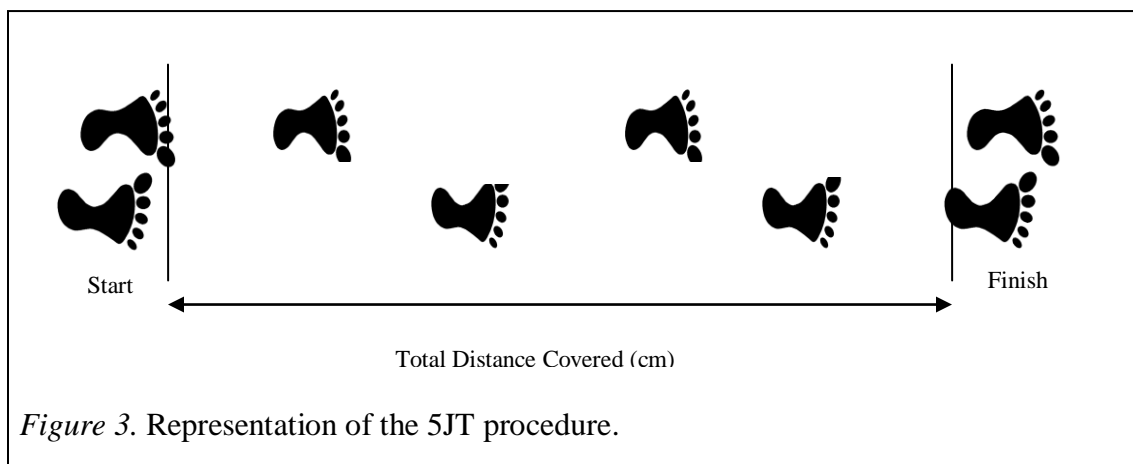


Figure 3. Representation of the 5JT procedure.

The greatest total distance performed in 5JT was noted as the absolute distance (i.e. 5JT [cm]). From this measure power relative to leg length (i.e. 5JT relative), and power relative to body mass (i.e. 5JT_BM) was determined, as per methods of Chamari et al. (2008). Because the 5JT is still not fully established as a field measure for LLEP and only validated by Chamari et al. in soccer using elite male soccer players, it was important for the present investigation to look at the validity of the 5JT relative to the CMJ and to determine reliability by test-retest. Equations for 5JT relative and 5JT_BM are shown below. In the equations, 5JT is the absolute performance (cm).

The 5JT relative = $1\text{Tread}/\text{LgLowLimbs}$. $1\text{Tread} = 5\text{JT (cm)}/5$ strides, with $\text{LgLowLimbs} = \text{standing height} - \text{seated height}$. The 5JT_BM value is determined by the following: $5\text{JT_BM} = 5\text{JT} \cdot \text{kg}$.

Counter Movement Jump (CMJ)

The protocol for the CMJ followed that described in a study performed by Slinde et al. (2008), who researched test-retest reliability for three different kinds of vertical jumps, including the CMJ. Participants performed a CMJ with the hands on hips method, without the use of arm-swing to eliminate potential influence of extraneous contribution variables (Slinde et al.; Harman, Rosenstein, Frykman, & Rosenstein, 1990; Harman et al., 1991). The CMJ was performed with the participants standing on a contact mat (Just Jump, Probotics, Huntsville, AL) with the legs in a hip wide position. A fast downward movement to about 90° knee flexion was immediately followed by a fast upward vertical movement jump for maximal height, all in one sequence. With regard to landing, both

feet must have been within the frames of the contact mat. It was important that the participants landed in the same extended body position as take off to avoid knee bending, which in turn increases flight time (Klavora, 2000; Markovic et al., 2004) (Figure 4). Investigators made sure of these criteria and participants who did not fulfill the criteria were asked to rest and then re-perform the trial. A video camera recorded CMJ trials in order to provide documentation for any flight time outliers. Three maximal jumps were performed with approximately 2-min rest between jumps; all jumps were recorded and the highest result was used for analysis (Slinde et al., 2008). CMJ participant instructions are in Appendix F.

The Just Jump System was used to estimate vertical jump height in the CMJ. This system included a square mat (27 in by 27 in) attached to a hand-held computer. The switch mat, which starts timing at takeoff and ends at landing, provides flight time. The computer displays both air time (0.01 s) and the height of the jump (to the nearest 0.5 in) simultaneously, this tool eliminates the need for calculations. The internal (Just Jump) calculation of flight time to height is: $h = (T^2 \times g)/8$ where h is height, T is the total flight time and g is the gravitational constant of 9.81 m/s^2 under the assumption that time to peak height is the same as the time from peak height to landing. The switch mat system had been used in numerous research studies including Leard et al. (2007); Wyon, Allen, Angioi, Nevill and Twitchett (2006).

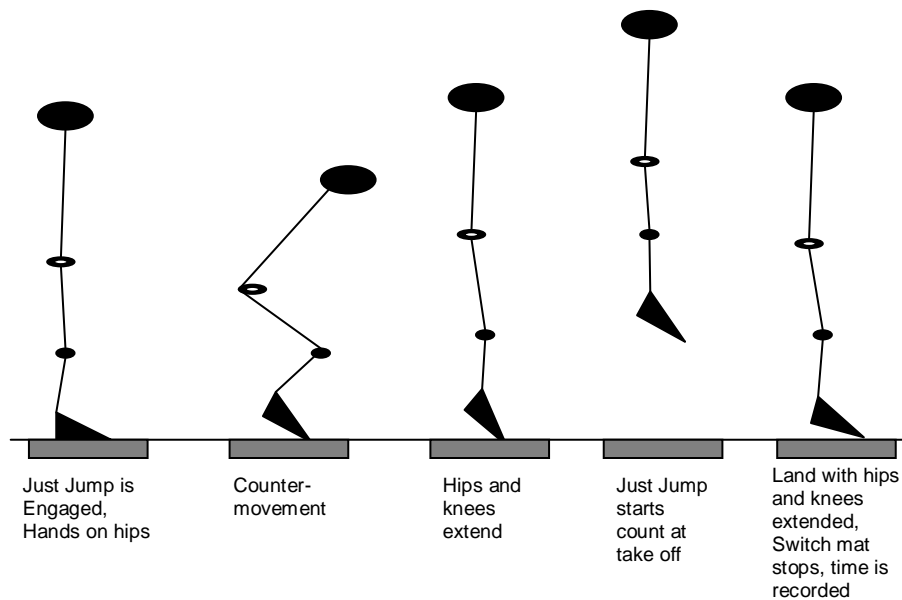


Figure 4. Description of the Just Jump timing device for CMJ.
Note. Adapted from Slinde et al. (2008).

Once CMJ performance was determined, calculations for absolute peak power (CMJPP) and peak power relative to body mass (CMJPP/BM) was found using equations from multiple regression analysis by Sayers et al. (1999). $CMJPP (W) = 60.7 \times (\text{jump height [cm]}) + 45.3 \times (\text{body mass [kg]}) - 2055$. Whereas, $CMJPP/BM (W \cdot kg^{-1}) = \text{Absolute peak power (W)} / \text{body weight (kg)}$ (Sayers, et al., 1999). This equation was derived originally for SJ but the reason this formula for power was chosen for the current investigation is because use of CMJ resulted in very small error (Sayers, et al.). Carlock et al. (2004) has used the Sayers et al. equation to estimate peak power from hands-on-hips CMJ performance using a switch mat. Leard et al. (2007) validated the Just Jump

System method compared to Vertec method by using a criterion reference 3-camera motion analysis system. The Pearson (r) between the 3-camera motion analysis system and the jump and reach (Vertec) was .91. The Pearson r between the 3-camera motion analysis system and contact mat (Just Jump) was .97. Both correlations were significant at the .01 level.

The high correlation and the minimal difference in the means between the Just Jump and the criterion reference 3-camera system strengthens the argument that Just Jump is a more valid test for measuring vertical jump height rather than the Vertec. Both of these methods are valid tests but the accuracy of the Just Jump would appear to be slightly better on the basis of the results of the Leard et al. (2007) study.

Statistical Analysis

Descriptive statistics were reported as mean \pm SD for all dependent measures. The Pearson Product-Moment Correlation was used to determine the relationships among the following variables: YYIRTL1 performance (m), CMJ (cm), CMJPP (watts), CMJPP/BM, 5JT (cm), 5JT relative, and 5JT_BM and 5JT/BM. Intra-class correlation coefficients (ICC) were determined to assess reliability of both CMJ and 5JT. Concurrent validity of the 5JT with the CMJ will be determined. The criterion for significance was set at an alpha level of $p \leq .05$. All statistical analyses were conducted using version 16.0 of the Statistical Package for the Social Sciences (SPSS, 2008).

Limitations

Limitations may compromise the internal validity of the study and may influence the interpretation of results. There are a number of limitations to the current study. The YYIRTL1 was validated as a measure of PMP in elite female players (Krustrup et al., 2005), and was assumed to be a valid measure of high-intensity match play in Division II female collegiate players. During the recovery period between shuttle-runs in the YYIRTL1 the athletes may have been able to mentally time the 10-s recovery period, resulting in a slow reaction time to the beep starting the next shuttle. Kinematic analyses, which are used in research supporting use of switch mat, have a tendency to underestimate force as compared to a force plate measure (Linthorne, 2001). Diet of the athletes was not controlled. Conditioning level and previous experience of the athletes was not controlled. Validity of the 5JT as a measure of LLEP in women is unknown.

Delimitations

Delimitations of the study which may affect the outcome of the study include: 1) measures were taken at the end of a summer fitness program, and although the coach had encouraged his athletes to perform a summer workout program he was not able to monitor it, therefore the assumption is that all the athletes' are returning from summer vacation prepared for such fitness testing; 2) the participants were only Division II women soccer players; and 3) PMP was only assessed using YYIRTL1; 4) LLEP was only measured using CMJ and 5JT; 5) strength, aerobic fitness and other possible

contributors to PMP were not determined; and 6) participants were be 18 years of age and older.

Operational Definitions

1) *PMP test*- Physical Match Performance was measured using YYIRTL1. Scores were expressed as distance covered, measured in meters.

2) *LLEP (Lower-Limb Explosive Power)*- The power in the legs measured using the CMJ and the 5JT.

3) *5JT*- A test where the participant jumped for maximal distance while stepping alternately four times and landed on two feet, expressed as absolute performance (cm).

4) *5JT-relative*- The power prediction from performance in 5JT relative to leg length calculated as $1\text{Tread}/L\text{gLowLimbs}$. Where $1\text{Tread} = 5\text{JT}/5$ strides and $L\text{gLowLimbs} = \text{standing height} - \text{seated height}$.

5) *5JT_BM* - The power prediction from performance in the 5JT relative to body mass, determined as $5\text{JT} \times \text{body mass (kg)}$.

6) *CMJ*- Is performed as a vertical jump preceded by a brief countermovement to a comfortable squat position before takeoff. Calculated from flight time on the Just Jump Switch Mat $h = (T^2 \times g)/8$. Where h is height, T is the flight time (s) and g is the gravitational constant of 9.81m/s^2 and under the assumption that time to peak height is the same as the time from peak height to landing.

7) *CMJPP*- Absolute peak power calculated using equation by Sayers et al. (1999).

8) $CMJPP (W) = 60.7 \times (\text{jump height [cm]}) + 45.3 \times (\text{body mass [kg]}) - 2055$.

9) *CMJPP-relative*- Is the peak power relative to body mass. $(W \cdot kg^{-1}) = \text{Absolute peak power (W)} / \text{body weight (kg)}$.

Chapter Three

Results

Participants in this study were 24 volunteers from the Humboldt State University NCAA Division-II women's soccer team. Testing was completed during the period of pre-season tryouts and over the three-week course of the study no participants dropped out. Descriptive statistics for age, year of eligibility, weight, and height are presented in Table 2.

Table 2

Characteristics of the participants (N = 24).

	Minimum	Maximum	Mean	Std. Deviation
Age (years)	18.0	22.0	19.6	1.4
Eligibility (years)	1.0	5.0	2.3	1.3
Weight (kg)	47.1	74.4	61.5	6.5
Height (cm)	151.1	175.9	164.2	7.4

Test Variables

The three major test variables for this investigation were YYIRTL1, 5JT and CMJ. YYIRTL1 was used to represent the PMP of the soccer players involved in the study. 5JT and CMJ were used to represent LLEP. Scores used for data analysis represented the total distance covered (m) by the athletes.

The 5JT was expressed as total distance covered in cm (i.e., 5JT [cm]). The best of three trials for 5JT, as measured by the principal investigator, was used for analysis. The 5JT was also expressed using measures previously described by Chamari et al. (2008), which were 5JT-relative to leg length (i.e., 5JT-relative) and 5JT multiplied by body mass (i.e., 5JT_BM). Additionally, given that power measures are sometimes expressed relative to BM (Castagna et al., 2006), a third measure was added; this measure was 5JT distance divided by body mass in units of kg (i.e., 5JT/BM). The Cronbach's alpha reliability coefficient for 5JT for the principal investigator was $r = .95$; The Cronbach's alpha reliability coefficient for 5JT for another tester was $r = .97$. Objectivity between both testers was reported as $r = .97$. The intra-class correlation coefficient (ICC) for each investigator for the 5JT in the current study was higher than that found by researchers using a variety of participants ($r = .91-.94$) (Chamari et al., 2008; Chtara et al., 2008; Slattery et al., 2006); objectivity was higher than that in previous research ($r = .81$) by Chtara et al. (2008).

CMJ was expressed as the height obtained from the switch mat measure, which was derived from flight time. The best CMJ, measured by the principal investigator, was used

for analysis (i.e., CMJ [cm]). CMJ performance was also expressed in the form of peak power (i.e., CMJPP), obtained using the equation from Sayers et al. (1999). Given that at least one other investigator (Castagna et al., 2006) has investigated CMJPP relative to body mass, CMJ performance was also expressed this way in the current study. The Cronbach's alpha reliability coefficient for CMJ for the principal investigator was .97; the Cronbach's alpha reliability coefficient for CMJ for the other tester was also .97. Objectivity was reported as .98. The ICC in the current study are higher than the range (.82-.98) of those reported by previous researchers (Chtara et al., 2008; Hoffman & Kang, 2002; Slinde et al., 2008) the objectivity was within the range (.90-.98) of what has been reported for CMJ in previous research (Chtara et al., 2008; Hoffman & Kang et al., 2002). Descriptive statistics for the YYIRTL1, the 5JT measures, and the CMJ measures are summarized in Table 3.

Table 3

Descriptive statistics for performance in YYIRTL1, 5JT, and CMJ (N=24).

Variable	Minimum	Maximum	Mean	SD
YYIRTL1 score (m)	760.0	1560.0	1013.3	239.9
5JT (cm)	795.0	1056.0	910.0	59.7
5JT-relative	2.1	2.9	2.4	0.2
5JT_BM (cm*kg)	42966.0	64557.1	55879.5	6491.5
5JT/BM (cm/kg)	11.5	19.4	15.0	2.0
CMJ (cm)	31.2	48.8	39.7	4.3
CMJPP (watts)	2558.9	3638.2	3135.3	337.1
CMJPP/BM (watts/kg)	43.1	60.3	51.2	4.3

Correlations

Pearson product-moment correlation coefficients were used to examine the relationships among YYIRTL1, 5JT, 5JT-relative, 5JT_BM, 5JT/BM, CMJ, CMJPP, and CMJPP/BM. A correlation matrix showing the results of these analyses is shown in table 4.

With regard to the first hypothesis of the current study (5JT would significantly relate to the CMJ), the 5JT did indeed significantly relate to the CMJ ($r = .71, p < .05$). Thus, the 5JT is concurrently valid with CMJ (US Department of Labor, n.d.). The scatter plot for the relationship between 5JT & CMJ is shown in Figure 5. Also, 5JT was significantly related to CMJPP and CMJPP/BM. In addition, some of the alternate ways of expressing 5JT significantly related to either CMJ or CMJ derivatives: specifically, 5JT-relative related to CMJ and CMJPP/BM ($r = .53, p < .05$ and $r = .60, p < .05$, respectively); 5JT_BM related to CMJPP ($r = .86, p < .05$); 5JT/BM related to CMJ and CMJPP/BM ($r = .54, p < .05$ and $r = .63, p < .05$, respectively).

Table 4

Intercorrelations Among YYIRTL1 and Absolute and Derived Measures for 5JT, and CMJ (N=24)

Subscale	1	2	3	4	5	6	7	8
1. YYIRTL1 (m)	--	.202	.323	-.343	.534**	.106	-.356	.186
2. 5JT (cm)		--	.637**	.458*	.568**	.710**	.456*	.701**
3. 5JT-relative			--	.221	.841**	.527**	-.152	.599**
4. 5JT_BM (cm*kg)				--	.463*	.158	.855**	.057
5. 5JT / BM (cm/kg)					--	.541**	-.342	.633**
6. CMJ (cm)						--	.535**	.990**
7. CMJPP (watts)							--	.435*
8. CMJPP/BM (cm/kg)								--

** . Correlation is significant at the .01 level (2-tailed).

* . Correlation is significant at the .05 level (2-tailed).

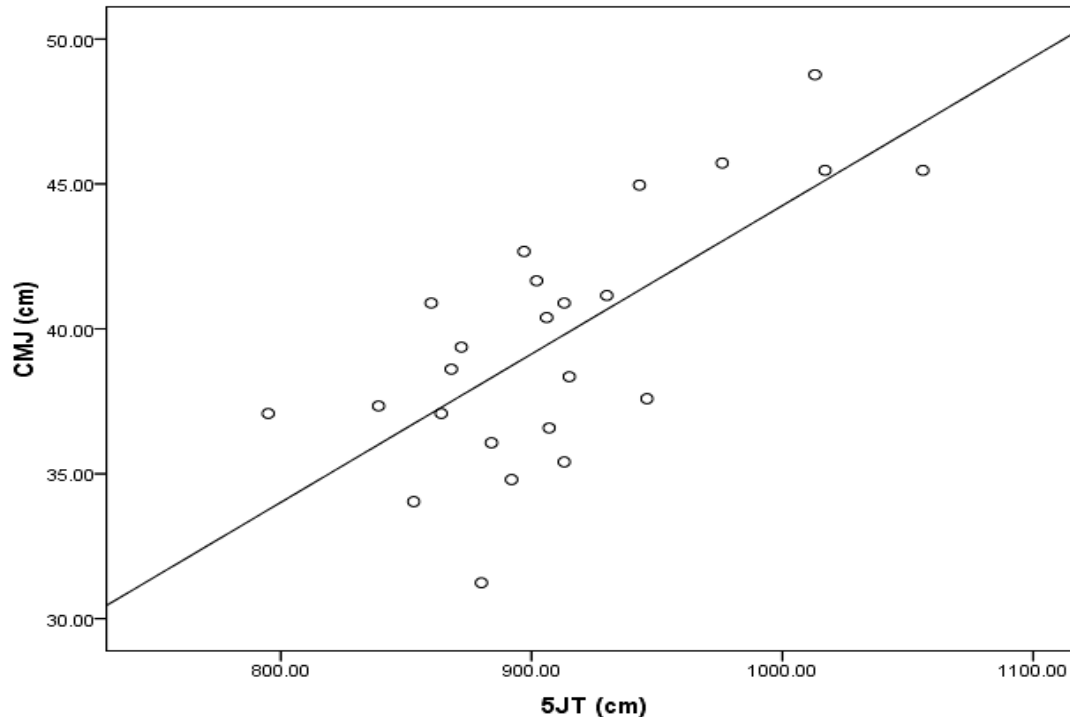


Figure 5. Scatter plot showing the relationship between CMJ and 5JT scores ($r = .71$, $p < .05$).

Regarding the second hypothesis (5JT would relate more strongly to YYIRTL1 than CMJ related to YYIRTL1), both 5JT and CMJ positively related to the YYIRTL1, but neither of these correlations reached statistical significance ($r = .20$, $p > .05$; $r = .11$, $p > .05$, respectively). Similarly, 5JT-relative and CMJPP/BM were positively related to YYIRTL1, but again these were not statistically significant. Scatter plots for relationship between 5JT and YYIRTL1 and the relationship between CMJ and YYIRTL1 are shown in Figures 6 and 7, respectively. Negative correlations occurred (between 5JT_BM and

YYIRTL1 and CMJPP and YYIRTL1), but these were not statistically significant. The only LLEP measure that significantly related to YYIRTL1 was 5JT/BM ($r = .53$ $p < .05$).

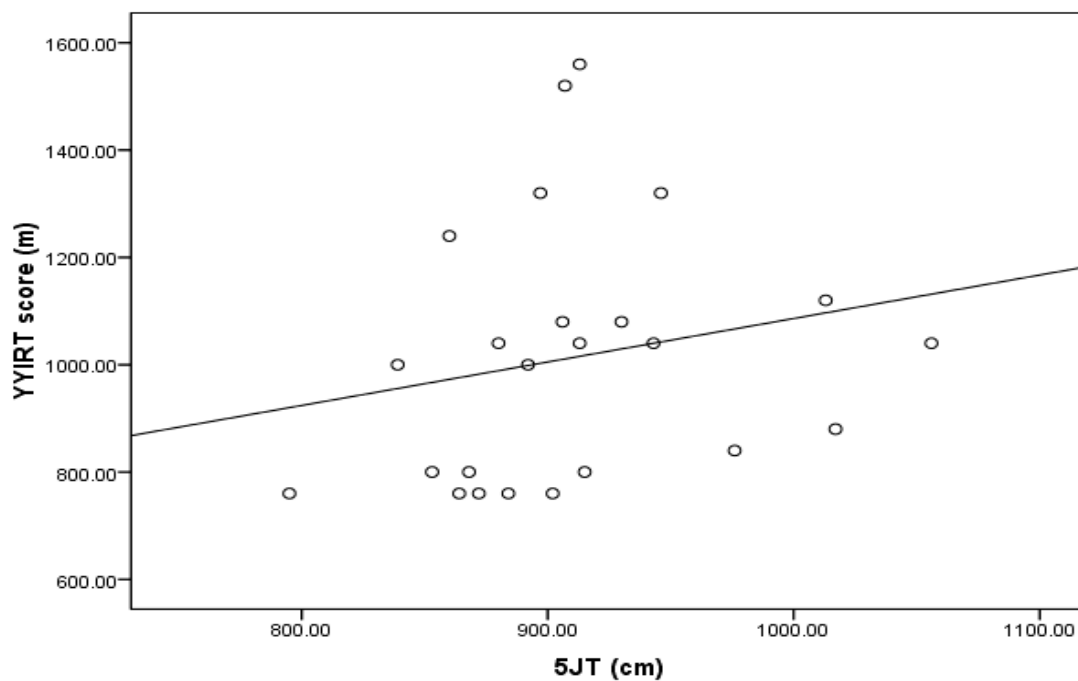


Figure 6. Scatter plot showing the relationship between YYIRTL1 and 5JT ($r = .20$, $p > .05$).

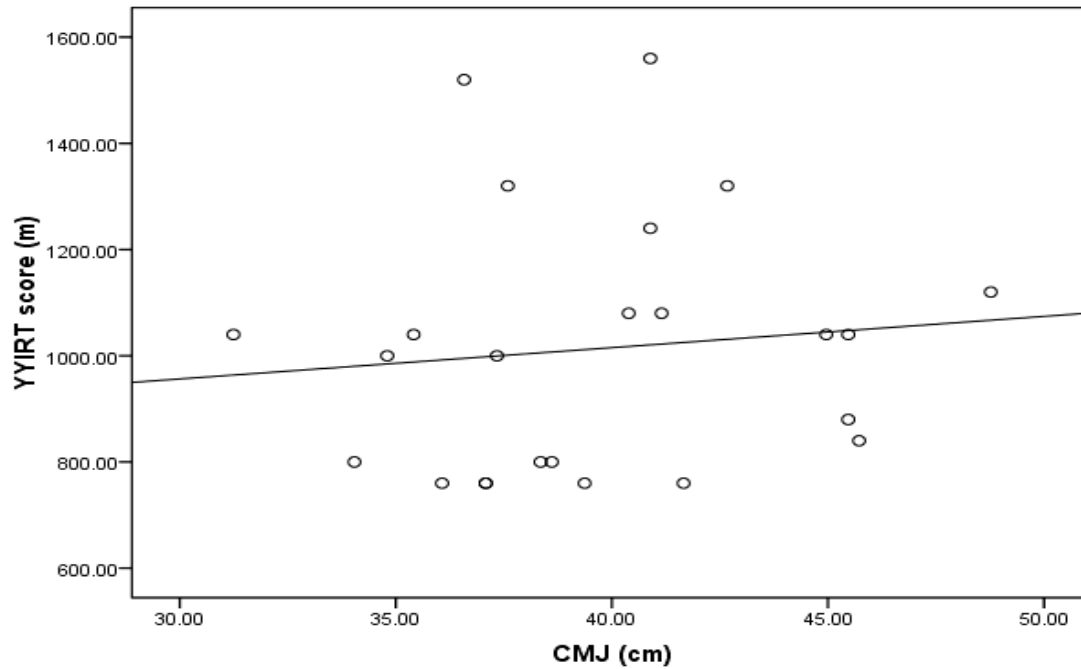


Figure 7. Scatter plot showing the relationship between YYIRTL1 and CMJ ($r = .11$, $p > .05$).

Chapter Four

Discussion

One purpose of this study was to determine if two tests of LLEP related to each other in Division II female soccer players. As hypothesized, absolute scores of 5JT were positively and significantly related CMJ. Also, 5JT was positively and significantly related to CMJPP and CMJPP/BM. Lastly, some of the 5JT derivative measures significantly related to CMJ as well as to some of the CMJ derivatives; the highest positive relationship was that between 5JT_BM and CMJPP.

The relationship between 5JT and CMJ is in agreement with results reported by Chamari et al. (2008) for 15 elite-level male soccer players (under-23 national team). In the study by Chamari et al. the athletes were able to freely use their arms while performing the CMJ on a force platform, in contrast to the present study. Chamari et al. found that 5JT and CMJ were significantly related ($r = .56, p < .05$), as were 5JT-relative and CMJ ($r = .71, p < .05$), 5JT-relative and CMJPP ($r = .52, p < .05$), and 5JT_BM and CMJPP ($r = .54, p < .05$). Similarly, Bouhlel, et al. (2006) found significant relationships between 5JT and CMJ, ($r = .63, p < .01$) and between 5JT and CMJPP/BM ($r = .74, p < .01$) in children (age, 12 ± 0.4 years); in the study by Bouhlel et al. CMJ was performed on a force platform. The current study and previous studies provide evidence that the 5JT is a valid measure of LLEP. Hence, either 5JT or CMJ can be used as a measure of LLEP in future studies.

As for the best way to express 5JT scores, Chamari et al. (2008), stated that “5JT performance is usually expressed in absolute terms as the overall distance covered (i.e., in meters) p. 944”. Chamari et al. went on to explore different ways of expressing 5JT and emphasized the importance of 5JT-relative measures based on their data. In the current study, the expression of 5JT in absolute distance covered had the highest correlation with CMJ height, i.e., none of the derived expressions had higher correlations with CMJ height than expressing 5JT as distance covered in cm. The only exploratory measure of 5JT performance in the current study that had a higher correlation than that of absolute distance to any CMJ variable was 5JT made relative to BM (5JT/BM), which was strongly related to CMJPP. This way of expressing LLEP should be investigated further in future studies.

Chamari et al. (2008) found a relationship of 5JT to CMJ, but not to CMJPP or to CMJ expressed relative to body mass to the two-thirds power. In the current study 5JT did relate to CMJPP and CMJPP/BM. The differences among the findings of the current study and Chamari et al. could be related to differences in the competitive level or sex of the athletes, the age of the participants, the scaling of body weight, and/or the alternative measurement methods used. For example, use of a force platform to measure anaerobic power in a CMJ is ideal, whereas a switch mat was used in the current study for the sake of practicality.

The difference between the switch mat and the force plate is that the switch mat records flight time which then can be used to estimate jump height, whereas a force plate collects the actual ground reaction force. Using the switch mat to measure height assumes

that the participant has the same body position at take off as they do at landing. Therefore, the participant theoretically spends the same amount of time during the ascending phase as during the descending phase of flight. Yet, in fact, it has been shown (in female collegiate physical education students using a force platform) that the center of gravity of participants during a CMJ at the moments of landing are lower than the momentary positions at takeoff (Amador, Javier, Alegre, Jimenez, & Aguado, n.d). Kibele (1998) add that using flight time as a method for estimating jump height leads to an overestimation of height jumped from 0.5 to 2 cm. Therefore, the results, and perhaps the correlations, from the present investigation may be different from those of Chamari et al. (2008) because of the differences in measurement tools for the CMJ. Even though the aforementioned difference between studies exists, it still is important to note that the results of the current study add to evidence from previous studies that support the idea that 5JT is a valid measure of LLEP. Field testing of soccer players using the 5JT may be a practical alternative to LLEP measures such as using a switch mat or force plate.

A second purpose of this research was to determine if one or both of the LLEP tests were related to PMP in this group of athletes. 5JT performance was expected to show a stronger relationship to YYIRTL1 than CMJ to YYIRTL1. Although there were positive relationships between 5JT performance and YYIRTL1, as well as between CMJ performance and YYIRTL1 (and the magnitude of the first relationship was greater than that for the latter relationship), neither correlation was statistically significant ($p > .05$).

This result was interesting, given that Castagna et al. (2006) had found statistically significant relationships between both CMJ height and CMJPP with YYIRTL1

performance in male soccer players ($r = .50$, $p = .01$, and $r = .57$, $p = .003$, respectively). Similarly, Mujika, Santisteban, Impellizzeri, and Castagna (in press) found a significant relationship between CMJ height and YYIRTL1 in female soccer players ($r = .60$, $p < .001$), however Mujika et al. did not find significant relationship in male soccer players. There may be explanations for why the results in the current study differed from that found by Castagna et al. (2006) and in Mujika et al. (in press). Explanations could relate, in part, to the methods used to measure the variables or participant selection.

Castagna et al. (2006) were the first researchers to explore LLEP as a predictor of PMP in soccer players. Castagna et al. measured LLEP using a CMJ on a force platform and expressed CMJ variables as height and CMJPP relative to body weight to the two-thirds power. In the current study, the CMJ was performed in a manner similar to that in the Castagna et al. study (i.e., hands on hips), but height measures were derived from time using a switch mat. Peak power was then estimated by an equation (Sayers et al., 1999) and expressed as both peak power and peak power relative to body mass to the first power. The limitations of measuring height in this manner, as well as problems in estimating power using an equation, may have led to errors in measurement which resulted in a decreased relationship of LLEP to YYIRTL1 in the current study.

Mujika et al. (in press), using methods similar to those of the current investigation (i.e., CMJ performed on a switch mat without the use of arms, and performance measured using YYIRTL1), found a significant relationship between CMJ height and YYIRTL1 in female soccer players ($r = .60$, $p < .01$). The female participants ($N = 34$) in the study by Mujika et al. were from an elite level club. The participants in Mujika et al. were

separated into groups by age (i.e., seniors and juniors) with average ages reported as 23.1 ± 2.9 and 17.3 ± 1.6 years, respectively. Similarly, the male players studied by Mujika et al. (N = 34) had an average reported age of 23.8 ± 3.4 years for seniors and 18.4 ± 0.9 years for juniors.

The significant relationship between LLEP and YYIRTL1 in male soccer players found by Castagna et al. (2006) does not fit with other research. Mujika et al. (in press) failed to find a significant relationship between CMJ and YYIRTL1 in a pooled group of senior and junior males ($r = .13$, $p > .05$); also no relationship between CMJ and YYIRTL1 was found in the female soccer players in the current investigation. However, there are a few possibilities that could explain this lack of agreement in findings between groups of participants and across studies including: differences in where the athletes were on the spectrum of performance, the spread or heterogeneity of the data, and the nature of the test used to measure PMP.

According to Mujika et al. (in press), there may be a point in the spectrum of performance in which LLEP has no effect on YYIRTL1 performance. Differences in the relationship between CMJ and YYIRTL1 performance across the spectrum of performance was evident when comparing the findings from Castagna et al. (2006) (i.e., amateur male players showed significant relationship) and those of Mujika et al. who found no such relationship in elite level male players. The select group of males at the elite-level (regardless of age) may require a superior level of power and fitness to make the team, therefore it would be challenging to demonstrate any relationship between power and performance in this group. Differences in the relationship of power to

performance across the spectrum of performance may be evident for female players as well, as the findings of the current study differed from what was found for the female groups studied by Mujika et al. The CMJ scores were considerably higher in the participants of the current study as compared to those reported by Mujika et al. It appears that at this higher level of LLEP there was no relationship to YYIRTL1 performance. It is difficult to compare findings for the female participants in the current study with the findings of Castagna et al. given the difference in sex of the participants, as there are large differences between males and females in YYIRTL1 (up to 153%) who are matched by age and level (Mujika et al., in press). Much more research in females needs to be done before identification of a point in the spectrum of performance can be identified where the importance of LLEP to performance no longer matters if such a point exists.

The scores of the YYIRTL1 in the current study were more homogeneous than the scores in Mujika et al. (in press) for the combined senior and junior groups, (i.e., range of 760 to 1560 m vs. approximately 600 to 1750 m, respectively). Correlations between CMJ and YYIRTL1 were not reported within the senior female group alone, or within the junior female group alone. The senior females studied by Mujika et al. scored an average of 48% higher in the YYIRTL1 than the juniors; it was also reported that senior females performed significantly better than junior females in CMJ. When Mujika et al. combined these two disparate groups, the correlation could be inflated relative to that seen in the current study, where there was a much more restricted range of values for the YYIRTL1. In fact, if only the data points within the range of scores of the current study for YYIRTL1 and CMJ are identified from the scattergram presented by Mujika et al. are

used to estimate the correlation in the Mujika et al. study, the magnitude of the correlation is reduced to approximately .30 or .35. Hence, if the range of values is restricted and extreme scores are removed from the scatter plot in Mujika et al., the correlation coefficient will be deflated.

As mentioned in the introduction, high-intensity running during a match was the primary way in which the YYIRTL1 was validated. High-intensity running only includes a small amount of power output provided by sprinting. This small power output may not significantly contribute to the variance in PMP. Based upon research of Hennessey and Kilty (2001), and Wisloff et al. (2004) speed has been found to relate to LLEP. The researcher in the current investigation was therefore attempting to relate power to only a small portion of the high-intensity running in a match. Specifically, in a 90 min soccer match, sprinting could account only for about 6% of the time (Reilly & Thomas, 1976). Therefore, the influence of anaerobic power may be too small of a factor to play a significant role in PMP for participants in the present investigation, and in the male participants of Mujika et al. (in press).

With regard to the relationship between LLEP and performance between the sexes, the lack of relationship between LLEP and YYIRTL1 in the current investigation contrasted with the significant relationship found by Castagna et al. (2006). This difference may be due to the differences in the energy capacities used during soccer performance. It was demonstrated by Krustup et al. (2005) that VO_2 max and high-intensity running were correlated in female players whereas there was no significant relationship between these parameters in males (Krustup et al., 2003). It may be that

aerobic power for the elite female game is more important than that for elite male game, and consequently anaerobic power may play less of a role in the female game. This suggests that there are differences between physical contributors to match performance between males and females. This idea of different kinds of soccer performance depending on the group may carry over to the comparison of elite females to non-elite or collegiate females. Differences in groups studied can therefore explain discrepancies in the relationship of power to performance across studies.

Lastly, the concept of fatigue may explain why there were no significant correlations found in the current study between LLEPs and YYIRTL1. The nature of the YYIRTL1 demands that athletes perform until they cannot not make it to a finish line while running 20 x 2-m bouts (which take about to ten seconds to complete at the lower levels of the test, but increases to a faster pace as levels progress). This model is representative of the definition and explanation of muscle fatigue as “Human muscle fatigue can be defined as a loss of force-generating capacity in voluntary contractions. Defined in this way fatigue is not an abrupt event like exhaustion or task failure.” (Sogaard, Gandevia, Todd, Peterson, & Taylor, 2006, p.511). What causes fatigue is still being explored and is beyond the scope of this study, however, it is generally accepted that persons with high power have a greater percentage of fast twitch fibers, and fast twitch fibers are highly fatigable (Enoka et al., 2008; Powers & Howley, 2007). This may explain why there are low correlations between LLEP and performance in the current study.

Conclusions

The 5JT was found to be a practical and valid practical measure of LLEP. No significant correlations between LLEPs and YYIRTL1 were found. To the knowledge of the investigator, this was the first study in which relationship between 5JT and YYIRTL1 were studied. For this reason comparison of LLEP to previous research was represented by the CMJ test, as other researchers have explored this. In regard to the lack of relationship between LLEP and PMP the findings of the present study showed agreement with the male population of Mujika et al. (in press) but disagreed with significant correlations found for the population of females in Mujika et al. and also disagreed with the significant relationship in males investigated by Castagna et al. (2006).

Possibilities for the lack of agreement with previous researchers may be attributed to limitations in the measurement methods for LLEP, or the participant selection. The YYIRTL1 is validated based on its relationship with high-intensity running (which only includes a small amount of “power-type” sprinting). It may be sprinting ability is such a small a portion of soccer performance that LLEP fails to explain variance in YYIRTL1. A more sport specific test (e.g., a sprint test) might better relate to soccer performance than a jump test. Differences in sex relating to match performance are evident and could explain some of the differences in correlations of LLEP to PMP studies. Lastly, the fatiguing nature of YYIRTL1 may explain why athletes higher in power, generally did not have better performance in the test. Overall, further investigation is required, as the idea of power as a predictor of performance is relatively new and literature supporting the evidence obtained in the current study is limited, especially for females.

Future research should focus on the validation of the YYIRTL1 in athletes across the spectrum of ability. Measures of aerobic performance, along with measures of power, should be taken in the same group of athletes to better explain the variance in soccer performance. Also, it would be beneficial to test a large number of athletes across a wide range of performance within each gender to be able to tease apart differences in the importance of LLEP to performance within competitive groups. Use of short sprint performance as a measure of power may correlate with YYIRTL1 and provide an even more sport-specific field test of LLEP. Lastly, as YYIRTL1 is likely a measure of fatigue, it would be of interest to explore doing five consecutive vertical jumps to obtain vertical displacements and/or observe fatigue over the course of the jumps. Data from this test could be used to determine the relationships of total work and power to YYIRTL1.

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Appendix A: Informed Consent

Lower-Limb Explosive Power and Physical Match Performance in Collegiate Female Soccer Players: A Correlational Study

INFORMED CONSENT PARTICIPATION

Please read the following as it provides information about this research study. Please understand that you are being asked to volunteer in this study and it is your choice to participate. By signing this form you are indicating that you have been informed of the nature of the study including the risks and benefits of its association and want to participate.

You are being asked to participate in a research project by Jenna Hunter, a graduate student in the Department of Kinesiology and Recreation Administration at Humboldt State University (1 Harpst Street, Arcata, CA). If there are any questions or concerns relating to this research please call Jenna Hunter at (707) 599-6209 or email sistah.jro@gmail.com. You may also call or email the supervising faculty member Dr. Tina Manos at (707)826-5962, tmm52@humboldt.edu . Additional contact may be made with the Dean of Research and Graduate Studies, Dr. Chris Hopper (707) 826-3853, cah3@humboldt.edu .

Explanation of Purpose

The primary purpose of this research is to determine the relationship between lower-limb explosive power (LLEP) and physical match performance (PMP) in Division II women's soccer players. If there is a strong relationship then the results may indicate that training for anaerobic power is important to improving PMP.

Participants

At least 22 women from Humboldt State University Women's soccer tryout will be recruited to participate in the study. Potential participants will be selected based on inclusion and exclusion criteria.

Procedures and Time Required

If you agree to participate in the study you will:

1. Complete a Medical Information and History questionnaire which determines the final inclusion into the study.
2. Demographics (including height, weight, and measurement of lower-limb length). Measurements will be taken by the female principal investigator (Jenna Hunter) in the Human Performance Lab to insure privacy.
3. During a day of your tryout you will perform the Yo-yo intermittent recovery test (YYIRTL1) for prediction of PMP. This test lasts 8 to 20 m. YYIRTL1 is a repeated shuttle run test consisting of 40 m (2 x 20 m). After each successful 40-m run, you will have a recovery period (10 s) where you walk or jog slowly around another mark 5 m behind the start mark and back in which you stop and

wait for the start signal of the next shuttle. The speed of the shuttle will progressively increase. When you fail to reach the finish mark by the time of the beep you will be warned. Your test will be completed when you; i) cannot not keep up with the pace of beeps on two separate occasions and /or ii) stop voluntarily. The total distance covered (i.e. 40 m x total shuttles run) will be recorded as the test result.

4. LLEP will be collected using two jump tests (countermovement and 5 jumps).
5. You will perform counter movement jump a maximum of 3 times on a switch mat. You will place your hands on your hips on a contact mat (Just Jump) with your legs in a hip-wide position. A fast downward movement to about 90° knee flexion immediately followed by a fast upward vertical movement as high as possible all in one sequence. When landing, both feet have to be within the frames of the contact mat. The switch mat will record flight time and convert that time into jump height using an equation.
6. You will also perform 5-jump a maximum of 3 times. 5-jump test consists of 5 consecutive steps with feet joined at the beginning and end of the jumps. From starting joined feet position participants jump forward with the one leg of her choice and continue alternately left and right for 4 steps. After both feet have landed two times each she will perform the fifth step and land on both feet again joined together. If you falls back on the last step or during any portion of the test the trial will need to be redone. The investigator will use a measuring tape to record the total distance of the starting point (where jumpers put their toes at the beginning) to the point where their heels landed at the end of the fifth jump. The total distance will be then converted to LLEP using an equation.

Location and approximate time commitment from participants (includes warm-up time for tests)

Introduction, signing of informed consent, demographics, and skinfolds (Human Performance Laboratory).....	30 min
Yo-yo Test (HSU Field House).....	90 min
Jump Tests (HSU Field House).....	90 min
Total.....	3-hrs,30 min

Description of Risks/Discomforts you may Experience and Risk Management Procedures

YYIRTL1

Risks and Discomforts: Risks include potential for musculoskeletal injury, muscle soreness and stiffness. You may feel discomfort in this test because it requires you will work until exhaustion.

Risk Management: You will be properly warmed up before performance and informed of proper technique. You will be able to stop at any point during performance.

Countermovement Jump Test

Risks and Discomforts: Risks include musculoskeletal injury.

Risk Management: You will be properly warmed up prior to performance. You will also be instructed on proper jumping and landing technique.

5 Jump Test

Risks and Discomforts: Risks include musculoskeletal injury.

Risk Management: You will be properly warmed up prior to performance. You will also be instructed on proper jumping and landing technique.

Benefits to Science and Society

By doing this research we are expanding the knowledge of soccer. If we can determine that LLEP related to PMP in Division II women's soccer players, we can determine proper training methods to improve or maintain that level. Soccer coaches, strength and conditioning coaches and athletes alike will be able to design and implement training regimens. You will be released the data from all tests and will benefit immediately from participation in this study as results will specifically inform them of you of your current physical capabilities.

Confidentiality

The privileged information that is obtained during the study will be treated at the utmost confidential level as described in Health Insurance Portability and Accountability Act of 1996. Other than the information that is used for statistical and scientific purposes, no personal information will be released to any person. Confidential information provided by or observed from participants will be assigned a number. The numbers will only be known to the P.I. (Jenna Hunter) and the faculty supervisor (Tina Manos). During the three weeks of data collection, the records will be kept under lock and key in a bookshelf in the residence of the P.I. All electronic files will be kept on a two separate flash drives and will be locked up with the hard copy data.

Compensation

You will not be paid for participation in this research.

Questions and Concerns

If you have any questions or concerns at any point (before, during or after) participation in this study you may direct them to Jenna Hunter (Principal Investigator) at 707-599-6209, or sistah.jro@gmail.com .

Freedom of Consent

Your participation in the study is voluntary. If you decide to participate in the study, you can withdraw your consent and stop your participation at any time without penalty to which you are allowed.

By signing below you are stating that:

I have read this form, and I understand the procedures that I will perform and the risks and discomforts associated with such physical tests. Knowing these risks and discomforts, and having had an opportunity to ask questions that have been answered to my satisfaction, I consent to participate in this research study.

Name of Participant (Printed) _____

Signature of Participant _____ **Date:** _____

Signature of Witness _____ **Date:** _____

Appendix B: Questionnaire

Medical Information and History, Questionnaire

The privileged information that is obtained in this questionnaire will be treated at the utmost confidential level as described in Health Insurance Portability and Accountability Act of 1996. Other than the information that is used for statistical and scientific purposes, no personal information will be released to any person. If any questions should arise please feel free to contact the Principle Investigator, Jenna Hunter (707)599-6209 sistah.jro@gmail.com.

General Information

Name _____

Age _____ Date of Birth _____

Sex _____

Playing position _____

Year of eligibility _____

Participant # _____ (for PI use only)
--

Exercise Patterns during Summer Prior to this Competitive Season

On Average, How many days a week did you (please fill in the following, if none please indicate 0):

1. Play Soccer? _____
2. Lift Weights? _____
3. Do plyometric training? _____
4. Run (more than 30 min.)? _____

It is very important you take the time to read the following medical information and history information as they may affect your testing progress in the study.

Medical History and Health Related Questions (check yes or no):

YES NO

() () 1. Do you have any orthopedic (muscle, joint, ligament) condition that is made worse by exercise?

() () 2. Do you know of any reason why you should not participate in strenuous physical activity?

() () 3. Are you or could you be pregnant?

If you answered yes to any of the above questions, please explain.

I certify that the information I have provided is complete and accurate to the best of my knowledge.

Signature of Participant _____

Date: _____

Appendix C: YYIRTL1 Protocol

Lower Limb Explosive Power and Physical Match Performance in Collegiate Female Soccer Players

Protocol

Yo-yo Intermittent Recovery Test (Level 1)

9:00am Warm up (staff)*

*Standard warm-up for 5-7 min as group. Players jog for about 3 min followed by increase in speed up to about 75-80% of max speed using the 20-m markers set out.

9:10am Read the following to participants:

- This is the Yo-yo Intermittent Recovery Test. The aim is to see how much distance you can cover while repeatedly running intense exercise after short recovery.
- This test is comprised of repeated shuttles; 20 m there 20 m back equals 1.
- Following each shuttle you will perform active recovery (10 s) in which they walk or jog slowly around the 5-m mark behind the start marker and return to the start line.
- You then briefly stop and wait for the start signal of the next shuttle.
- The speed of each 2x20-m shuttle will progressively increase by the sounds of a beep.
- You will hear a beep to start you. You will hear a beep at the 20 m line which helps to pace you. You want to reach the 20 m line at the sound of that beep.
- Early in the test the speed will be slow but will increase rapidly.
- Two beep sounds means the speed is increased.
- The test starts at level 5. Speed at level 5 until speed 14 rapidly increases.
- Starting at speed level 14 you will perform 8 rounds at that speed before progressing to the next speed. Each level thereafter is 8 rounds each.
- Each successful shuttle (2 x 20 m) will be included in your overall total distance covered.
- You will be warned if not breaking the plane of finish line by the sound of the beep.
- We encourage you to give it your all in this test; it is a test to exhaustion.

Termination

- Test will be terminated when you
 - i) You can not keep up with the pace of beeps on two separate occasions (not necessarily two in a row)
 - ii) You stop voluntarily
 - iii) You must cross the finish line with anything from a head to toe. Hands do not count.

Rules (if you break one of these rules you will first be warned then terminated)

- You must touch the 20 m line with your foot before returning to the finish line.
- You must stop at line before beginning the next shuttle.
- No talking, no cheering or encouraging, that will come from only the coaches.
- Do not start false start (start before the beep)
- When you are done stay out of the way, go and get water and stretch if desired.

Scoring

- The total distance covered (i.e. 40 m x total shuttles run) will be recorded as the test result.
- The active recovery distance covered will not count in the total distance covered.

Helpful Suggestions

- Alternate turning foot at the 20 m mark to eliminate fatigue on one side of the body.
- Count the 10 s recovery period in your head to limit the reaction time.

9:13am Separating into Groups and Begin with Group A

- Divided into 2 groups (A and B)
- Group A will run first
- Group A will warm up using the first 3 min of the YYIRTL1 test.
- Group B will each select one player from group A and monitor that player as they cross the finish line.
- When the monitors observe an infraction they will alert the participant verbally by raising their hand and saying “warning” followed by the name of the player.
- Monitor will alert the PI (Jenna) of a warning as well as termination of participant from the test
- Groups switched roles after all players from group A were finished with the test.

9:45am Group B first warms up using first three minutes of YYIRTL1 then begins test.

Appendix D: YYIRTL1 Data collection sheet

Yo-yo Test Scoring Sheet

Instructions: For a warning mark X. For termination of test mark Ø

Group:

Number of Completions

Name	5.1	9.1	11.1	11.2	12.1	12.2	12.3	13.1	13.2	13.3	13.4	14.1	14.2	14.3	14.4	14.5	14.6	14.7	14.8	15.1	15.2	15.3	15.4	15.5	15.6	15.7	15.8	Cont'd
	1	1	1	2	1	2	3	1	2	3	4	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	below
	1	1	1	2	1	2	3	1	2	3	4	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	1	1	1	2	1	2	3	1	2	3	4	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	1	1	1	2	1	2	3	1	2	3	4	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	1	1	1	2	1	2	3	1	2	3	4	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	1	1	1	2	1	2	3	1	2	3	4	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	1	1	1	2	1	2	3	1	2	3	4	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	1	1	1	2	1	2	3	1	2	3	4	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	1	1	1	2	1	2	3	1	2	3	4	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	1	1	1	2	1	2	3	1	2	3	4	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	1	1	1	2	1	2	3	1	2	3	4	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	1	1	1	2	1	2	3	1	2	3	4	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	1	1	1	2	1	2	3	1	2	3	4	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	1	1	1	2	1	2	3	1	2	3	4	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	

Group:

Number of Completions

Name	16.1	16.2	16.3	16.4	16.5	16.6	16.7	16.8	17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8	18.1	18.2	18.3	18.4	18.5	18.6	18.7	18.8	19.1	19.2	19.3	Cont'd
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	Below
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	
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	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	

Group:

Number of Completions

Name	19.4	19.5	19.6	19.7	19.8	20.1	20.2	20.3	20.4	20.5	20.6	20.7	20.8	21.1	21.2	21.3	21.4	21.5	21.6	21.7	21.8	22.1	22.2	22.3	22.4	22.5	22.6	22.7	22.8
	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
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	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8

Appendix E: 5JT Protocol

5JT PROTOCOL**Participant Instructions and Directions**

- You want to jump for 5 steps as far as possible.
- You start with two feet on the line shoulder width apart.
- You will jump forward with the leg of your choice and alternately until you count 4 steps.
- At the end of the 4 consecutive steps you must land with both feet.
- You will jump along the line
- Watch demonstration by investigator
- In the case you fall backward at landing the test must be performed again.
- Any questions so far?
- You will perform 3 trials
- After you perform a trial you go to the end of your same line
- As individuals of each group finish their respective test, they then go to the other test and wait for investigator instructions.
- We encourage you to give your maximal effort on the jump test.

Scoring

- The investigator will pay close attention to your final landing position as you will most likely not be able to hold that position.
- The total jump distance (to the nearest cm) will be measured with a tape measure from the fixed starting location to the back edge of the feet at the final position.

Appendix F: CMJ Protocol

CMJ PROTOCOL

Participant Instructions and Directions

- Here you want to jump as high as possible
- You will perform a CMJ with your hands on your hips like so (demo)
- You will stand on the contact mat with the legs in a hip wide position.
- You will perform a fast downward movement to a comfortable knee flexion and immediately begin your jump like so (demo).
- Three maximal jumps will be performed
- The criteria for good trial:
- When landing, both feet have to be within the frames of the contact mat.
- You are required to land with your toes touching the mat first.
- You will go to the end of the line after each trial
- Again we are looking for you to jump as high as possible

Appendix G: Standing Height Protocol

Standing height protocol for examiner

- Participant will stand erect on the floor board of the stadiometer with her back to the vertical backboard of the stadiometer. The weight of the participant is evenly distributed on both feet.
- The heels of the feet are placed together with both heels touching the base of the vertical board. Participants feet will point slightly outward at a 60 degree angle (see figure 4). If the participant has knock knees, the feet will be separated so that the inside of the knees are in contact but not overlapping.
- The buttocks, scapulae, and head are positioned in contact with the vertical backboard. If the participant cannot maintain a normal standing position while also placing their heels against the backboard then such participant's will be positioned so that only the heels and buttocks are in contact with the vertical board, and the body is positioned vertically above the waist.
- The arms will hang freely by the sides of the trunk with palms facing the thighs.
- The participant will be asked to inhale deeply and to stand fully erect without altering the position of the heels.
- The participant's head is maintained in the Frankfort Horizontal Plane position while the examiner lowers the horizontal bar snugly to the crown of the head with sufficient pressure to compress the hair.

- Hair ornaments, buns, braids, etc. must be removed to obtain an accurate measurement. The bar is locked in place and measurement is recorded to the nearest 0.5 cm.

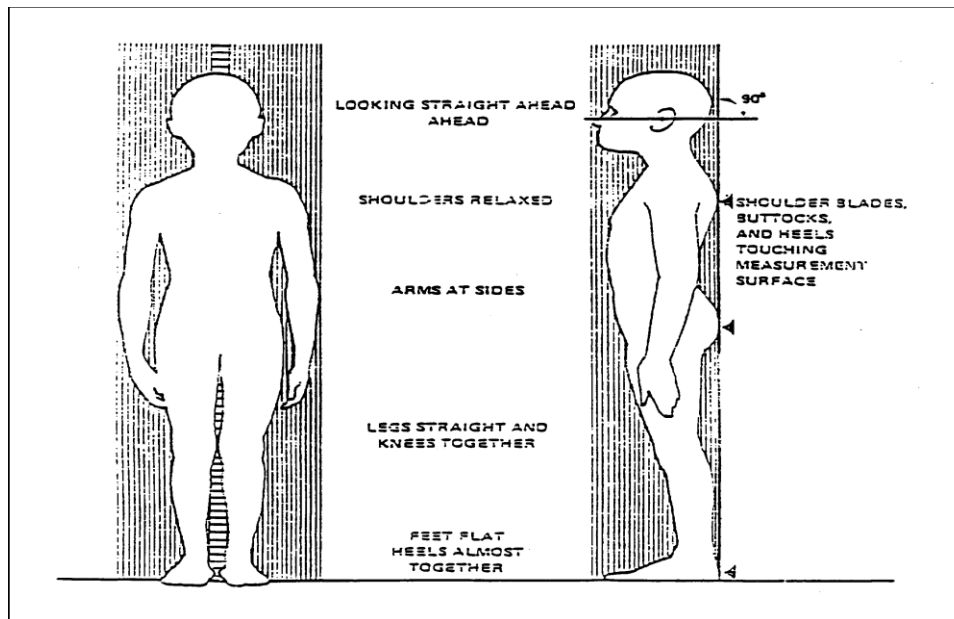


Figure 8. Position of standing height. From NHANES.

Appendix H: Seated Height Protocol for Examiner

Seated height protocol for examiner

- For measuring sitting height, the examiner moves the specially-made measurement box onto the floor board of the stadiometer.
- The measurement from the top stadiometer base to the top of the box was noted.
- The participant sits on the box with her back and buttocks to the backboard of the stadiometer.
- The participant sits as erect as possible with the head in the Frankfort Horizontal Plane***.
- The knees are directed straight ahead with the arms and hands resting at the sides (see figure 5).
- Participant will be asked to sit tall, take a deep breath, and then bring the horizontal bar down snugly to the head.
- The participant's head is maintained in the Frankfort Horizontal Plane position while the examiner lowers the horizontal bar snugly to the crown of the head with sufficient pressure to compress the hair.
- The bar is locked in place and final measurement will be recorded to the nearest 0.5cm.

***The Frankfort Plane found by imagining a line drawn from the orbital ridge to the upper edge of the ear canal. This line will need to be parallel to the floor and perpendicular to the stadiometer backboard.

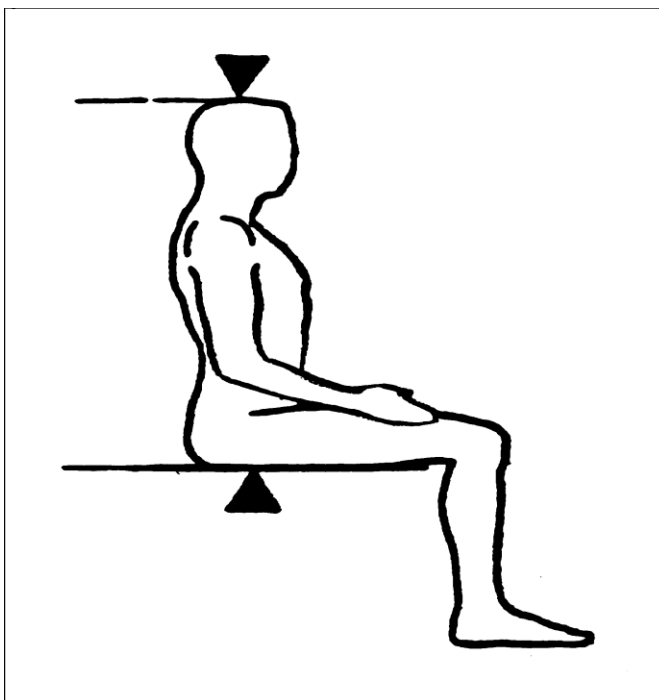


Figure 8. Seated height. Image from NHANES

Appendix I: Data Collection Sheet for Height and Weight

**Lower Limb Explosive Power and Physical Match Performance in Collegiate
Female Soccer Players: A Correlational Study**

**Jenna R. Hunter, Humboldt State
University**

CMJ Protocol

Name _____

Date _____

Time _____

Participant # For PI use only
--

_____ Weight (nearest .25 kg)

_____ Height (nearest 0.5 cm)

_____ Seated height (nearest 0.5 cm)

_____ Shoed foot length (0.5 cm)