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Jason C. Siegler
The University of Montana

The University of

Montana

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CHANGES EVALUATED IN SOCCER-SPECIFIC POWER ENDURANCE EITHER WITH OR WITHOUT A 10-WEEK, IN-SEASON STRENGTH AND PLYOMETRIC TRAINING PROGRAM

By

Jason C. Siegler

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A E Gaskill Ph.D.

Chairperson

Dean, Graduate School

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Changes Evaluated in Soccer-Specific Power Endurance Either With or Without a 10-Week, In-Season Strength and Plyometric Training Program

Director: Steven Gaskill, Ph.D.

The purpose of this study was to evaluate changes in soccer-specific power endurance of 34 female high school soccer players throughout a varsity season either with or without a strength and plyometric training program. *METHODS:* 34 high school female soccer players were tested prior to the start of the 2000 fall season and again 10-weeks later. The tests included an abridged, 45min shuttle test (LIST), hydrostatic weighing, vertical jump, 20m running-start sprint, and 30s Wingate test. The experimental group (EG)(n=17,age 16.5±0.9) completed a 10-week, in-season strength and plyometric program. The control group (CG)(n=17,age 16.3±1.4) completed only traditional aerobic soccer conditioning. *RESULTS:* The EG group showed significant improvements in the LIST (EG=Δ394s±124s, $p<0.02$), 20m-sprint (EG=Δ-0.10s±0.10s, $p<0.0003$), fat free mass (EG=Δ1.14kg±1.22kg, $p<0.004$), and fat mass (EG=Δ-1.40±1.47, $p<0.0008$) comparing pre- to post-season. *DISCUSSION:* Although this study did not compare lab test results to soccer match performance, prior research suggests that improvements in power endurance result in improved match performance. This study suggests that traditional aerobic training may not improve soccer-specific performance. However, soccer-specific power-endurance training may improve match performance and decreasing fatigue in adolescent female soccer players.

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Chapter I

INTRODUCTION

The incorporation of sport-specific training into fitness protocols is widely practiced (9)(10)(21)(22)(27)(28)(32)(41)(51)(53). Research in this area consistently focuses on new techniques for enhancing the performance of elite athletes. However, little research exists on adolescent sport-specific performance (10)(21)(32). This creates the problem of interpretation for the thousands of coaches and adolescent athletes competing at other levels. With increasing numbers of adolescents participating in sports such as soccer, further research is warranted.

Multiple sprint sports such as soccer, rugby, and hockey have been characterized as intermittent, high intensity activities (8)(43)(44)(52). The parameters most often tested to evaluate soccer at the elite level include maximal aerobic power and functional tests developed to correlate directly with soccer match-specific activity (7)(33)(40)(41)(50).

STATEMENT OF THE PROBLEM

Little is known about the affects of sport-specific training on female high school soccer players. Research focusing on soccer-specific training has been conducted primarily on males competing at an elite level (7)(22)(50). Researchers have created soccer-specific exercise protocols by extensively analyzing match play at the elite level (8)(44)(52). Studies have been conducted to monitor movement patterns such as overall distance covered, average intensities, and ratios evaluating percentages of walking: jogging: sprinting during match play (8)(43)(44)(52). Movement patterns have provided researchers with the means to assess soccer-specific fitness (7)(33)(40)(41)(50).

However, little soccer-specific fitness assessment in adolescents has been done (10)(21)(32) and, to the investigator's knowledge, no widely accepted research exists on soccer-specific training in adolescent females.

FITNESS ASSESSMENT

The sport of soccer has proven difficult for researchers in the respect that direct fitness testing during match competition using current methods has led to a gross underestimation of energy expenditure. Indirect measurement, relating heart rates to VO_2 has proven the most accurate method for the estimation of energy expenditure during soccer matches (3). Blood lactate and glucose levels have also been determined throughout match play and are both considered accurate indicators of performance (1)(5)(45)(54). However, these applications are not practical for many of the players participating in the sport at the non-elite level.

The Loughborough Intermittent Shuttle Test (LIST) was designed as a field test that simulates the activity pattern of elite level soccer (40). The test offers the advantages of requiring no sophisticated equipment and the ability to test many individuals at once (33)(40). Abridging this test relative to the activity pattern of female adolescent soccer players could prove beneficial for fitness evaluation at a non-elite level.

POSSIBLE IMPACT OF ADOLESCENT EVALUATION

Research conducted on the injury rates of youth soccer has shown a higher rate of injury for adolescent girls than for boys (14)(28)(31). Injuries appear to be more prevalent in the lower extremities than upper extremities for adolescent girls (31). Speculation has arisen as to whether this is due to lack of lower leg strength, range of motion (ROM), joint laxity, or other factors (14). The lack of research focusing on proper training techniques for female adolescents is apparent. Whether improper training techniques are the cause of increased injury rates of adolescent females is debatable. The implementation of a strength-training program during the high school soccer season might prove beneficial in reducing injuries in adolescent girls.

PURPOSES OF THIS STUDY

1. Study the sport-specific power endurance changes of 34 female high school soccer players throughout the varsity season with and without a strength and plyometrics training program.
2. Document and observe individual improvements in strength and aerobic power with the implementation of a strength training and plyometrics program during the high school season.
3. Evaluate the sensitivity of an abridged version of the Loughborough Intermittent Shuttle Test (LIST) in evaluating aerobic fitness for female high school varsity soccer players.

HYPOTHESES

1A. H_o: Improvements in lean body mass, vertical jump, 20m maximum sprint speed, and anaerobic power will not occur with the implementation of a within season strength and plyometric program.

1B. H_R: There will be significant improvements in lean body mass, vertical jump, 20m maximum sprint speed, and anaerobic power with the implementation of a within season strength and plyometric program.

2A. H_o: An abridged version of the Loughborough Intermittent Shuttle Test will not demonstrate differences in power endurance pre-to post-training.

2B. H_R: An abridged version of the Loughborough Intermittent Shuttle Test will demonstrate differences in power endurance pre to post training.

LIMITATIONS

1. There are many factors other than strength training that can affect the injury rate in soccer. Field conditions, poor tackling technique, improper warm-up, and other factors can induce both minor and season ending injuries.
2. There are many other factors that may affect speed, power, and endurance other than the intervention.
3. The results of the study should only apply towards the training of adolescent high school girls playing at a varsity level.
4. Growth is still a factor for some females in this range and may influence the strength gains independently of the strength program implemented.

DELIMITATIONS

1. The experimental population will consist of 17 girls playing on the varsity soccer team at a high school in Missoula, Montana. The control group will consist of 17 girls playing on a varsity soccer team at a different high school in Missoula, Montana.
2. All tests will be conducted in a laboratory setting with the exception of the abridged LIST, which will be conducted in an adjacent gymnasium so as to accommodate the entire team.

DEFINITION OF TERMS

Loughborough Intermittent Shuttle Test (LIST). A field test designed to simulate the activity pattern of elite level soccer (40). It was designed due to the adherent difficulty of implementing direct fitness measurements during match play (40). Research on intensity ratios was derived from elite level match analysis. The LIST attempts to simulate the 'multiple sprint' nature of soccer, consisting of periods of support running and recovery interspersed with brief periods of sprinting (40). The current study used an abridged version of the LIST to estimate power endurance in adolescent female soccer players.

Wingate Test. A standardized 30-second maximal effort cycle ergometer test designed to obtain maximal anaerobic output.

Hydrostatic Weighing. A standard laboratory technique using underwater weighing to determine body density, from which body composition can be estimated.

Maximum Sprint Speed. A test designed to measure a subject's maximum sprint speed over a 20-meter distance with a 10-meter running start.

Vertical Jump. A test to measure explosive power consisting of a standing vertical jump performed indoors in a controlled environment.

Plyometrics. A method of power training that is associated with high ground reaction forces and includes a wide variety of exercises specifically designed to increase muscular strength and power in the lower extremities (53). Activities are based on the premise that increasing eccentric preload on muscle induces the myotatic stretch reflex and may cause a more forceful contraction (53).

Strength Training. General or specific resistance training using free weights and machines designed to increase the strength and power of the subject.

High School Female Athletes. Females ranging from 15 to 18 years of age playing on the high school varsity soccer programs at two different high schools in Missoula, Montana.

SIGNIFICANCE OF THE STUDY

Little data exists as to whether a conditioning program implemented throughout the season benefits adolescent female soccer players. No data exists as to whether a 10-week program will increase power endurance, leg power, lean body mass, sprint speed, or maximal leg anaerobic power output in adolescent female soccer players. The abridged version of the LIST and other simple fitness tests may aid high school coaches in determining the effectiveness of their training sessions.

Chapter II

REVIEW OF LITERATURE

Soccer is a sport played worldwide by millions of individuals. With the relatively recent success of the United States Women's National Team, the popularity of the sport has increased in America. With the large amount of adolescents currently playing soccer in the United States, disparity between training techniques are unavoidable. Problems arise when coaching and training techniques designed for elite level athletes are misinterpreted and imposed on adolescent athletes. Fitness parameters and training techniques available in the literature were designed based on research using data from elite level soccer players, not adolescents. Little research has focused on sport-specific training techniques and adolescent soccer players.

Soccer played at the elite level has been categorized as a high intensity, non-continuous intermittent exercise (25). The ratio of rest-to-low and rest-to-high intensity periods varies according to the individual style of play and position on the field. The average distance covered by players throughout a match is around 11km (9)(44)(52) with a variation among players of ± 2km to 3km (25). Energy expenditure differences observed between players does not appear to relate to overall distance covered, but rather the percentage of overall fast speed distance during the match as well as absolute values of maximal speed play during a match (25). A player's average oxygen consumption during an elite match may achieve nearly 80% of maximal oxygen consumption, a value generally near the anaerobic threshold (25)(50). Although differences exist between elite and non-elite level athletes, the generalization that soccer is a physically demanding sport can be assumed at all levels.

Research focusing on elite level match analysis has demonstrated positional differences between players (9)(44)(52). Mean distances covered throughout a match vary between midfielders (11.4km), forwards (10.5), and defenders (10.1km) (6). It appears the level of competition relates directly to the total distance covered throughout a match (6). However, larger fields and longer playing times must also be taken into account when comparing total distance covered between elite and non-elite level players.

A more reasonable comparison would be to compare high intensity activities rather than to compare the total distance covered during a match. High intensity running accounts for 8.1% of the total time transpired throughout a match (6). Further examination of mean distances covered throughout a match has led to percentages being developed; 20.5% at walking pace; 36.8% jogging; 20.5% running; and 11.2% sprinting (44). These percentages as well as heart rate/ VO_2 relationship were used in the creation of intermittent shuttle tests to evaluate elite level fitness (3)(40).

LITERATURE RELATING TO SOCCER SPECIFIC INTERMITTENT EXERCISE TESTS

The average exercise intensity of a soccer match has been estimated to be around 75-80% VO_{2max} (43). VO_{2max} has been shown to correlate significantly with the distance covered in a match (43). This underlies the need for a high work rate and a high aerobic fitness level. The importance of a player's ability to maintain their work rate throughout a match is illustrated by that player's relative effectiveness. Fitness tests have been designed for elite level players using the aforementioned research. These tests have evolved from general multi-stage shuttle runs to those developed specifically for elite level soccer players (33)(40)(41)(50).

Leger et al. constructed one of the first multi-stage 20m shuttle run developed specifically for soccer (33). Oxygen uptake was measured directly using indirect calorimetry and estimated using heart rate data. The shuttle run was designed to test its validity versus a treadmill, as well as measure the reliability of testing groups of adults. The test consisted of:

1. The subjects ran back and forth on a 20m course for 5 minutes at a speed beginning with 7.5km/hr.
2. Pace was set with audio signals and increased at specified intervals.
3. Subjects were instructed to complete as many stages as possible and the test was stopped when the subject believed they could no longer complete a stage (33).

Data revealed that the maximal speed of the multistage shuttle run could estimate maximal aerobic power endurance (r = 0.84) with a standard error of $\pm 5.4 mlkg^{-1}min^{-1}$ (33). The test offered the advantage of performing in groups, as well as requiring no sophisticated equipment.

Rambsbottom et al. conducted a similar test, which estimated maximal oxygen uptake during a 20m progressive shuttle test (41). With the addition of a 5km time trial at the end of the test the investigators were able to estimate VO_{2max} more accurately than Leger (41). Similar tests have reproduced accurate VO_{2max} estimations with similar sport-specific intermittent exercise protocols (7)(22)(50). A review of these tests using long term, intermittent exercise performance and sport-specific endurance capacity with progressive shuttle tests suggest that the tests are both reliable and valid.

The Loughborough Intermittent Shuttle Test (LIST) was derived from previous research in attempts to simulate the activity pattern characteristic of elite level match play (40). It consists of periods of lower intensity jogging, running, walking, and recovery interspersed with brief periods of sprinting over a 20m distance (40). The LIST concludes with a final stage of alternate running and jogging with increasing intensity until volitional exhaustion. It was determined that the LIST could provide investigators with a valid assessment of exercise capacity under accurately simulated physiological demands of match play (40).

The validity of abridging intermittent shuttle tests to simulate adolescent soccer-specific activity has not been investigated. Research regarding assessment of power endurance in adolescent soccer is minimal.

LITERATURE REGARDING STRENGTH AND CONDITIONING

Many reasons have been proposed suggesting the need to implement a strength and conditioning program for adolescent soccer players. It has been determined that more muscular and stronger players have historically been better able to survive the rigors of a prolonged season (49). Soccer performance is related to both aerobic and anaerobic fitness. Fitness assessment therefore must encompass both these parameters, while also allowing for differences between playing positions. As previously mentioned, the use of 20m intermittent shuttle tests has proven valid in estimating VO_{2max} and power endurance capacities. Proper assessment of anaerobic capacity is also warranted. The use of vertical jump, sprinting, and maximal exertion on a cycle ergometer to measure anaerobic capacity is common throughout soccer research (19)(35)(49)(52).

Soccer-specific training has generally focused on three aspects; high intensity, short duration, and multiple interval work (52). Withers et al. has suggested that interval training should be specific to the movement of soccer with a focus on increasing anaerobic power (52). Withers also suggests that a majority of high intensity training should be conducted immediately after warm-up while the remaining bulk of the fitness should come at the end of the training sessions. Sprint training should cover distances ranging from 5-55m (52).

Agility, frequency turning and counter movement, and other soccer-specific movements tests have also been suggested (49)(52). Flexibility training is important in soccer and has been found to decrease the incidence of injury (43). Even anaerobic power tests at the elite level reveal the need for improvement in the protocols used to measure muscle strength (43).

It has been suggested that soccer players need to be trained relative to their position on the field. Research indicates that there are significant differences between the player's positions and their relation to the total distance covered throughout a match (9)(35)(44). However, Withers et al. states that much of the high intensity work conducted on the field is comprised of short distances and brief duration, and found no significant differences between positions (52). Significantly greater distances covered traditionally by the midfield were comprised of low intensity jogging (9).

Recent studies however have shown that, at the elite level, position specific training may be warranted (35)(50). Different positions were measured according to nine different criteria. Results indicated significant differences in certain position-specific criteria deemed essential to peak performance at the elite level (35).

Evaluation of aerobic and anaerobic power throughout the season is critical in enhancing and monitoring performance. By increasing the available force of muscle contraction, acceleration and speed skills critical to enhancing performance may improve the fitness level of the athlete (50). Sprinting, changing pace, and turning may also improve fitness. Proper evaluation of training techniques will present coaches and trainers with the ability to adjust training protocols as needed.

Little research exists on muscle developments and aerobic power improvements in adolescent soccer players (10)(21)(32). Parameters designating time and duration for training relative to the competitive season have not been established for female adolescent soccer players. VO_{2max}, anaerobic performance, body composition, and tests of muscular strength and endurance are the most commonly tested parameters for evaluating performance in male adolescent soccer players, however parameters have not been designated for females (32)(45)(53).

Age, height, and weight seem to have a significant affect on VO_{2max} in prepubescent children (10). However, there appears to be an increase in aerobic power with training at all ages, even after adjusting for age (10). Proper muscle development and flexibility improvements in the lower extremities are important variables in enhancing performance. The lower extremities account for a majority of all musculoskeletal injuries encountered by adolescent soccer players, especially females (21)(28)(32)(43)(53). Effects of long term (six-month) comprehensive exercise training focusing on lower extremities in adolescent boys revealed reduced percent body fat, increased lean body mass, improvements in aerobic power and faster sprint times (21).

Plyometric training has been accepted as a plausible means to increase soccer-specific performance. Plyometric jump training is associated with high ground reaction forces and includes a wide variety of exercises specifically designed to increase muscular strength and power in the lower extremities (53). The activities are based on the premise that increasing eccentric preload on a muscle induces the myotatic stretch reflex and may cause a more forceful concentric contraction (53). Plyometrics added to strength and conditioning programs have been advocated to increase performance and reduce the risk of injury (28). Implementing plyometric jump programs appears to benefit females by improving the hamstring/quadriceps strength ratio. This is important as hamstring strength is proportional to knee stabilization (28). Plyometric training has been shown to safely and effectively improve lower body strength and power in adolescent women (53).

The benefits of implementing strength conditioning and plyometric programs for female adolescent soccer players have not been documented. Lower extremities are the most prevalent sites of injury in female adolescents (31). Whether lack of strength or mechanical instability causes the high rate of injury is unknown (14). It has been suggested that conditioning programs would enhance performance in adolescent female soccer players while possibly decrease the incidence of injury (19).

LITERATURE RELATING TO ENHANCED SOCCER PERFORMANCE UNRELATED TO STRENGTH AND PLYOMETRIC PROGRAMS

There are other factors which may contribute towards enhancing performance at both the elite and non-elite level. The importance of maintaining muscle glycogen has been thoroughly researched at the elite level (1)(5)(11)(46)(54). Studies indicate that the endurance capacity of a player during match play is influenced by pre-exercise muscle glycogen concentrations (5). To perform optimally players must eat, in preparation for practice and competition, a diet high in carbohydrates. Plasma glucose levels have also been measured during elite level matches. The importance of maintaining blood glucose is evident in the decreased performance and lower glucose levels observed at the end of a match (11). However, it must be noted that research has shown skill performance and development may not be affected by muscle glycogen levels (1)(54).

With the addition of a soccer-specific strength and plyometric program researchers must consider the additional caloric requirements. Energy expenditure in female soccer players competing in match play is estimated around 70% VO_{2max} (13). The relative intensity experienced by females during a match is similar to that of males. With this in mind, energy intake must be sufficient to counter balance energy expenditure. Researchers must keep in mind female athletes generally have a lower energy intake as compared to males (13). In constructing exercise protocols for female adolescent soccer players these factors must be considered (13)(16).

Chapter III

METHODS

High school female soccer players were tested prior to the start of the 2000 fall season and again 10-weeks later at the end of the season. The tests included an abridged version of the LIST, hydrostatic weighing, vertical jump, 20m-sprint, and 30s Wingate test. The abridged LIST was performed as a group test by each team to measure power endurance. The hydrostatic weighing, vertical jump, 20m-sprint, and 30s Wingate test were conducted individually to measure aerobic power outputs and estimate body density. Approval was obtained from the Internal Review Board for research with the Human Subjects Committee at the University of Montana and informed consent given by the players and parents/guardians.

Subjects were divided according to varsity teams from the two participating high schools in Missoula, Montana. The experimental intervention team (EG) implemented a series of strength training and plyometric exercises throughout the season. The strength training consisted of two sessions a week and lasted about ½ hour. A total of four lower body exercises were incorporated; squats, leg extensions, leg curls, and calf raises. The plyometric sessions were conducted 3 times per week and lasted approximately 10-15 minutes per session. Individual data was recorded throughout the experimental period and the investigator conducted all training sessions. The control team (CG) did not partake in a regimented strength training or plyometrics program. Their program consisted of distance and endurance training 2-3 times per week. Endurance capacity was assessed using a timed mile protocol. Additional shuttle runs were implemented as the coach assessed fitness throughout the season.

SUBJECTS

The respective coaches of two local high school varsity girl's soccer teams of similar ability (as noted by previous season's record) were approached with the idea of implementing a strength training and plyometrics program designed to enhance performance. Terms of the study were addressed in a formal letter, stating generalities of the study and providing the coaches with an opportunity to address any concerns. The coaches then held team meetings, which included the parents or guardians of prospective players, to determine the interest level of the players. Both the coaches and investigator stressed that the study would be conducted on a strictly volunteer basis and if the players chose not to participate it would in no way affect their status on the team. Thirty-four subjects, 17 from each team, volunteered to participate.

All subjects were given thorough explanations both verbally and written as to what the study would entail and what their respective roles would be. Tests were administered individually with the exception of the abridged LIST. Subjects were allowed to choose times for their individual tests. The primary researcher guaranteed subject confidentiality.

TESTING DATES

Baseline testing was scheduled to coincide with the beginning of the fall 2000 soccer season and post-testing was scheduled within one week of the final game of the season. Individual testing was conducted after group testing in both pre- and post-season scenarios (Table 1).

TESTS ADMINISTERED EACH VISIT

ABRIDGED VERSION OF THE LIST:

The abridged version of the LIST was the initial test conducted on each team (Test Period 1,1A, 3 & 3A). The test was conducted at indoor gymnasiums on the campus of the University of Montana, Missoula, Montana. Ambient temperature and humidity were collected and recorded each test period. The running surface was composed of wood and cleaned before the test was conducted. Prior to the tests, the teams were given instructions as to what was expected of them and what to wear to the test. Upon arrival to the gymnasium, the team warmed up and stretched accordingly. Players were then fully familiarized with the testing procedure via verbal explanation and a practice trial. All questions were answered prior to the start of the test.

The abridged version of the LIST consisted of two parts, A) a soccer match simulation period and B) an exhaustive exercise stage. The lap speeds were estimated from trial times recorded in a pilot test. The speeds were dictated by an audio signal recorded on audiotape. The tape was developed manually with the use of a bell and drum. The bell signaled the subjects to begin and the drum designated the prescribed finishing time for each 16m segment. The pattern of exercise for Part A was as follows:

(a) Fixed period of variable-intensity shuttle running over 16 meters (Figure 1.)

   a. 3 X 16m at walking pace
   b. 1 X 16m at maximal running speed
   c. 4s recovery

d. 3 X 16m at running speed corresponding to 55% of individual estimated maximal sprint speed

e. 3 X 16m at running speed corresponding to 95% of individual estimated maximal sprint speed

   i. Two 15 minute exercise periods separated by 3 minutes of recovery

   ii. All together two 15 minute blocks were completed

Part B consisted of alternating jogging and running. Initial times were 8s jog and 5.7s run. Subjects were allowed 2s rest intervals between laps. Jogging and running times were decreased by 0.1s/lap every minute until volitional exhaustion was reached or the subject was unable to meet the required time on two consecutive running frames (Figure 2.).

Time to volitional exhaustion was the recorded variable for Part B. Time was also taken throughout both tests in case a subject was unable to complete Part A. All subjects tested were able to finish Part A. The test was administered separately to each team and the results were recorded individually for each player.

INDIVIDUAL TESTS ADMINISTERED (TEST PERIODS 2, 2A, 4, & 4A, Table 1)

All individual tests were conducted after completion of the abridged LIST. They were also conducted consecutively and repeated pre and post season. The subjects were briefed both verbally and written as to what to bring to the lab and what to expect.

SUBJECT HEIGHT:

The subject's height was determined to the nearest 0.1cm with the use of a wall scale produced by Narragansett Machine Company. Shoes were removed.

SUBJECT WEIGHT:

The subject's weight was determined to the nearest 0.1kg with the use of a Befour weight scale. Shoes were removed and weight recorded wearing a bathing suit.

BODY COMPOSITION:

Body composition was estimated using hydrodensitometry. Underwater weight was measured using an electronic scale (Exertech Body Density Measurement Systems, Dresbach, MN), which was calibrated prior to each measurement. The subjects were allowed as many trials as necessary for a consistent underwater weight measurement until two trials were recorded within 0.1g. Underwater weights were recorded to the nearest 0.001kg. Residual lung volume was estimated using equations derived from Goldman and Becklace. Body density was calculated from underwater weight after adjustments for water temperature, residual volume, and 200ml GI gas (12). Percent body fat was estimated using sex dependent equations of Lohman. Percent body fat was used to estimate fat free mass (FFM) and fat mass (FM).

VERTICAL JUMP:

Vertical jump was measured using a wall tape. Subjects were instructed to reach above their head within normal extension limits to record standing reach. The same initial reach was used in both pre- and post-season measurements. The subjects were then allowed three trial jumps to obtain their maximal vertical jump. Subjects were allowed arm movement but not a preliminary step.

20-METER SPRINT:

The 20-meter sprint was recorded using an Alge-Sports electronic timer, Model S3 (ALGE Electronic Timing, Lustenau, Austria) set at a height of 25cm. The trial was conducted outside on a concrete sidewalk. Subjects were given ample warm-up time prior to the sprint and allowed three separate trials. A distance of 30 meters was marked at 0, 10, and 30m with a tape. The timing lights were placed at 10 and 30 meters. Subjects accelerated for 10m before breaking the first light beam and starting the clock. The final elapsed time was recorded at 30m. The fastest time of the three trials was accepted as the subject's maximum sprint speed.

30s WINGATE TEST:

Subjects were allowed 5-10 minutes warm-up at 70 revolutions per minute (RPMs) on a Monarch 824 weighted cycle ergometer (Sweden). During the warm-up period subjects were briefed on the dynamics of the test and what was expected of them. The standard 30s Wingate protocol was followed with resistance adjusted to the nearest 0.5kg based on the subject's kg body weight. Once the subject verbally acknowledged she was ready, the test was initiated. Peak, average, and minimum power (watts), as well as percent decline ((peak-minimum)/peak) were measured and adjusted for flywheel inertia using a computerized recording system (SMI, St. Cloud, MN).

CONFIDENTIALITY

All subjects were assigned a reference number for all reports. Individual information was released only to the subject. Group means were made available to each coach and participant.

DEBRIEFING OF SUBJECTS

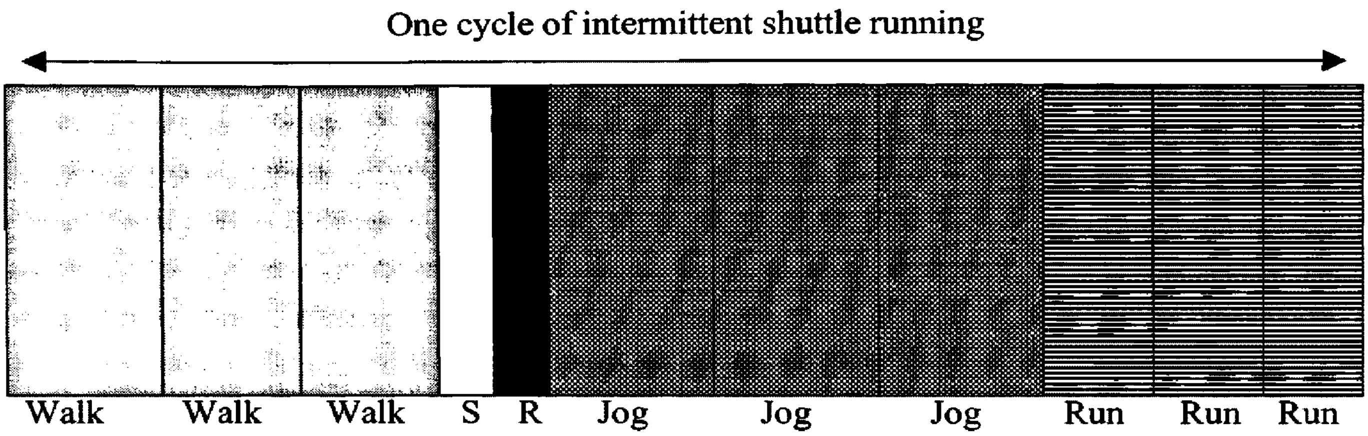
Following each individual test the subjects were allowed to address any questions about the data or relevance of test results they may have had. Subjects were provided with final data summaries, which included a table of means with subsequent explanations as well as their individual data.

Table 1.

Testing dates

Month and year	Test Period	Date
August of 2000 (Pre)	Test Period 1 Test Period 1A	August 16 August 17, 18, 21, 22
August of 2000 (Pre)	Test Period 2 Test Period 2A	August 22 August 24, 25, 28, 29
October of 2000 (Post)	Test Period 3 Test Period 3A	October 23 October 24, 25, 26
October of 2000 (Post)	Test Period 4 Test Period 4A	October 30, November 1 November 2, 3, 4

Figure 1.



Walk 16m (18.5s)

Sprint 16m (4.1s)

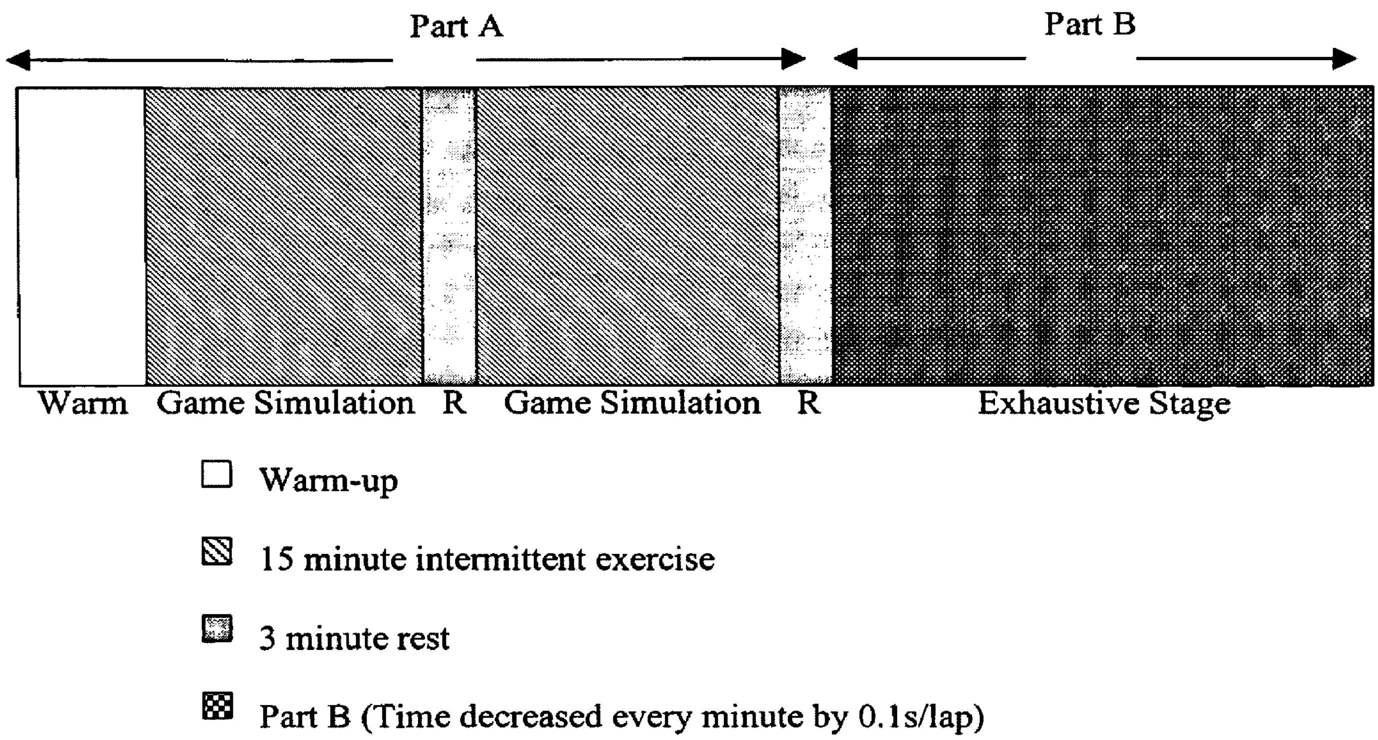
Active recovery (-4s)

Jog 16m @ 55% estimated maximal sprint speed (7.5s)

Run 16m @ 95% estimated maximal sprint speed (5.2s)

* Repeated 9 times per 15 minute bout

Figure 2. Complete Abridged LIST



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MANUSCRIPT – Submitted to Journal of Strength and Conditioning Research

Introduction: Soccer, when played at the elite level, requires tremendous endurance, speed, and power. The benefits of incorporating soccer-specific training into fitness protocols and assessment procedures have been well documented at the elite level (3)(4)(7)(8)(10)(11)(13)(17)(23)(25). Research in this area has consistently focused on creating new techniques for enhancing the performance capabilities of elite soccer players. However, little soccer-specific fitness assessment in adolescents has been done (4)(7)(13) and, to the investigator's knowledge, no widely accepted research exists on soccer-specific training in adolescent females. This creates the problem of interpretation for the thousands of coaches and adolescent athletes competing at the non-elite level. With increasing numbers of female adolescents participating in soccer, further research is warranted.

A few soccer-specific fitness tests have been accepted by the soccer community as appropriate and useful assessment measurements. These tests include, but are not limited to, maximal aerobic power as well as functional tests developed to correlate directly with soccer match-specific activity (3)(8)(9)(14)(16)(17)(22). Using data from these tests, training protocols were then designed to enhance the designated performance parameters of elite soccer.

Researchers have also created soccer-specific exercise protocols by extensively analyzing match play at the elite level (2)(19)(24). Studies have been conducted to monitor movement patterns such as overall distance covered, average intensities, and percentages of time spent walking, jogging, and sprinting during match play (2)(18)(19)(24). These studies of movement patterns have provided researchers with the scientific basis for assessment of elite level soccer-specific match fitness (1)(14)(16)(17)(22). However, a continual focus on elite players leads to the inherent difficulty of interpreting this data to properly assess adolescent soccer players.

The purposes of this study were to; 1) Evaluate the sensitivity of an abridged version of the Loughborough Intermittent Shuttle Test (LIST) in determining aerobic fitness for female high school varsity soccer players; 2) Study the soccer-specific changes in power endurance of 34 female high school soccer players throughout the varsity season either with or without a strength and plyometric training program; 3) Document and observe individual improvements in strength and aerobic power with the implementation of a strength and plyometric training program during the high school season.

METHODS

Thirty-four high school female soccer players were tested prior to the start of the 2000 fall season and again 10-weeks later at the end of the competitive season. Approval was obtained from the Internal Review Board for research with human subjects at the University of Montana and informed consent given by the players and parents/guardians. The tests included an abridged version of the Loughborough Intermittent Shuttle Test (LIST), hydrostatic weighing using estimated residual volumes, vertical jump, 20m-sprint, and 30s Wingate test. The abridged LIST was performed as a group test by each team to measure power endurance. Tests estimating body density (hydrostatic weighing) and anaerobic power outputs (vertical jump, 20m-sprint, and 30s Wingate test) were conducted individually.

Subjects were members of varsity teams from two participating high schools in Missoula, Montana. The experimental intervention team (EG) implemented a series of strength training and plyometric exercises throughout the season. The strength training consisted of two sessions a week, with each session requiring approximately 30 minutes prior to practice. A total of four lower body, free weight exercises were used. These exercises included; squats, leg extensions, leg curls, and calf raises. Pre- and post-season training 1RM was estimated from 10-15RM efforts using equations developed by Corbin et al, 1978. The focus of training sessions varied from explosive power sets to slower, muscle building activities. The investigator supervised all weight-training sessions. Plyometric sessions were conducted 3 times per week at practice and lasted approximately 10-15 minutes per session. Explosive jumping (box jumps), quickness (timed jumping, re-jumping), and power endurance (skipping for height and distance) were stressed during the workouts. Typical training sessions used either the width of the soccer field or the 18-yard box. The exercises progressively increased in quantity and intensity, peaking at the end of the season. All plyometric sessions were conducted after skill-specific sessions were completed. Individual data were recorded throughout the experimental period and the investigator conducted all training sessions.

The control team (CG) did not partake in a regimented strength training or plyometrics program. The training program for the CG consisted of distance and endurance training 2-3 times per week, plus regular soccer practices and matches. Endurance capacity was assessed using a timed mile protocol. Additional shuttle runs were implemented as the coach assessed fitness throughout the season. Strength training was eliminated from the CG's training program.

TESTING DATES

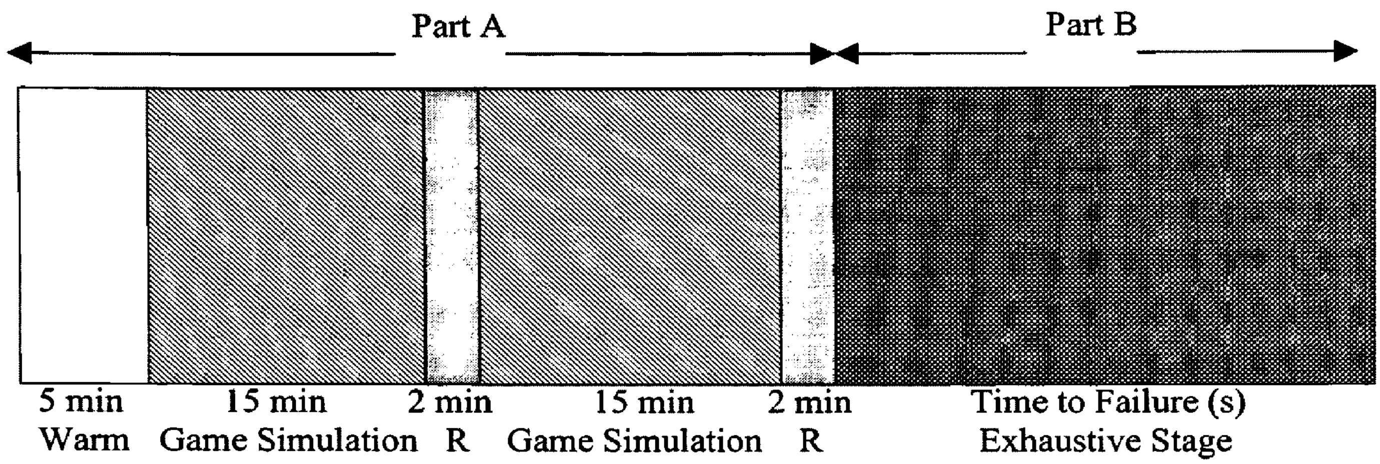
Baseline testing was scheduled to coincide with the beginning of the fall 2000 soccer season and post-testing was scheduled within one week after the final game of the season. Individual testing was conducted after group testing in both pre- and post-season scenarios.

TESTS

ABRIDGED VERSION OF THE LIST:

The abridged version of the LIST was given to all participants pre- and post-season and completed prior to the individual tests. The test was conducted at indoor gymnasiums on the campus of the University of Montana, Missoula, Montana. The running surface was composed of wood and cleaned before the test was conducted. Prior to the tests, the teams were given standard pre-test instructions for diet, exercise, and clothing. Upon arrival to the gymnasium, the athletes warmed up and stretched. Players were then familiarized with the testing procedure via verbal explanation and a practice trial. All questions were answered prior to the start of the test.

The abridged version of the LIST consisted of two parts, A) a soccer match simulation period and B) an exhaustive exercise stage. The test used a 16m distance over which the players walked, jogged, ran, and sprinted laps in a specific order and at specific speeds. The lap speeds were estimated from trial times recorded in a pilot test. The speeds were dictated by an audio signal recorded on audiotape. Audio signals indicated the start and end times for each lap.



The pattern of exercise for the game simulation was as follows:

(b) Two game simulated 15 minute periods of variable-intensity shuttle running over 16 meters separated by a 3 minute rest. The order of laps was repeated 9 times during each 15 minute game simulation, following the cycle listed below (times shown are the lap time for 16m):

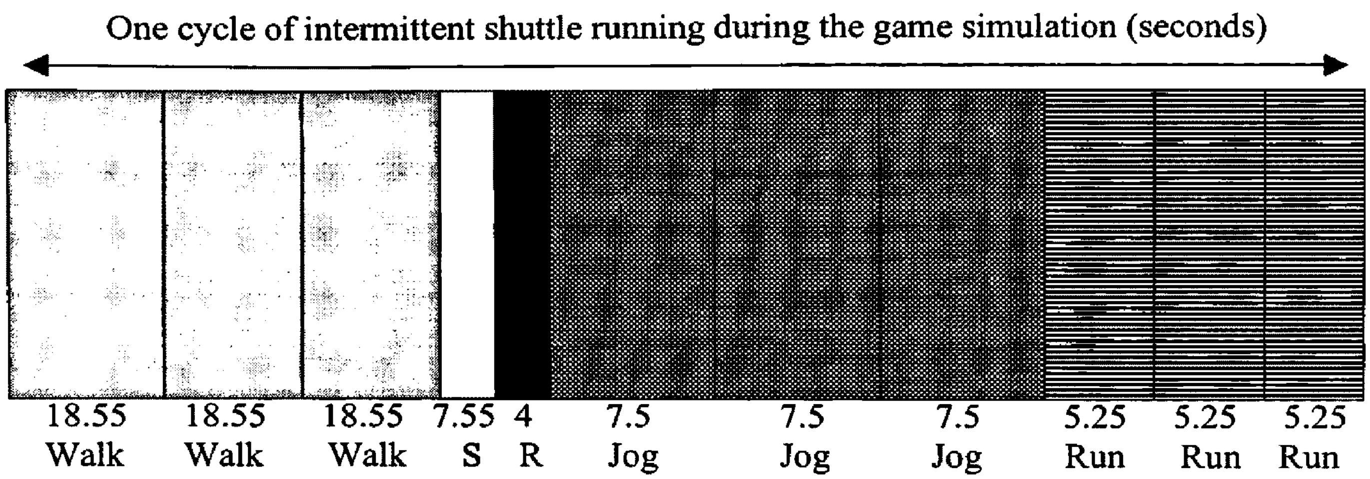
a. 3 laps at walking pace (18.5s)

b. 1 lap at maximal running speed (4.1s)

c. 4s recovery

d. 3 laps at running speed corresponding to 55% of individual estimated maximal sprint speed (7.5s)

e. 3 laps at running speed corresponding to 95% of individual estimated maximal sprint speed (5.2s)



* Repeated 9 times per 15 minute bout

The exhaustion exercise stage was designed to progressively become more difficult until volitional exhaustion was reached. The mode consisted of alternating jogging and running. Initial times were 8s jogging one direction for 16m, and then returning with a 5.7s run. Subjects were allowed 2s rest intervals between laps to decelerate and reverse direction. Jogging and running times were decreased by 0.1s/lap every minute until volitional exhaustion was reached or the subject was unable to meet the required time on two consecutive running laps. Time to volitional exhaustion was recorded. Time was also taken throughout the game simulation in case a subject was unable to complete Part A. All subjects tested were able to finish Part A. The test was administered separately to each team and the results were recorded individually for each player.

INDIVIDUAL TESTS

All individual tests were conducted both pre- and post-season at least one day after completion of the abridged LIST.

DESCRIPTIVE VARIABLES:

The subject's height without shoes was determined to the nearest 0.1cm with the use of a stadiometer (Narragansett Machine Company, Providence, RI). The subject's weight wearing only a bathing suit was recorded to the nearest 0.1kg with the use of a calibrated electronic Befour weight scale (Cedarburg, WI). Age was recorded to the nearest year at the start of the study.

BODY COMPOSITION:

Body composition was estimated using hydrodensitometry. Underwater weight was measured using an electronic scale (Exertech Body Density Measurement Systems, Dresbach, MN), which was calibrated prior to each measurement. The subjects were allowed as many trials as necessary for a consistent underwater weight measurement until two trials were recorded within 0.1g. Underwater weights were recorded to the nearest 0.001kg. Residual lung volume was estimated using equations derived from Goldman and Becklace. Body density was calculated from underwater weight after adjustments for water temperature, residual volume, and 200ml GI gas (5). Percent body fat was estimated using sex dependent equations of Lohman. Percent body fat was used to estimate fat free mass (FFM) and fat mass (FM).

VERTICAL JUMP:

Vertical jump was measured using a wall tape. Subjects were instructed to reach above their head within normal extension limits to record standing reach. The same initial reach was used in both pre- and post-season measurements. The subjects were then allowed three trial jumps to obtain their maximal vertical jump (cm). Subjects were allowed arm movement but not a preliminary step.

20-METER SPRINT:

The 20-meter sprint was recorded using an Alge-Sports electronic timer, Model S3 (ALGE Electronic Timing, Lustenau, Austria) set at a height of 25cm. The trial was conducted outside on a concrete sidewalk. Subjects were given ample warm-up time prior to the sprint and allowed three separate trials. A distance of 30 meters was marked at 0, 10, and 30m with a tape. The timing lights were placed at 10 and 30 meters. Subjects accelerated for 10m before breaking the first light beam and starting the clock. The final elapsed time was recorded at 30m. The fastest time of the three trials was accepted as the subject's maximum sprint speed.

30s WINGATE TEST:

Subjects were allowed 5-10 minutes warm-up at 70 revolutions per minute (RPMs) on a Monarch 824 weighted cycle ergometer (Sweden). During the warm-up period subjects were briefed on the dynamics of the test and what was expected of them. The standard 30s Wingate protocol was followed with resistance adjusted to the nearest 0.5kg based on the subject's kg body weight. Once the subject verbally acknowledged she was ready, the test was initiated. Peak, average, and minimum power (watts), as well as percent decline ((peak-minimum)/peak) were measured and adjusted for flywheel inertia using a computerized recording system (SMI, St. Cloud, MN).

STATISTICAL ANALYSIS:

A two-way, mixed design ANCOVA was used to determine differences between groups for the LIST due to baseline differences in pre-season testing. Power and body composition measurements were assessed using a two way, mixed design ANOVA (1 within, 1 between) with a priori planned comparisons to evaluate differences between groups. Mean change pre- to post-season was assessed using a one-tailed independent t-test to determine differences in group specific responses.

RESULTS

Table 1 includes descriptive body composition data pre- to post-training portrayed as group means (EG and CG). No significant differences between groups were observed for age, height, or weight at baseline or pre-to post-season. Significant differences were observed in the EG for changes of FM (-1.40±1.47, $p=0.004$) and FFM (1.14±1.22, $p=0.0008$).

Table 2 shows pre- and post-training means ±SD for the LIST. Significant differences were observed between groups post-season using the ANCOVA ($p<0.02$).

Table 3 shows pre- and post-training means ±SD for each power variable tested by group. Significant pre-to-post training differences between groups were evaluated using a two way, mixed ANOVA (1 within, 1 between) with a priori planned comparisons.

Table 1: Descriptive Data, Body Composition for the Control and Experimental Groups. Data are mean ±SD.

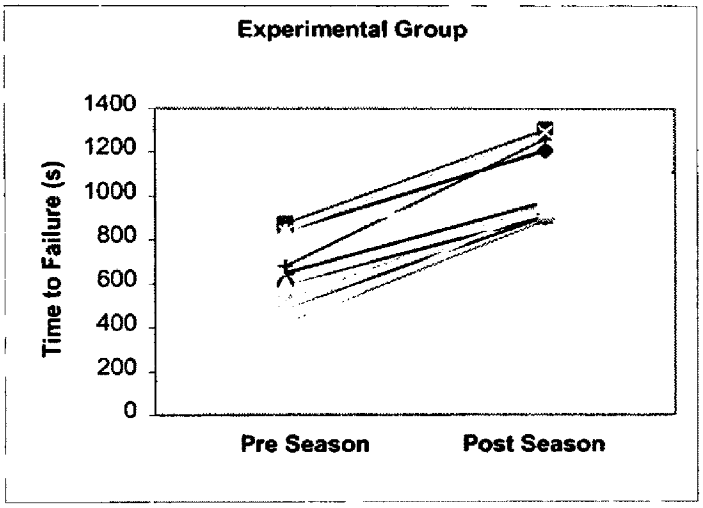
Subjects	CG: 17 EG: 17			
Age	CG: 16.27±1.38 EG: 16.49±0.91			
Height (cm)	CG: 166.7±4.71 EG: 167.42±4.64			
VARIABLE:	**GROUP**	**PRE**	**POST**	**CHANGE (PRE – POST)**
Body Weight (kg)	CG	58.00±7.23	58.14±7.65	-0.04±1.82
	EG	61.46±9.43	61.21±9.26	-0.25±1.82
FFM (kg)	CG	48.96±4.63	49.56±4.88	0.59±1.84
	EG	49.33±6.37	50.48±6.92 $^{\alpha}$	1.14±1.22
FM (kg)	CG	9.17±4.11	8.54±4.07	-0.63±1.61
	EG	12.13±4.66	10.73±4.26 $^{\alpha}$	-1.40±1.47

$^{\alpha}$ $p<0.05$ pre-to post-season within group testing

Table 2: Pre- and post-season LIST performance for both groups. Data are mean ±SD.

SUBJECTS:	PRE (s)	POST (s)	CHANGE (PRE - POST)
CG	1064.00±195.15	1115.00±157.51	50.00±176.37 [α]
EG	646.00±167.47	1040.00±157.33	394±123.59

[α] $p<0.05$ ANCOVA change between groups pre-to post-season



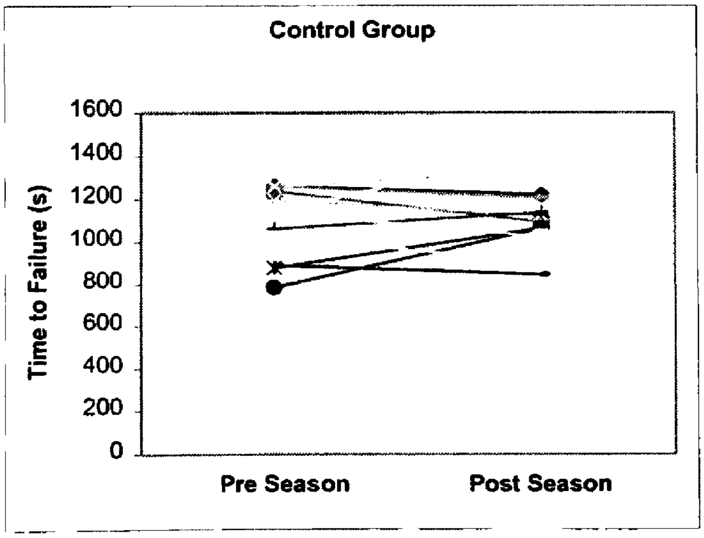


Table 3: Both pre- and post-season data are shown for the vertical jump, 20m-sprint, and Wingate test. Data are mean ±SD.

VARIABLE:	GROUP	PRE	POST	CHANGE (POST-PRE)
Vertical Jump (cm)	CG	38.46±3.68	39.19±4.45	0.73±3.37
	EG	37.65±4.77	39.37±4.69	1.72±3.83
20m Sprint (s)	CG	2.89±0.13	2.85±0.13	-0.04±0.09 $^{\alpha}$
	EG	3.00±0.15	2.90±0.13	-0.10±0.10
Peak Power (kg)	CG	9.59±0.92	9.78±1.36	0.19±1.01
	EG	10.36±2.38	10.68±2.20	0.32±3.61
Average Power (kg)	CG	7.76±0.60	7.73±0.78	-0.03±0.51
	EG	7.27±0.49	7.37±0.64	0.10±0.58
Minimum Power (kg)	CG	5.80±0.50	5.65±0.74	-0.14±0.58
	EG	4.86±0.65	4.91±0.97	0.05±0.93
Percent Decline	CG	39.23±6.00	42.00±8.00	0.02±0.06
	EG	51.00±12.45	52.45±12.00	0.02±0.16

$^{\alpha}$ $p<0.05$ significant differences within groups using planned comparisons pre-to post-season

LIST: The CG showed a non-significant change in overall time to failure during the LIST test (50.00±176.37s) while the EG improved (394.00±123.59s). This 344.00s difference in improvement on the LIST between groups was significant ($p=0.02$) even after adjusting for baseline values.

Vertical Jump: Both the EG and CG improvements pre- to post-season were not significant (1.72±3.83, $p<0.06$; 0.73±3.37, $p<0.46$).

20m Sprint: Significant improvements in sprint times were observed pre- to post-season for EG (-0.10±0.10, $p<0.0003$). The CG's reduction in sprint time pre- to post-season was not significant (-0.04±0.09, $p<0.15$).

Wingate Cycle, Leg Power Test: No significant within or between group differences were observed pre- to post-training in peak power, average power, minimum power, and percent power decline in the Wingate test data. This non-significant difference was consistent whether data were evaluated in absolute or body weight adjusted values.

Body Composition: No significant differences between groups were observed in the change in body weight pre- to post-training. Pre- to post-season changes in FM and FFM in the EG were significant (-1.40±1.47, $p<0.004$; 1.14±1.22, $p<0.0008$). No significant changes were observed pre- to post-season for FM and FFM values in the CG.

DISCUSSION

The present findings suggest that soccer-specific power endurance training with adolescent females may enhance soccer match fitness. Incorporating power-endurance training into adolescent female soccer programs, while reducing the focus of aerobic training, was shown to improve soccer match fitness. These data also show that adjusting training parameters derived from studies of elite athletes is a valid and effective technique if proper adjustments are made for the target population.

Current research regards the LIST as the most accurate measurement technique to evaluate the metabolic and physiologic demands of an elite level soccer match (16). In the current study, the LIST was abridged to simulate a female adolescent soccer match (adjusting time and distance) and allowed match fitness, relative to females, to be accurately assessed. Although the current study was conducted in a controlled environment, one advantage provided by the abridged LIST is the relative ease with which the test could be applied in a field setting. Using the abridged LIST, youth coaches or trainers will be able to accurately assess their club's overall match fitness at any point throughout the season. Group specific adjustments to times and distance will eventually provide trainers of all age, sex, and ability groups a simple, but valid and useful, soccer-specific fitness assessment tool.

The EG's in-season training protocol was modeled to include intermittent high-intensity exercise bouts along with plyometrics and strength training, and may have attributed to the enhanced overall soccer-specific match fitness as measured by the improved LIST time. The CG's in-season training protocol consisted predominately of aerobic conditioning, with a limited amount of anaerobic sessions. Training sessions designed to increase aerobic capacity, such as these done by the CG, may not enhance power endurance to the level necessary for match play in female adolescents. These findings are similar to that of Hickson et al (12). After implementing a 10-week strength program, they discovered significant increases in time to exhaustion (endurance capacity) after conducting VO_{2max} cycle and treadmill tests (12). Training sessions designed to increase 'high-intensity fitness' and to enhance recovery rates may be more appropriate. Previous research indicates that high-intensity running accounts for approximately 10-15% of total elite-level match time (3). Further study has indicated fatigue associated with high-intensity running to be the most attributable factor to decreased performance throughout a match (1)(3). The EG's training protocol was designed to have similar percentages of high intensity running, assuming that these percentages are appropriate for adolescent matches. The EG's protocol focused primarily on high-intensity plyometrics and short distance sprints.

In the current study, the EG's significant post-training increase in time to failure in the abridged LIST (+394.00, ±123.59s) over the soccer season compared to the CG's post-training increase (+50.00±176.37s) was significant ($p<0.02$) between groups. The CG's large standard deviation values may be attributed to the different individual responses to training. The abridged LIST is a relatively easy test to administer which can show effectiveness of training programs. Throughout the course of a season, fitness can be easily assessed using the abridged LIST and training programs can then subsequently be adjusted accordingly.

Muscular power, as it relates to elite soccer performance, has traditionally been measured by a number of techniques (18). In the current study, increases in high-intensity, explosive power output were assessed by measuring changes pre- to post-season in vertical jump, 20m-sprint speed, and 30s Wingate Cycle Test. Both groups increased vertical jump and decreased sprint speeds. Further evidence of increased strength and power were shown by the significant pre- to post-season strength gains of the EG in extrapolated 1RM resistance in squats (19.42, ±25.17lb, $p<0.01$), leg extensions (9.82, ±17.75lb, $p<0.05$), and calves (62.44, ±57.79lb, $p<0.0003$). Strength gains were only measured in the EG so differences between groups was not assessed.

Previous studies have measured elite soccer players' anaerobic capacity using a 30-second Wingate cycle test (6)(21)(15). Conclusions were made that the Wingate cycle test was an accurate indicator of lower body power output as it related to soccer performance. However, in the present study no pre- to post-season improvements in anaerobic capacity were observed in either group when assessed with a 30-second Wingate cycle test. The lack of change in power assessed by the Wingate cycle test, differing from the 20m-sprint and vertical jump tests which both showed improvement, may be attributed to the lack of specific cycle training. Other reasons for the different results between the tests may include relative muscle recruitment or overall muscle coordination specific to the muscles predominately used in soccer. These findings suggest that the Wingate cycle test may not be appropriate to assess improvements throughout the course of a 10-week season in female adolescents. Using a 20m-sprint or vertical jump measurement may be more applicable when determining anaerobic power specific for adolescent female soccer players. The measurement may also be more practical for youth coaches and trainers, as they require little expense or equipment.

Designing soccer training protocols for female adolescents is difficult as there is limited research and few validated sports-specific measures to evaluate adolescent soccer-specific training. The abridged LIST protocol, designed for this study, proved a beneficial means for assessing adolescent female soccer match fitness. The LIST accurately depicted differences in training protocols throughout a 10-week season with the EG showing significant improvements while no improvement was observed in the

CG. The implementation of a plyometrics and strength-training program during the high school soccer season, focusing primarily on intermittent, high intensity exercise bouts as they relate to soccer-specific fitness, appears to be beneficial in improving match fitness in adolescent females.

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Appendices A: Given to all subjects

Summer Exercise Suggestions...

Have you ever received information from a coach on training in the off-season and said to yourself, "Give me a break, who do they think they are?" Well, though it may sound a bit overbearing, they have your personal health in mind. Maintaining fitness during the off-season is important and may reduce the incidence of injuries during the season. Here are just a few suggestions for summer exercising:

1. *Running*...I know not everyone likes to run, but it will not only keep you in shape, but also help increase strength of your legs. Work up to jogging 3 to 4 times/week for around 20-30 minutes. You'll be surprised how easy it is once you get into a routine. If you find yourself losing motivation, drag someone else with you!
2. *Cycling*...an alternative to running! For those of you who like the thrill of a good downhill, don't drive up to the top of Pattee Canyon, RIDE! Try to get on your bike 3 to 4 times/week and ride 20-30 minutes. Remember, you can always ride your bike to work and home again. As long as you maintain some intensity, this will be adequate.
3. *El Futbol*...I'm sure Geoff will be more than willing to write up a few drills on paper for you. Just remember, call during the day that way you can just leave a message and he won't be able to talk during your 30 minute exercise routine!
4. *STAY ACTIVE*...For those of you with no desire to do either of the previous three suggestions, this one's for you! Just staying active throughout the summer will help. Go for walks, hikes, or swim. Don't lay around in front of the tube, get out and enjoy the summer!

*When exercising, try to maintain 50-85% of your max heart rate. This is called your target heart rate. It's easy to figure out:

220 – (your age) = ?   This is your estimated max heart rate

Now take that value (?) and multiply by .5 and .85. This is your target heart rate zone. Take your pulse during exercise and see if you are working in this realm.

*If you have had instruction about weight lifting, feel free to continue. If not, I'd rather get you started when practice begins in the fall.

*Stretching a great after you finish your workout. It allows for your body to cool down while increasing your flexibility. You can even stretch while watching your favorite TV show!

Have a great summer and I'll see you all in the fall for the 2000 season! Good luck and enjoy the break!

Appendices B:

PARTICIPANT INFORMATION AND CONSENT FORM
Human Performance Laboratory
Dept of Health and Human Performance
University of Montana

TITLE: Effectiveness of an Intermittent Shuttle Test to evaluate strength and fitness in High School Female Soccer players

INVESTIGATORS: Dr. Steven Gaskill, McGill Hall, 243-4268
Dr. Brent Ruby, 111 McGill Hall, 243-2117
Jason Siegler, Graduate Student, 549-1350

Participant______________________ Date______________________

Special instructions to the potential participant:

*This consent form may contain techniques and words previously unaware to you. If you have any questions, please call Dr. Gaskill, Dr. Ruby or Jason Siegler.

Purpose:

*You are being asked to take part in a research study evaluating the effect of strength training on reducing knee and ankle injuries and on the value of using an intermittent shuttle test (a series of short sprints on a treadmill) to evaluate physical fitness in soccer players.

*You have been chosen because the coach of your high school soccer team has expressed interest for better conditioning and exercise programs.

*The purpose of this research study is to determine whether this test is a legitimate test for monitoring the conditioning of high school female soccer athletes and if the results of a strength training program during the soccer season will help to reduce injuries.

Procedures:

*If you agree to take part in this research study you retain the right at any time to remove yourself from the study by contacting any of the investigators and informing them that you wish to discontinue participation.

*You will be asked to follow the training regime given throughout the season. This training will generally be done during the scheduled practice time, and in agreement with desires of your coach. However, there may be some additional

training time, not to exceed about 1 ½ hours each week. The researcher will be on hand throughout the season to assist you in following the training program.
*You will be asked to participate in a maximal exertion fitness test on a treadmill (about 12 minutes on the treadmill) and also a short (1 minute) leg power test on a stationary bike at the Health and Human Performance Lab at the University of Montana. You will also do a short series of strength tests on a special machine in our lab. None of these lab tests present any danger, but they will require a maximal effort and may cause you to feel very tired and uncomfortable for a short period of time. You will also be asked to perform an intermittent shuttle run conducted on the treadmill consisting of a series of short sprints. It will be conducted pre and post season.
*Heart rate, metabolic gas exchange, and ratings of perceived exertion data will be collected.

The study will take place at both the University of Montana's Health and Human Performance Laboratory and Playfair Park. Strength training will be done at the YMCA facility next to Playfair Park.

The sessions in the lab will last approximately 60 minutes and the sessions at Playfair and the YMCA will run according to practice schedules set up by the coach.

Risks/Discomforts:
- You may experience some mild discomfort and fatigue when conducting the lab maximal exertion test and intermittent shuttle run.
- Throughout the course of the season you may also experience general muscle soreness and fatigue due to the physical activity.

Benefits:
- As a participant you may experience enhanced performance due to the physical training.
- Strength gains and increased flexibility may also be observed throughout the course of the season. Previous research in other groups has shown that the strength and fitness training help to decrease injury rates. We anticipate, though cannot guarantee this benefit.

Confidentiality:
- Your records will be kept private and will not be released without your consent except as required by law.
- Only the faculty researcher and graduate assistant will have access to the files.
- Your identity will be kept confidential.
- If the results of this study are written in a scientific journal or presented at a scientific meeting, your name will not be used.
- The data will be stored in a locked file cabinet.
- Your signed consent form will be stored in a cabinet separate from the data.

- Data collected will be stored on disc and hard drive of the Health and Human Performance Lab's computer, then erased once the information pertaining to you has been used.
- Your individual results will not be shared with the coaches or any other individuals

  without your written consent, and the written consent of your guardian(s).

Compensation for Injury:
Although we do not foresee any risk in taking part in this study, the following liability statement is required in all University of Montana consent forms.

The University is will not be held liable for *"In the event that you are injured as a result of this research you should individually seek appropriate medical treatment. If the injury is caused by negligence of the University or any of its employees, you may be entitled to reimbursement pursuant to the Comprehensive State Insurance Plan established by the Department of Administration under the authority of M.C.A., Title2, Chapter 9. In the event of a claim for such injury, further information may be obtained from the University's Claim representative or University Legal Counsel."*

VOLUNTARY PARTICIPATION/WITHDRAWAL

- You have the right to request that a test be stopped at any time.
- Your decision to take part in this research study is entirely voluntary.
- You may refuse to take part in or you may withdraw from the study at any time without penalty or loss of benefits to which you are normally entitled.
- You may leave the study for any reason.

You may be asked to leave the study for any of the following reasons:

- Failure to follow the study investigator's instructions.
- A serious adverse reaction which may require evaluation.
- The study director/investigator thinks it is in the best interest of your health and welfare
- The study is terminated.

QUESTIONS

- You may wish to discuss this with others before you agree to take part in this study.
- If you have any questions about the research now or during the study contact: Steven Gaskill (406)243-4268 or Brent Ruby (406)243-2117
- If you have any questions regarding your rights as a research participant, you may contact the Chairman of the Independent Board through the Research Office at the University of Montana at 243-6670.

PARTICIPANT'S STATEMENT OF CONSENT

I have read the above description of this research study. I have been informed of the risks and benefits involved, and all my questions have been answered to my satisfaction. Furthermore, I have been assured that a member of the research team will also answer any future questions I may have. I voluntarily agree to take part. I understand I will receive a copy of this consent form.

____

Printed Name of Participant

______________________________ ______________

Participant's Signature Date

________________________ ______________

Signature of Parent or legally Authorized Date
Representative (for participants less than 18 years old)

Appendices C: Soccer Data – Individual Tests (Pre-season)

Team	Age	Ht (cm)	Wt (kg)	LIST (min)	LIST (sec)	VJ (cm)	Sprint (sec)	Peak Power/kg	Mean Power/kg	Min Power/kg	% Decline
EG	16	167	59.3	10	50	31.8	3.08	9.76	7.23	4.44	54.5
EG	15	178	69.1	14	02	36.8	2.77	9.78	7.77	5.82	40.4
EG	16	168.5	61.4	14	35	39.4	2.86	9.56	7.62	5.00	47.7
EG	17	162.5	57.8	13	57	43.2	2.75	9.69	7.87	5.80	40.1
EG	18	167.5	60.1	8	41	34.3	3.11	14.28	7.19	4.66	67.4
EG	17	166.0	67.0	8	09	36.8	2.79	9.45	7.42	5.24	44.6
EG	17	164.0	66.9	9	59	27.9	2.94	8.97	6.28	4.04	55.0
EG	16	167.0	71.5	11	20	43.2	2.96	9.37	7.02	4.60	50.9
EG	16	171.0	72.6	10	50	39.4	2.98	9.41	7.45	5.21	44.7
EG	16	162.5	48.2	13	15	44.5	2.86	9.71	7.53	4.90	49.5
EG	17	162.0	68.0	7	00	45.7	3.04	16.21	6.62	3.57	78.0
EG	17	172.5	59.3	13	13	35.6	3.17	15.18	7.49	4.22	72.2
EG	14	164.0	52.2	6	46	36.8	3.17	9.58	8.07	4.79	50.0
EG	16	169.5	63.8	9	45	35.6	3.11	9.39	6.97	4.22	55.1
EG	17	165.0	76.7	9	59	40.6	3.10	8.76	6.41	4.76	45.7
EG	15	161.0	45.3	13	57	33.0	3.26	8.72	7.42	5.50	36.8
EG	16	162.5	45.6	8	09	35.6	3.06	8.31	7.28	5.81	30.1
CG	17	170.0	61.4	21	00	43.2	2.83	8.52	7.46	6.04	29.1
CG	15	161.0	48.8	20	40	43.2	2.86	10.43	8.40	6.25	40.1
CG	15	164.5	54.2	19	59	49.5	2.74	10.87	7.49	4.87	55.1
CG	18	163.5	63.6	11	32	38.1	3.05	9.70	7.80	5.61	42.1
CG	15	169.0	54.6	19	59	38.1	2.75	11.04	8.48	6.37	42.2
CG	17	163.0	60.8	14	39	38.1	2.81	8.49	6.76	4.67	44.9
CG	17	169.5	73.0	13	06	36.8	2.89	8.40	6.92	5.33	36.6
CG	15	159.0	53.9	17	45	40.6	2.68	11.17	8.89	6.10	45.3
CG	14	168.0	53.0	15	39	44.5	2.92	9.09	7.66	5.79	36.2
CG	14	171.0	48.6	14	28	36.8	3.02	9.94	7.63	5.53	44.3
CG	17	163.0	50.0	14	52	33.0	2.93	9.74	7.74	5.70	41.5
CG	17	177.0	63.9	21	00	38.1	2.85	10.27	8.15	5.71	44.3
CG	17	161.5	64.2	19	00	33.0	3.08	9.35	7.54	5.92	36.6
CG	14	171.5	56.6	19	00	45.7	2.71	9.49	7.67	6.08	36.0
CG	14	168.0	54.6	14	39	35.6	3.10	8.64	7.20	5.27	38.9
CG	15	167.5	58.1	14	53	35.6	3.09	8.76	6.97	5.03	42.7
CG	16	164.5	59.9	21	00	38.1	2.83	9.02	8.06	6.58	27.0

Appendices C: Soccer Data – Individual Tests (Pre-season) Continued

Team	H_2O ©	H_2O density	UWW	RV	Body density	%BF	FM	FFM
EG	35	0.99406	1.100	1.041	1.041	23.9	14.16	45.14
EG	35	0.99406	3.090	1.072	1.072	9.9	6.81	62.29
EG	35	0.99406	1.850	1.504	1.054	18.0	11.05	50.35
EG	35	0.99406	2.370	1.064	1.064	13.2	7.62	50.17
EG	35	0.99406	1.540	1.049	1.049	20.1	12.10	48.00
EG	35	0.99406	1.411	1.040	1.040	24.3	16.30	50.70
EG	35	0.99406	1.363	1.038	1.038	25.2	16.83	50.07
EG	35	0.99406	1.905	1.045	1.045	22.1	15.77	55.73
EG	35	0.99406	1.860	1.045	1.045	21.9	15.87	56.74
EG	35	0.99406	1.779	1.065	1.065	12.8	6.19	42.02
EG	35	0.99406	1.523	1.039	1.039	24.8	16.85	51.15
EG	34	0.99440	2.014	1.062	1.062	14.2	8.43	50.87
EG	34	0.99440	1.552	1.055	1.055	17.2	8.99	43.21
EG	35	0.99406	1.383	1.044	1.044	22.6	14.42	49.38
EG	34	0.99440	1.351	1.033	1.033	27.6	21.20	55.50
EG	35	0.99406	1.415	1.059	1.059	15.4	6.98	38.32
EG	35	0.99406	1.467	1.062	1.062	14.4	6.57	39.04
CG	35	0.99406	0.993	1.039	1.039	24.7	15.16	46.24
CG	35	0.99406	2.068	1.070	1.070	10.8	5.28	43.52
CG	35	0.99406	2.104	1.065	1.065	13.0	7.06	47.14
CG	35	0.99406	2.174	1.055	1.055	17.5	11.15	52.45
CG	35	0.99406	1.877	1.062	1.062	14.1	7.68	46.92
CG	35	0.99406	1.865	1.052	1.052	19.0	11.55	49.26
CG	35	0.99406	2.072	1.048	1.048	20.8	15.16	57.84
CG	35	0.99406	2.270	1.065	1.065	12.9	6.97	46.93
CG	35	0.99406	1.803	1.062	1.062	14.2	7.52	45.49
CG	35	0.99406	1.846	1.072	1.072	9.7	4.74	43.86
CG	35	0.99406	2.261	1.074	1.074	8.9	4.43	45.57
CG	35	0.99406	2.750	1.072	1.072	9.7	6.18	57.72
CG	35	0.99406	1.496	1.041	1.041	23.8	15.28	48.92
CG	35	0.99406	1.157	1.047	1.047	21.1	11.95	44.65
CG	35	0.99406	2.476	1.074	1.074	8.8	4.82	49.79
CG	34	0.99440	1.531	1.051	1.051	19.4	11.25	46.85
CG	35	0.99406	2.430	1.064	1.064	13.4	8.05	51.85

Appendices D: Soccer Data – Individual Tests (Post-season)

Team	Age	Ht (cm)	Wt (kg)	LIST (min)	LIST (sec)	VJ (cm)	Sprint (sec)	Peak Power/kg	Mean Power/kg	Min Power/kg	% Decline
EG	16.2	167	60.7	DNP	DNP	38.1	2.99	9.41	7.27	4.37	53.6
EG	15.2	179.5	70.1	20	08	45.7	2.65	10.98	8.84	6.99	36.3
EG	16.2	168.5	62.0	21	44	41.9	2.88	13.50	7.39	4.52	66.5
EG	17.2	162.5	56.5	15	20	45.7	2.69	10.21	7.81	4.85	52.5
EG	18.2	167.5	64.6	16	10	38.1	2.92	8.65	6.66	4.85	44.0
EG	17.2	166.0	65.8	15	06	38.1	2.81	9.94	7.78	5.64	43.3
EG	17.2	164.0	65.8	15	05	30.5	2.85	9.62	6.69	4.01	58.2
EG	16.2	167.0	67.7	21	00	38.1	2.96	16.54	7.75	5.57	66.4
EG	16.2	171.0	72.2	16	15	38.1	3.06	12.95	8.17	5.37	58.5
EG	16.2	163.0	46.1	DNP	DNP	48.3	2.70	10.26	8.22	5.79	43.7
EG	17.2	162.0	66.9	14	50	40.6	2.93	9.55	6.92	4.62	51.6
EG	17.2	172.5	60.2	18	16	33.0	2.97	9.37	6.61	4.65	50.4
EG	14.2	164.0	51.8	16	00	35.6	2.94	13.78	7.20	2.22	83.9
EG	16.2	169.5	64.5	DNP	DNP	39.4	2.97	9.50	7.21	5.04	47.0
EG	17.2	165.0	74.9	15	37	44.5	3.11	9.27	6.85	4.82	48.0
EG	16	161.0	46.0	21	30	38.1	2.94	9.09	7.22	5.17	43.1
EG	16.2	162.5	44.7	15	37	35.6	2.95	8.88	6.71	4.92	44.7
CG	17.2	170.0	65.6	20	20	43.2	2.82	8.29	6.86	5.20	37.2
CG	15.2	161.0	47.9	18	11	38.1	2.83	10.00	8.06	5.55	44.5
CG	15.2	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
CG	18.2	163.5	63.4	17	45	40.6	2.82	12.76	8.50	5.74	55.0
CG	16	169.2	54.3	18	43	40.6	2.84	10.99	8.29	5.69	48.2
CG	17.2	161.7	61.3	17	45	38.1	2.77	8.91	7.11	4.52	49.2
CG	17.2	169.0	75.0	17	45	38.1	2.81	7.68	6.53	4.93	35.8
CG	15.2	158.0	54.7	18	56	40.6	2.68	10.80	9.05	6.89	36.2
CG	14.2	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
CG	14.2	171.0	49.2	DNP	DNP	43.2	2.87	10.43	7.72	5.55	46.8
CG	17.2	162.5	49.5	14	02	30.5	3.08	8.81	6.69	5.01	43.1
CG	17.2	175.5	62.5	20	06	44.5	2.73	10.42	8.10	5.54	46.9
CG	17.2	161.0	60.9	23	43	30.5	3.03	9.03	7.03	5.07	43.8
CG	14.2	175.5	56.4	17	01	43.2	2.71	10.85	8.37	6.81	37.2
CG	14.2	168.0	55.1	DNP	DNP	35.6	3.11	8.46	7.60	5.81	31.2
CG	15.2	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
CG	17	164.5	57.5	22	10	41.9	2.76	9.48	8.33	6.85	27.6

* DNP: Did not participate

Appendices D: Soccer Data – Individual Tests (Post-season) Continued

Team	H_2O ©	H_2O density	UWW	RV	Body density	%BF	FM	FFM
EG	34.5	0.99424	1.688	1.590	1.051	19.3	11.74	48.97
EG	34.5	0.99424	3.592	1.981	1.080	6.3	4.39	65.71
EG	34.5	0.99424	2.052	1.638	1.057	16.5	10.23	51.77
EG	34.5	0.99424	2.649	1.455	1.072	9.8	5.52	50.98
EG	34.5	0.99424	1.648	1.624	1.047	21.1	13.60	51.00
EG	34.5	0.99424	1.787	1.567	1.047	20.9	13.74	52.06
EG	34.5	0.99424	1.645	1.503	1.044	22.5	14.79	51.01
EG	34.5	0.99424	2.253	1.590	1.054	17.9	12.12	55.58
EG	34.5	0.99424	2.088	1.718	1.049	20.0	14.43	57.77
EG	34.5	0.99424	2.010	1.462	1.075	8.4	3.88	42.22
EG	34.5	0.99424	1.810	1.439	1.045	22.1	14.79	52.11
EG	34.5	0.99424	2.025	1.775	1.061	14.7	8.83	51.37
EG	34.5	0.99424	1.620	1.476	1.057	16.4	8.49	43.31
EG	34.5	0.99424	1.473	1.670	1.045	22.0	14.21	50.29
EG	34.5	0.99424	1.811	1.535	1.041	24.1	18.05	56.85
EG	34.5	0.99424	1.240	1.398	1.055	17.6	8.11	37.89
EG	34.5	0.99424	1.592	1.446	1.067	12.2	5.45	39.25
CG	35	0.99406	1.344	1.695	1.042	23.4	15.32	50.28
CG	35	0.99406	2.192	1.389	1.074	8.8	4.21	43.69
CG	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
CG	35	0.99406	2.203	1.496	1.055	17.2	10.90	52.50
CG	35	0.99406	2.539	1.660	1.077	7.5	4.05	50.25
CG	35	0.99406	2.056	1.429	1.054	18.0	11.00	50.30
CG	35	0.99406	2.165	1.663	1.047	20.9	15.70	59.30
CG	35	0.99406	2.275	1.293	1.063	13.7	7.47	47.23
CG	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
CG	35	0.99406	1.735	1.700	1.068	11.3	5.58	43.62
CG	35	0.99406	1.876	1.455	1.066	12.6	6.24	43.26
CG	35	0.99406	3.110	1.871	1.080	6.3	3.91	58.59
CG	35	0.99406	1.634	1.407	1.046	21.5	13.09	47.81
CG	35	0.99406	1.588	1.844	1.058	15.9	8.98	47.42
CG	35	0.99406	2.353	1.604	1.071	10.3	5.67	49.43
CG	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
CG	35	0.99406	2.321	1.519	1.065	12.9	7.40	50.10

*DNP: Did not participate

Appendices E: Daily training records

Team	8/21 Plyo	8/22 S.T.	8/23 Plyo	8/24 S.T.	8/25 Plyo	8/28 Plyo	8/29 S.T.	8/30 Plyo	8/31 S.T	9/1 Plyo	9/4 Plyo	9/5 S.T.	9/6 Plyo	9/8 S.T.
EG	DNP (I)	P	P	P	P	P	P	P	P	P	P	P	P	P
EG	DNP (I)	P	P	P	P	P	P	P	P	P	DNP (I)	P	P	DNP (A)
EG	P	P	P	P	P	P	P	P	P	P	DNP (A)	P	P	P
EG	P	P	P	P	P	P	P	P	P	P	DNP (I)	DNP (I)	DNP (I)	DNP (A)
EG	P	P	P	P	P	P	P	P	P	DNP (I)	P	DNP (A)	P	P
EG	P	P	P	P	P	P	P	P	P	P	P	P	P	P
EG	P	P	P	P	P	P	P	P	P	P	P	P	P	P
EG	P	P	P	P	P	P	P	P	P	P	P	P	P	P
EG	P	P	P	P	P	P	P	P	P	P	P	P	P	DNP (A)
EG	P	P	P	DNP (A)	P	P	P	DNP (A)	P	P	DNP (A)	P	P	P
EG	P	P	P	P	P	P	P	P	P	P	P	DNP (A)	P	DNP (A)
EG	P	P	P	P	P	P	P	P	P	P	P	P	P	P
EG	P	P	P	P	P	P	P	P	P	P	P	P	P	P
EG	P	P	P	P	P	P	P	P	P	P	P	P	P	P
EG	P	P	P	P	P	P	P	P	P	P	P	P	P	P
EG	P	P	P	P	P	P	P	P	P	P	P	DNP (A)	P	DNP (A)
EG	DNP (I)	P	DNP (I)	P	P	P	P	DNP (I)	DNP (I)	DNP (I)	DNP (I)	P	P	P

*DNP: Did not participate - (I): injury (A): absent
*P: Participated
*Plyo: Plyometric sessions
*S.T.: Strength training sessions

Appendices E: Daily training records (Continued)

Team	9/11 Plyo	9/12 S.T.	9/13 Plyo	9/18 Plyo	9/20 Plyo	9/21 S.T.	9/22 Plyo	9/25 Plyo	9/26 S.T.	9/27 Plyo	9/28 S.T.	9/29 Plyo	10/2 Plyo	10/3 S.T.
EG	P	P	DNP (A)	P	DNP (A)	DNP (A)	P	P	P	DNP (A)	P	P	DNP	DNP (A)
EG	P	P	DNP (I)	DNP (A)	P	P	P	P	P	P	P	P	DNP	P
EG	P	P	P	P	P	P	DNP (A)	P	P	P	P	P	DNP	DNP (A)
EG	DNP (I)	DNP (I)	DNP (I)	DNP (I)	DNP (I)	P	P	P	P	P	P	P	DNP	P
EG	P	DNP (A)	P	P	P	DNP (A)	P	P	P	P	P	P	DNP	P
EG	DNP (A)	DNP (A)	P	P	P	P	P	P	P	P	P	P	DNP	P
EG	P	DNP (A)	P	P	P	P	P	P	P	P	P	P	DNP	DNP (A)
EG	P	P	P	P	P	P	P	P	P	P	P	P	DNP	P
EG	P	P	P	P	P	P	P	P	P	P	P	P	DNP	P
EG	DNP (A)	P	P	P	P	P	P	P	P	P	P	P	DNP	P
EG	P	P	P	P	P	P	P	P	P	P	P	P	DNP	P
EG	DNP (A)	DNP (A)	P	P	P	P	P	P	P	P	P	P	DNP	DNP (A)
EG	P	P	P	P	P	P	P	P	P	P	P	P	DNP	DNP (A)
EG	DNP (A)	P	P	P	P	P	DNP (A)	P	P	P	P	P	DNP	DNP (A)
EG	P	P	P	P	P	P	P	P	P	P	P	P	DNP	DNP (A)
EG	P	P	P	DNP (A)	DNP (A)	P	P	P	P	P	P	P	DNP	P
EG	P	P	P	P	P	P	P	P	P	P	P	P	DNP	P

Appendices E: Daily training records (Continued)

Team	10/4 Plyo	10/5 S.T.	10/6 Plyo	10/11 S.T.	10/12 Plyo	10/16 Plyo	10/17 S.T.	10/18 Plyo
EG	P	P	P	P	P	P	DNP (A)	P
EG	P	DNP (A)	P	DNP (A)	P	P	P	P
EG	DNP (A)	P	P	P	P	P	DNP (A)	P
EG	P	P	P	P	P	P	DNP (A)	P
EG	P	P	P	DNP (A)	P	P	DNP (A)	P
EG	P	P	P	DNP (A)	P	P	DNP (A)	DNP (A)
EG	DNP (A)	P	P	DNP (A)	P	DNP (A)	P	P
EG	DNP (A)	P	P	P	P	P	P	P
EG	P	P	P	P	P	P	P	P
EG	P	P	P	DNP (A)	DNP (I)	DNP (I)	P	P
EG	P	P	P	DNP (A)	P	P	P	DNP (A)
EG	P	P	P	DNP (A)	P	P	P	P
EG	P	P	P	DNP (A)	P	P	P	DNP (A)
EG	P	P	P	DNP (A)	P	P	P	P
EG	P	P	P	P	P	P	P	P
EG	P	P	P	DNP (A)	P	P	P	P
EG	P	P	P	DNP (A)	P	DNP (I)	P	P