Physiological and sport skill characteristics of Olympic developmental soccer athletes
by Miriam Lydia Vanderford

A thesis submitted in partial fulfillment of the requirements for the degree Of Master of Science in
Health and Human Development

Montana State University

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Abstract:

Although many studies have examined the physiological profile of soccer athletes, no comprehensive studies have been conducted on developmental soccer athletes in the United States. Therefore, the purpose of this study was to quantify physiological and sport-specific skill characteristics of Olympic Developmental soccer athletes by age group and region. Following written informed consent, 59 male athletes (age=14.6±2 yrs; wt=60.5±1.4 kg; ht=172.4±1.2 cm) completed a battery of tests to determine oxygen consumption (VO₂max), heart rate (HRmax), ventilation (VE_{max})1 respiratory exchange ratio (R_{max})1 anaerobic threshold (AT), and blood pressure (BP_{restzmax}) during a Bruce graded exercise test (GXT). Anaerobic power [peak power (PR), mean power (MP)1 total work output (TWO)] was achieved using a Wingate test. Leg power (vertical squat and countermovement jumps), percent body fat, and flexibilities (trunk, spine, hip, knee, and ankle) were assessed. Agility and sport-specific skill were determined using accepted sport-specific protocols (T-test, line drill test, juggling test, Johnson wall volley, and modified-Zelenka circuit). Factor analyses with subsequent MANOVAs indicated significant (p<.05) main effects across age only. When compared to values reported for athletes of similar age and activity, these athletes were similar in aerobic power and anaerobic power/capacity, lower in leg power, and similar in agility and flexibility. Overall, this study has shown that although these athletes were similar in aerobic performance, improvements in anaerobic power, agility, and sport skill should be addressed. It is hoped that these results may serve as a point of reference for high school and club soccer coaches, as well as for further studies conducted with athletes of this age group and sport.

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MONTANA STATE UNIVERSITY
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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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This work is first of all dedicated to God who has been my ever constant source of strength and guidance (Proverbs 3: 5-6 - "Trust in the Lord with all your heart and lean not to your own understanding. In all your ways acknowledge him, and he will direct your paths.") I would also like to dedicate this work to my family who has always stood behind me to encourage and support me in every dream I pursued.

VITA

The author of this work is Miriam Lydia Vanderford. She was born on July 31, 1972, in Rome, Georgia, to Rev. Kenneth A. and Mrs. Louise G. Vanderford. Lydia received her Bachelor of Science degree June, 1994, from the Valdosta State University Education Department with an emphasis in Athletic Training. This work was written in partial fulfillment of her Master of Science degree from the Montana State University Department of Health and Human Development, where her major field of study is Exercise Physiology. Her professional experience includes a graduate teaching assistantship at Montana State University, where her duties included working as a certified athletic trainer for the MSU Athletic Department. Lydia was also a Chief Athletic Trainer for the 1996 Centennial Olympics.

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ABSTRACT

Although many studies have examined the physiological profile of soccer athletes, no comprehensive studies have been conducted on developmental soccer athletes in the United States. Therefore, the purpose of this study was to quantify physiological and sport-specific skill characteristics of Olympic Developmental soccer athletes by age group and region. Following written informed consent, 59 male athletes (age=14.6±2 yrs; wt=60.5±1.4 kg; ht=172.4±1.2 cm) completed a battery of tests to determine oxygen consumption ($\text{VO}_{2\text{max}}$), heart rate (HR_{max}), ventilation (VE_{max}), respiratory exchange ratio (R_{max}), anaerobic threshold (AT), and blood pressure ($\text{BP}_{\text{rest/max}}$) during a Bruce graded exercise test (GXT). Anaerobic power [peak power (PP), mean power (MP), total work output (TWO)] was achieved using a Wingate test. Leg power (vertical squat and countermovement jumps), percent body fat, and flexibilities (trunk, spine, hip, knee, and ankle) were assessed. Agility and sport-specific skill were determined using accepted sport-specific protocols (T-test, line drill test, juggling test, Johnson wall volley, and modified-Zelenka circuit). Factor analyses with subsequent MANOVAs indicated significant ($p<.05$) main effects across age only. When compared to values reported for athletes of similar age and activity, these athletes were similar in aerobic power and anaerobic power/capacity, lower in leg power, and similar in agility and flexibility. Overall, this study has shown that although these athletes were similar in aerobic performance, improvements in anaerobic power, agility, and sport skill should be addressed. It is hoped that these results may serve as a point of reference for high school and club soccer coaches, as well as for further studies conducted with athletes of this age group and sport.

CHAPTER 1

INTRODUCTION

Soccer is an intermittent activity sport, taxing both the aerobic and anaerobic systems (Raven, Gettman, Pollock, & Cooper, 1976; Withers, Roberts, & Davies, 1977). During competition, a player's workload intensity will range from walking to sprinting (Reilly & Thomas, 1976). In order to sufficiently sustain the ability to perform during a soccer match, a player must possess a strong anaerobic component that combines strength, speed, and power (Berg, LaVoie, & Latin, 1985; Kirkendall, 1985). Flexibility and agility are also key factors that allow for the quick stops, starts, and turns these athletes must perform (Tumilty, 1993), as well as sport-specific skills that are essential to successfully compete at a national and international level (Marey, Boleach, Mayhew, & McDole, 1991; Raven et al., 1976).

Numerous studies have investigated various physiological characteristics of adult soccer players during actual competition or following training (Ekblom, 1986; Leatt, Shephard, & Plyley, 1987; Mosher, Rhodes, Wenger, & Filsinger, 1985; Raven et al., 1976; Reilly & Thomas, 1976; Rhodes, Mosher, McKenzie, Franks, Potts, & Wenger, 1986). Of the several studies published on youth soccer (Caru, Le Coultre, Aghemo, & Limas, 1970; Chin, So, Yuan, Li, & Wong, 1994; Garganta, Maria, & Pinto, 1992; Garganta, Maria, Silva, & Natal, 1992; Jones & Helms, 1992; Leatt et al., 1987; Mosher et al., 1985; Tumilty & Smith, 1992), only two have examined U.S. athletes, utilizing limited standard laboratory procedures and information on characteristics specific to soccer athletes (Berg et al., 1985; Kirkendall, 1985). At this time, little attention has been

directed towards agility and sport-specific skill assessment in young soccer athletes, especially addressing age and regional differences at the developmental level of competition (Leatt et al., 1987; Mosher et al., 1985).

During the last 10 years, the popularity of youth soccer in the United States has greatly increased (Berg et al., 1985; Kirkendall, 1985). According to the 1993-94 Athletics Participation Survey conducted by the National Federation of State High School Associations, boys' soccer ranks as one of the top five most popular high school sports with the number of participants reaching 255,538. Soccer also ranks as one of the top ten most popular high school sports (National Federation of State High School Associations, 1995). Therefore, it seems there is a disparity between the popularity of soccer in this country, and attempts to study the physiological and performance characteristics of these young athletes are warranted.

Purpose

The purposes of this study were to quantify physiological and sport-specific skills of Olympic Developmental Program soccer athletes and to examine whether differences existed between age group or region. Results were also compared to other intermittent sport competitors.

Significance of the Study

The results of this comprehensive study should be of value to soccer athletes, coaches, and sport scientists as they attempt to more clearly define optimal levels of physiological fitness and sport skills specific to youth soccer. This should ultimately lead to more effective conditioning and training regimens.

Research Objectives

This investigation attempted to fulfill the following objectives:

1. Quantify physiological response of youth soccer athletes.
2. Quantify sport-specific skills of youth soccer athletes.

Null Hypotheses

For the purposes of this study, the following null hypotheses were tested:

1. There will be no significant difference observed in the physiological responses of ODP soccer athletes when classified by age group and region.
2. There will be no significant difference observed in the quality of sport skill of ODP soccer athletes when classified by age group and region.

Assumptions

Assumptions regarding this investigation were:

1. Subjects were adequately informed by investigators on all procedures and phases of the study to ensure optimal understanding of physiological and sport skill testing.
2. Subjects were expected to exert maximal effort for optimal physiological and sport skill responses.

Limitations

Limitations regarding this investigation were:

1. Due to the small sample size involved in the study, any inference to a larger population would be difficult.
2. Due to a narrow age range, inference to other age populations would be limited.

3. Due to travel across long distances and time zones, the limited opportunity for athletes to fully acclimatize would have compromised optimal testing response.
4. Due to meals being provided by the ODP soccer camp, control of nutritional intake was limited throughout the week.
5. Due to the subjects' varying camp schedules and coaching requirements, consistent testing schedules were improbable.

Delimitations

Delimitations regarding this investigation included:

1. Soccer athletes were selected from the Olympic Developmental Program, which should have elicited a high degree of athletic performance and maximal response.
2. Prior to participating in the study, athletes were exposed to all testing procedures to enhance familiarity and optimal response potential.
3. Aerobic assessments were conducted no earlier than 48 hours following arrival in Bozeman for those traveling from lower altitudes to become acclimatized.
4. Subjects were instructed to consume meals high in carbohydrates for restoration and maintenance of muscle glycogen throughout the week.
5. Time between testing periods and sport competition were kept in a consistent manner to minimize an undesired effect on test response.
6. Circadian rhythmicity was addressed by testing individuals of the same group at different times throughout the day so that the subjects' shifts in chronobiological rhythm would balance out.

Definition of Terms

- Aerobic capacity - The amount of aerobic energy the body is able to produce independent of time, using aerobic glycolysis and beta oxidation. This variable is measured as the amount of oxygen uptake (VO_2) an individual is capable of consuming during exercise (Fox, Bowers, & Foss, 1989; Rhodes et al., 1986).
- Aerobic energy - The breakdown of glycogen and fat in the presence of oxygen through aerobic glycolysis and beta-oxidation, respectively, followed by passage of fuel substrates into the Krebs cycle and electron transport system (ETS) for the production of ATP (Fox et al., 1989).
- Aerobic power - The rate at which one can maximally consume oxygen, defined as VO_{2max} , which is obtained from an athlete during exercise (Fox et al., 1989; Rhodes et al., 1986).
- Agility - The ability to change direction quickly while maintaining body control (Semenick, 1990b).
- Anaerobic capacity - The total amount of work one is able to perform in the absence of adequate oxygen, using immediately available ATP and phosphagen derived from anaerobic glycolysis and phosphagen systems (Fox et al., 1989; Sharp, Johnson, & Thorland, 1984).
- Anaerobic energy - The ATP produced by the breakdown of glycogen and/or phosphocreatine in the absence of oxygen (Fox et al., 1991).
- Anaerobic power - The highest amount of work performed in a specified period of time; usually during the first or second 5-second period of time (Sharp et al., 1984).
- Flexibility - The range of motion (ROM) about any given joint, measured by goniometric technique (American Academy of Orthopaedic Surgeons, 1965).
- Muscular (leg) power - The rate of work performed by the lower extremity musculature, as measured by vertical jump (Fox et al., 1989; Semenick, 1990c).
- Residual volume - The amount of gas left in the lungs following a maximal expiration (Fox et al., 1989).

CHAPTER 2

REVIEW OF LITERATURE

Although several studies have been conducted on international soccer players (Bangsbo, Norregaard, & Thorso, 1991; Davis et al., 1992; Ekblom, 1986; Ghosh, Ahuja, & Khana, 1987; Oberg, Ekstrand, Moller, & Gillquist, 1984; Reilly & Thomas, 1976; Thomas & Reilly, 1979), a limited number have focused on athletes in the United States (Berg et al., 1985; Kirkendall, 1985; Raven et al., 1976). More importantly, no comprehensive physiological and sport-specific skill studies have been published. The majority of studies have quantified the competitive season's effect on physiological response, have documented physiological differences between laboratory and field testing, have provided partial athletic profiles with limited sport application, or have quantified the efficacy of various training regimens (Bangsbo & Lindquist, 1992; Davis et al., 1992; Ghosh et al., 1987; Malomsoki, Ekes, Martos, & Nemeskeri, 1990; Reilly & Thomas, 1977; White, Emery, Kane, Groves, & Risman, 1988).

Anthropometric Status

Sport performance is affected by the ratio of body fat to lean body mass (LBM) (Riendeau, Welch, Crisp, Crowley, Griffin, & Brockett, 1958). An increase in LBM enhances speed and agility, whereas an increase in body fat negatively influences quickness of horizontal movements (Maud & Shultz, 1984; Raven et al., 1976; Riendeau et al., 1958). Thus, body composition is an important determinant in assessing the physical capabilities of soccer athletes (Green, 1992; Leatt et al., 1987).

Percent body fat values reported for soccer athletes are similar to those of other intermittent activity athletes. Professional soccer athletes exhibited percent body fat ranging from 7.3% to 13.3% (Chin et al., 1992; Davis et al., 1992; Raven, et al., 1976; Rhodes et al., 1986). These values are similar to those reported for other intermittent activity athletes involved in baseball, rugby, field hockey, and judo (Hagerman, Starr, & Murray, 1989; Maud & Shultz, 1984; Reilly & Borrie, 1992; Thomas, Cox, LeGal, Verde, & Smith, 1989).

There are a number of anthropometric techniques that are used to assess body composition. These include hydrostatic weighing, skinfold measurements, electrical bioimpedance, and air displacement (Boulier, Fricker, Thomasset, & Apfelbaum, 1990; Davis et al., 1992; Dempster & Itchiness, 1995; Hagerman et al., 1989; Leatt et al., 1987; Maud & Shultz, 1984; McCrory, Gomez, Bernauer, & Mole, 1995; Jackson & Pollock, 1977; Rhodes et al., 1986). Hydrostatic weighing is considered the gold standard in the clinical setting when attempting to quantify body composition in both general and athletic populations (American College of Sports Medicine, 1991; Horswill, Lohman, Slaughter, Boileau, & Wilmore, 1990; Meyers et al., 1992; Williford, Smith, Mansfield, Conerly, & Bishop, 1986). Subject habituation, however, is essential for optimal success. Reported test-retest reliability coefficients for hydrostatic weighing have ranged from .93 to .99 (Katch, Michael, & Horvath, 1967).

Skinfold measurement is a simple technique to perform. The technique is noninvasive, requires limited subject participation/experience, and does not require expensive laboratory equipment. Thus, it is often used in settings where limited funding is available. In addition, skinfold measurements are also used to compare accuracy of measurements obtained by other anthropometric methods (American College of Sports Medicine, 1991). Skinfold correlation coefficients have ranged from .78 to .90, slightly

lower than values established for hydrostatic weighing (Stout, Housh, Johnson, Housh, Evans, & Eckerson, 1995).

Aerobic Power

In the sport of soccer, an adequately trained aerobic system is necessary to sustain long-term performance during a match, and provides a foundation for sport-specific training of other energy systems (Korshunov & Kirillov, 1979). Studies documenting the distance and intensity of work required of athletes during soccer competition have indicated that players travel an average of 10 km during a match, with distances ranging from 8.68 to 10.98 km (Bangsbo & Lindquist, 1992; Bangsbo et al., 1991; Reilly & Thomas, 1979; Tumilty, 1993). Additional research has quantified work load by both distance, and by the percentage of time spent at various intensities of exercise, i.e., rest, low-intensity running, high-intensity running. Bangsbo and colleagues (1991) reported that standing accounted for 17.1% of the time spent during a competitive match, with walking, low-intensity running, and high-intensity running accounting for 40.4%, 35.1%, and 8.1%, respectively. Other studies have revealed that high intensity running accounts for 19% of time played or approximately 2.1 km (Bangsbo & Lindquist, 1992; Withers, Maricic, Wasilewski, & Kelly, 1982).

Some researchers, however, have expressed a concern for additional aerobic training. Bangsbo et al. (1991) reported a 5% decrease in distance from the first to second halves of a soccer match, a factor possibly influenced by a change in the amount of low-intensity running. This decrease in distance traveled from the first to the second half, may reflect insufficient aerobic training. Other studies have also indicated a decrease in game distance or intensity, as indicated by heart rate (HR) telemetry, from

the first to the second half of play, attributing the change to possible physical fatigue (Ali & Farrally, 1991; Reilly & Thomas, 1976).

Assessments of heart rate (HR) and maximal oxygen uptake (VO_{2max}) during exercise are commonly performed to quantify an individual's functional capacity (Bangsbo et al., 1991; Davis et al., 1992; Raven et al., 1976; Rhodes et al., 1986). Heart rate measurements are obtained to identify the level of intensity and is the single most used indicator of aerobic fitness (American College of Sports Medicine, 1991). Of these techniques, however, VO_{2max} is considered to be the criterion by which other measurements in the clinical setting are compared (McArdle, Katch, & Katch, 1991).

Investigators examining soccer athletes have used both HR and VO_{2max} to quantify aerobic power (Bangsbo et al., 1991; Raven et al., 1976). Various HR values recorded for soccer athletes include supine HR_{rest} values of 54-65 bpm, HR_{mean} during play of 170 bpm, and HR_{max} values ranging from 188 to 195 bpm (Ali & Farrally, 1991; Raven et al., 1976; Rhodes et al., 1986; Thomas & Reilly, 1979).

Interestingly, VO_{2max} values obtained from professional and young elite soccer players are similar. Aerobic power of professional soccer athletes have ranged from 53.7 $ml \cdot kg^{-1} \cdot min^{-1}$ to 66.4 $ml \cdot kg^{-1} \cdot min^{-1}$, depending on the position played (Bangsbo et al., 1991; Chin, Lo, Li, & So, 1992; Raven et al., 1976; Rhodes et al., 1986; Tumilty, 1993). Midfielders seem to possess the highest aerobic power when compared to other field positions, possibly related to their dual role as both attackers and defenders during a match (Davis et al., 1992). Studies involving young athletes have reported VO_{2max} values of 50 $ml \cdot kg^{-1} \cdot min^{-1}$ in club players between the ages of 11-12 (Berg et al., 1985), 42.3-50.2 $ml \cdot kg^{-1} \cdot min^{-1}$ in non-elite soccer players ages 14-18 (Caru et al., 1970), and 57.7 and 59 $ml \cdot kg^{-1} \cdot min^{-1}$ in elite under-18 (U-18) and under-16 (U-16) athletes, respectively (Leatt et al., 1987).

The method typically used to assess VO_{2max} in both athletic and general populations is a symptom-limited graded exercise test (GXT) using standardized treadmill protocols (Bangsbo, Michalsik, & Petersen, 1993; Berg et al., 1985; Binkhorst, Saris, Noordeloos, van't Hof, & de Haan, 1986; Thomas & Reilly, 1979). The Bruce protocol is widely used to assess cardiovascular response of individuals ranging in age from 4 through adulthood (Binkhorst et al., 1986; Bruce, Kusumi, & Hosmer, 1973; Cumming, Everatt, & Hastman, 1978; Cumming & Hnatiuk, 1980; Cyran, Grzeszczak, Haas, & Baylen, 1993). Reliability and validity coefficients for the Bruce protocol have been firmly established across a wide array of populations (Bruce et al., 1973).

Anaerobic Power/Capacity

Along with aerobic conditioning, anaerobic capacity/power are also critical components for successful soccer performance. Soccer players have been documented sprinting 15 meters every 90 seconds, and performing some level of high intensity work once every 30 seconds (Reilly & Thomas, 1976). Other studies have indicated that soccer involves high intensity, intermittent work loads requiring both anaerobic capacity and power (Bowers & Fox, 1988; Maud & Shultz, 1984; Reilly & Borrie, 1992).

Several methods have been employed to evaluate the anaerobic capacity of athletes involved in sports such as baseball (Hagerman et al., 1989), rodeo (Meyers, Wilkinson, Elledge, Tolson, Sterling, & Coast, 1992), and soccer (Davis et al., 1992; Rhodes et al., 1986). These methods include blood analysis quantifying lactate concentration, indirect calorimetry to determine anaerobic threshold (as a percent of VO_{2max}), and ergometry tests that measure peak/mean power, and total work output (Bangsbo et al., 1993; Bangsbo et al., 1991; Chin et al., 1992; Malomsoki et al., 1990; Rhodes et al., 1986). Studies have documented mean lactate values of $4.4 \text{ mmol} \cdot \text{l}^{-1}$

following competitive matches, $7.8 \text{ mmol}\cdot\text{l}^{-1}$ after interval field tests, and peak lactate values of $12.9 \text{ mmol}\cdot\text{l}^{-1}$ following exhaustive treadmill running in professional soccer athletes (Bangsbo & Lindquist, 1992; Bangsbo et al., 1993; Bangsbo et al., 1991). Other studies have revealed anaerobic threshold values ranging from 80.5% to 88% of $\text{VO}_{2\text{max}}$ (Bunc, Heller, Leso, Sprynarova, & Zdanowicz, 1987; Chin et al., 1992; Leatt et al., 1987; Rhodes et al., 1986). Another study using the Wingate cycle ergometer test revealed peak power outputs of 14.6 to $14.79 \text{ W}\cdot\text{kg}^{-1}$, a mean power output of $9.72 \text{ W}\cdot\text{kg}^{-1}$, and a mean fatigue index of 38.3% across all positions (Davis et al., 1992).

For noninvasive research, the Wingate test is the most utilized method for quantifying intermediate-term anaerobic performance (Bouchard, Taylor, Simoneau, & Dulac, 1991; Maud & Shultz, 1989). Peak power, mean power, total work output, and a decline in work performance (referred to as fatigue index) are obtained as a subject attempts to pedal on a leg or arm ergometer for 30 seconds with maximal exertion (Bar-Or, 1987). The Wingate is recommended for use in both athletic and general populations ranging in age from 8 through adulthood (Blimkie, Roche, & Bar-Or, 1986; Davis et al., 1992; Grodjinovsky, Inbar, Dotan, & Bar-Or, 1980; Hagerman et al., 1989; Inbar & Bar-Or, 1986; Tharp et al., 1984). Test-retest reliability and validity have been firmly established (Bouchard et al., 1991).

Muscular (Leg) Power

Muscular strength, power, and endurance are also critical components for successful performance during soccer competition. The quick accelerations and changes of direction required of soccer athletes demand immediate and consistent muscular response (Rhodes et al., 1986).

Several techniques have been employed for the assessment of muscular response. These include vertical jump, isokinetic dynamometry, cable tensiometry, and the 1-repetition maximum technique (Clarke, Bailey, & Shay, 1952; Glencross, 1966; Holmes & Alderink, 1984; McArdle et al., 1991; Williford, Kirkpatrick, Scharff-Olson, Blessing, & Wang, 1994). Of these procedures, the vertical jump test is a reliable and frequently used indicator of leg power for both laboratory and field settings (Berg et al., 1985; McArdle et al., 1991; Oberg et al., 1984; Tumilty, 1993). The vertical jump protocol provides immediate feedback to assess explosive muscular power in a sport-specific, weight-bearing manner, typically experienced in competition (Faina, Gallozzi, Lupo, Colli, Sassi, & Marini, 1988).

The vertical jump test was developed in 1921 by D. A. Sargent (Gray, Start, & Glencross, 1962), and is primarily used to quantify explosive response of the hip, knee, and ankle (Kraemer & Newton, 1994). Although a correlation between jump height and power may be made if the length of jump time or a nomogram are used, the majority of soccer studies have not reported this information. Vertical jump values reported for junior to professional soccer athletes have ranged from heights of 41 to 66 cm, limiting extrapolation to actual power (Ekblom, 1986; Green, 1992; Islegen & Akgun, 1988; Kirkendall, 1985; Raven et al., 1976; Reilly & Thomas, 1977; White et al., 1988). In studies examining more than one division or team, however, the more elite teams jumped higher (Kirkendall, 1985; Reilly & Thomas, 1977), indicating that the vertical jump test could be used to differentiate between higher-skilled and lower-skilled athletes.

Fortunately, findings from studies performed on athletes of other sports using the vertical jump test have reported their results in units of power. Values have ranged from 14.3 to 18.0 W·kg⁻¹ in adolescent track athletes (Hollings & Robson, 1991), and high school football placekickers (Meyers, Marley, Duhon, Ingram, & Sterling, 1995). Power

outputs have also been established for national judo, rugby, tennis, and hockey players, as well as cyclists, sprinters, and endurance runners (Maud & Shultz, 1984; Thomas et al., 1989; Vandewalle, Peres, Heller, Panel, & Monod, 1987).

The opportunity to correlate the vertical jump with anaerobic cycle ergometry enhances the opportunity to evaluate anaerobic response with accuracy using multiple sport-specific criteria. With the addition of a force plate or center-of-gravity device with specific equations or standardized nomograms, power can be calculated in lieu of expensive laboratory equipment, i.e., isokinetic dynamometry, with reasonable accuracy.

The Harman (Harman, 1991) and Lewis nomograms (Fox et al., 1989) are two such examples of standardized equations used in conjunction with a vertical jump test. The Lewis formula is an older and more widely known formula commonly used by educators, coaches, and researchers. The Harman nomogram is a more recently developed formula that was developed to adjust for the incorrect estimates observed with the Lewis nomogram. The Lewis formula supposedly represents the power exerted on the body by gravity on its return to the ground, rather than the power produced by the leg muscles in generating force to initiate the jump (Harman, Rosenstein, Frykman, Rosenstein, & Kraemer, 1991). Correlations of the two formulas to values established using a force-platform, however, have shown little difference. Correlation coefficients comparing the Lewis nomogram to peak and average power produced on a force-platform were .83 and .72, respectively, while use of the Harman nomogram resulted in coefficients of .88 and .73, respectively (Harman et al., 1991).

Agility and Sport Skill

The ability to accelerate, to control directional change, and to maintain ball control are mandatory skills an athlete must possess in order to successfully play soccer.

Research conducted on soccer athletes indicates that during a match, players change speed and direction approximately every five seconds (Kirkendall, 1985). Leatt and colleagues (1987) suggested that the demands for sport-specific skill, teamwork, anticipation of an opponent's movements, and agility during a match may be more important than the physiological variables frequently examined in an exercise science laboratory. Leatt's speculation is supported by data from other researchers which indicate that for successful performance in intermittent-activity sports (i.e., basketball, lacrosse, tennis, and volleyball), an athlete must possess agility, as well as the skills specific to that sport (Beise & Peaseley, 1937; dos Remedios, 1993; Gates & Sheffield, 1940; Ghosh et al., 1987; Marey et al., 1991; Plisk & Stenersen, 1992). Studies quantifying the field sense of soccer athletes, however, are limited, making it difficult to determine the accuracy of Leatt's supposition (Raven et al., 1976; White et al., 1988).

Two types of testing programs have been used to evaluate agility and sport skill: 1) agility tests, which require an athlete to perform movements *similar* to those required during competition, and 2) specific skill tests in which an athlete performs the *actual* skills used during competition. Examples of agility tests that closely imitate movements in soccer include the T-test and the line drill test. These tests measure controlled directional change and the capacity to anaerobically perform at maximal levels of play (Semenick, 1990a; Semenick, 1990b). These tests have been employed in other sports training programs such as basketball and lacrosse (dos Remedios, 1993; Plisk & Stenersen, 1992). Due to the recent development of these tests, however, test-retest reliabilities have not been established.

Skills that are highly desirable and fundamental to soccer include ball control, kicking accuracy, and the ability to maneuver oneself around and between opposing players. One technique used to assess ball control is the juggling test, which requires a soccer player to tap a soccer ball in the air as many times as possible within a 30-second period of time (Baumgartner & Jackson, 1987). During the test, any part of the body may be used to keep the ball in the air, with the exception of the arms and hands. This technique has been accepted by the American Professional Soccer League as a viable test of soccer skill in young athletes (Baumgartner & Jackson, 1987).

Kicking accuracy is typically assessed utilizing some form of target (i.e., wall or board) representing the dimensions of a soccer goal. The Johnson wall volley test requires a player to kick a ball from a 15-foot restraining line into a goal-sized target on a wall and then trap the ball on the rebound as many times as possible within a 30-second time period. Validity and reliability coefficients of .85 and .92, respectively, have been established for this test (Collins & Hodges, 1978).

To account for overall soccer ability, the modified-Zelenka test or circuit, has proven to be an excellent test of skill and is purported to imitate the cardiorespiratory demands of a soccer match (Nettleton & Briggs, 1980). Test scores have correlated significantly with coaches' perception of an athlete's field ability, while observed heart rates are similar to those found during a soccer match (Nettleton & Briggs, 1980). The correlation reported between the Zelenka circuit time and the subjective assessment of match performance was reported to be .81 ($p < .01$) (Nettleton & Briggs, 1980) which may indicate the circuit's potential to differentiate between higher and lower skilled athletes.

Flexibility

Flexibility, or joint range of motion (ROM), is vital for prevention of injury and improvement of sport performance (Ekstrand & Gillquist, 1982). Flexibility has become an integral part of the physical profiles of athletes in such sports as baseball (Hagerman et al., 1989), and soccer (Berg et al., 1985; Chin et al., 1992; Ekstrand & Gillquist, 1982; Leatt et al., 1987; Raven et al., 1976).

The results of flexibility studies on soccer athletes are equivocal, with reports indicating either less flexibility than the general population, (Chin et al., 1992; Ekstrand & Gillquist, 1982, 1983; Oberg et al., 1984; Rhödes et al., 1986), or greater ROM than values exhibited by individuals within the same age group (Berg et al., 1985; Leatt et al., 1987; Raven et al., 1976). Studies in which athletes have exhibited limited flexibility have primarily involved adult soccer players, while those in which more flexibility was observed examined mostly young athletes. Thus, ROM differences may be influenced by the age of athletes examined. Since muscular inflexibility has been shown to create a predisposition for injury (Ekstrand & Gillquist, 1983), assessment of flexibility may be critical for minimizing injury potential in young athletes.

Goniometry is an accepted method used for the measurement of joint ROM (American Academy of Orthopaedic Surgeons, 1965; Hubley-Kovey, 1991). Since soccer is a sport which predominately involves the lower extremities, measurements of flexibility generally include the ankle, knee, and hip (Agre & Baxter, 1987; Oberg et al., 1984). Reliability studies have revealed goniometric error to be mainly attributed to intratester variation (Ekstrand, Wiktorsson, Oberg, & Gillquist, 1982; Hellebrandt, Duvall, & Moore, 1949; Low, 1976; Salter, 1955); however, by paying attention to certain specifications (i.e., hard surface for the subject to lie on, stabilization of other joints during movement, and accurate marking of reference points), intratester interassay coefficients of variance

(variation for the same tester during different measuring sessions) of $1.9 \pm 0.7\%$ have been confirmed (Ekstrand et al., 1982).

Summary

In summary, soccer is a sport which encompasses many physiological and sport skill characteristics. Few comprehensive studies have been conducted concerning these attributes. Examined together, these physiological and sport-specific skill factors should provide a more complete understanding of an elite developmental soccer player's capabilities.

Young ODP athletes were selected for this study because of the limited amount of published research concerning youth soccer in the United States. Of the two studies conducted with youth soccer athletes in the United States, limited comprehensive information was provided concerning physiological response and sport-specific skills. In addition, no research has been published addressing characteristics of soccer athletes at the Olympic developmental level of competition.

For the purposes of testing, the youth selected for the study were divided by age group and region. With regard to region, it was hypothesized that exposure to a greater number of games played per season would improve a soccer athlete's physiological status and sport-specific skills. With the number of games played per season ranging from 30 to 100 over a 13 state region, a disparity of experience and skill level might be apparent.

A couple of factors responsible for the disparity of seasonal games played between regions are the natural environment and the availability of competitors. For example, in states such as Montana and Alaska, the weather limits outdoor competition to approximately 4 or 5 months per year. In addition, the sparse population of these

states limits the number of accessible teams within reasonable driving distance. Thus, both the environment and the number of teams available for competition may limit the athletes' playing time, and ultimately, their physical skill development.

The harsher environment in the northern tier of states also influences the number of practices possible, often forcing coaches and athletes to devise alternative forms of training. In states such as California, however, year-round competition and an ample number of soccer athletes exist, providing an unlimited number of games and/or practices and potentiating greater opportunity for skill development. To test this hypothesis, players from the 11 Western and 2 Non-continental states were divided into subregions based on the number of games played per season. Data were also grouped by age to determine maturational effects on physical response.

CHAPTER 3

METHODOLOGY

This study was conducted with athletes participating in the Olympic Development Program camps from 11 Western and 2 Non-continental states comprising Region 4 of the U. S. Youth Soccer organization. The camp participants were divided into 3 groups by their year of birth: 81 or U-14 athletes (12-14 years old), 80 or U-15 athletes (14-15 years old), 79 or U-16 athletes (15-16 years old). For purposes of this study, the ODP athletes were also divided into three subregions depending on the number of games they played per season, ranging from 75-100 for Subregion A, 55-65 games for Subregion B, and 30-45 games in Subregion C. Subregion A (n=18) consisted of Southern California, Northern California, Western Washington, Nevada, Idaho, and Utah. Subregion B (n=20) consisted of Colorado, Arizona, Eastern Washington, New Mexico, Wyoming, Oregon, and Hawaii. Subregion C (n=21) consisted of Alaska and Montana. Subjects were selected from volunteers who had responded to a letter of invitation mailed to each of the 604 participating athletes prior to the start of camp.

Following written informed consent from each subject and his parent/guardian, and clearance from the Montana State University Human Subjects Committee, physiological and sport-specific skill assessments were performed on 59 Olympic Development Program (ODP) soccer athletes. A partial assessment (graded exercise test) was performed on one subject who elected to not complete the full test battery. The values for this subject were included in the study due to the significance of the aerobic data. Following random selection from the soccer players at ODP camp who volunteered

for the study, the subjects accompanied the primary investigator to the Human Performance and Ergonomics Laboratory to become acquainted with testing procedures.

Tests were arranged so as to allow the subjects sufficient rest, considering both the intensity of exercise testing and the primary energy system used (Fox et al., 1989). The order of testing for the study was as follows: Wingate anaerobic test, flexibility measurements, vertical jump test, and maximal graded exercise test (GXT). Hydrostatic weighing, skinfold procedures, and the agility/sport-specific field tests were conducted at predetermined times based on the availability and scheduling of the facilities required to successfully complete the tests.

The time of day in which testing occurred was also addressed. Two aspects of circadian rhythmicity which may affect an athlete's performance are circadian range (time-dependent change in the levels of physiological processes) and circadian amplitude (change from mean level to peak level of the rhythm) (Winget, DeRoshia, & Holley, 1985). Due to these processes, individuals experience optimal performance potential at specific times during the course of a day. In light of these variables, and the fact that everyone could not be tested at their optimal performance potential, individuals from the same group were tested at different periods throughout the day in an effort to balance out potential differences in performance created by the subjects' rhythms (Jehue, Street, & Huizenga, 1992; Winget et. al., 1985).

Since the ODP soccer camp was conducted in Bozeman, MT, at an altitude of 4850 feet (1478 meters), the effects of altitude were also a concern. The decrement of aerobic work capacity is approximately 4 to 6% at altitudes of 1200 to 1500 meters (Balke, Nagle, & Daniels, 1965; Squires & Buskirk, 1982). While results from altitude studies indicate that a 10-day acclimatization period is recommended to elicit aerobic values similar to sea level performance by individuals traveling from sea level to altitudes

of 2100 meters or higher, subjects were only available for testing over a five day period. Also, differences in aerobic performance have not been observed in subjects tested between a two to four day time period at higher altitude (Adams, Bernauer, Dill, & Bomar, 1975; Balke et al., 1965). Thus, because Bozeman's altitude is less than elevations described in acclimatization studies, but still sufficient to influence aerobic response, aerobic testing was conducted no earlier than 48 hours following the arrival of subjects from elevations close to sea level. Subjects arriving from higher elevations were tested prior to lower altitudes competitors.

Due to the extensive travel necessary to participate in the ODP camp, consideration was also made for the effects of jet-lag due to transmeridian travel. Studies conducted on the effects of jet-lag have suggested that three or more time zones must be crossed before individuals experience the effects of jet-lag, such as an offset in internal rhythms (i.e., sleep-wake cycle) influenced by external cues (i.e., light-dark cycle). Such effects may produce symptoms of insomnia, poor mental and psychological task performance, reduced appetite, fatigue, apathy, weakness, and headaches. Jet-lag primarily affects performance on tests involving the aerobic system (Jehue et al., 1992; Winget et al., 1985). It has also been noted that it takes approximately 24 hours per time zone, when traveling eastward, for the body to fully adapt to the new conditions (Jehue et al., 1992; Loat & Rhodes, 1989). Thus, athletes arriving at ODP camp from three or more time zones away were not tested aerobically until 4 days after arrival to allow for resynchronization of the circadian rhythm (Jehue et al., 1992; Winget et al., 1985).

Criteria for exclusion from the study involved the acknowledgement, complaint, or observed evidence of any medical or orthopaedic problem severe enough to disrupt an athlete's performance or endanger his health. These problems were determined by the parents, athletes, and primary investigator. The parents and athletes were asked to

report any previously existing condition of which they were aware, and the primary investigator (a certified athletic trainer) conducted a pre-participation health screening and injury-specific evaluation tests. Subjects were allowed to participate in the study following parental consent and the athlete's consent to the testing instructions.

Upon selection for the study, each individual was instructed to abstain from large meals, any drinks containing caffeine, as well as any physical activity beyond that required by camp, prior to testing. For meals other than those affected by testing, subjects were asked to maintain a high carbohydrate diet to aid the body in the replacement and maintenance of muscle glycogen. Subjects were also instructed to get a good night's sleep prior to testing and to wear soccer clothes, with running shoes for the laboratory tests and soccer cleates for the field tests.

Anthropometric Status

Body composition was determined utilizing both hydrostatic weighing technique and skinfold procedures (Katch, Michael, & Horvath, 1967; Jackson & Pollock, 1977). All anthropometric testing was conducted in the Marga Hoseaus Physical Education Complex pool area at Montana State University.

Skinfold measurements were conducted using the seven site technique (Jackson & Pollock, 1977) using calibrated Lange calipers (Cambridge Scientific Industries, Inc., Cambridge, MD). Each site was measured according to standard anatomical landmarks, which were marked with a pen to insure accuracy of instrument placement. In accordance with standard procedures, three measurements were obtained at each site on the right side of the body, with the mean value from each site added together for the sum total (Jackson & Pollock, 1977). The formula used with skinfold values for the calculation of body density (D_b) was as follows (Jackson & Pollock, 1978):

$$D_b = 1.112 - 0.00043499 [\text{sum of seven sites}] + 0.00000055 [\text{sum of seven sites}^2] - 0.00028826 [\text{age}]$$

Where: 1.112 = standardized regression coefficient to account for variance of body circumference

0.00043499 = standardized regression coefficient to account for variance of sum of skinfolds

0.00000055 = standardized regression coefficient to account for variance of sum of skinfolds squared

0.00028826 = standardized regression coefficient to account for variance of age

To conduct the hydrostatic weighing, the subject stepped down into the pool, thoroughly soaked his hair and swim suit, and briefly submerged underwater to eliminate air bubbles. When the subject reemerged, he was then instructed to sit on a seat attached to a Chatillon model 114508 scale (John Chatillon and Sons, Inc., Kew Gardens, NY). Upon command, the subject flexed at the hip while seated, submerged himself underwater, and attempted to exhale completely in a controlled manner. The subject temporarily remained still underwater at full expiration to ensure settling of the scale for an accurate reading of his weight in water, measured in kilograms. Five to ten trials were performed, with the highest value (obtained at least twice) used as the subject's "true" underwater weight (Katch et al., 1967).

To determine body density (D_b) from standardized equations used in hydrostatic weighing, residual volume (RV) for each subject was calculated from their vital capacity (VC) measurements collected with a Vacumed model 16800 Zebra spirometer and computer software (Vacumetrics Inc., Ventura, CA) by standard spirometric techniques (Wilmore, 1969; McArdle et al., 1991). The subject wore a nose clip and performed a maximal inspiration followed by a maximal forced expiration into the spirometer. The formula used to calculate residual volume was as follows:

$$\text{Residual Volume (L)} = \text{VC (L)} \times .24 \times \text{BTPS conversion factor}$$

Where: VC (L) = vital capacity in liters
 .24 = constant used to control for anatomical dead space
 BTPS conversion factor = value for conversion from ATPS to BTPS using room temperature

Body density (D_b), percent body fat (BF), and lean body mass (LBM) in kilograms were then calculated according to accepted procedures using the hydrostatic weighing data (Brozek, Grande, Anderson, & Keys, 1963; Goldman & Buskirk, 1961):

$$D_b = \frac{\text{weight of subject in air (kg)}}{\frac{\text{weight in air (kg)} - \text{weight in water (kg)} - [\text{residual volume} + .01\text{L}]}{\text{density of water}}}$$

$$\text{Body Fat \%} = (457/D_b) - 4.142 \times 100$$

$$\text{Lean Body Mass (kg)} = (100 - \%BF) \times \text{body weight (kg)}$$

Where: weight in air (kg) = weight of the subject in air
 weight in water (kg) = weight of the subject in water
 .01 = constant value used to control for air remaining in intestinal tract
 457 = constant value used for "obesity tissue"
 4.142 = constant value used for "fat-free mass"

Aerobic Power

Aerobic power was determined by having a subject complete a maximal GXT using the Bruce treadmill protocol (Bruce et al., 1973). Prior to testing, the subject's age was recorded, and height (cm) and weight (kg) were determined using a Detecto model 437S (Detecto, Webb City, MO) calibrated scale. Room temperature, barometric pressure, and relative humidity were recorded for subsequent ventilatory and metabolic

calculations. These values ranged between 22-25°C, 638-650 mm Hg, and 37-56%, respectively.

A pretest was performed to prepare each subject for the GXT. For optimal conductivity, each subject's chest was shaved if necessary and then debrided with gauze and alcohol. Following electrode placement and ECG lead attachment in accordance with the Mason-Likar modified 12-lead protocol for stress testing (American College of Sports Medicine, 1991), supine, hyperventilation, and standing ECG readings were recorded on a Marquette Max-1, 12-lead electrocardiograph (ECG) (Marquette Electronics, Milwaukee, WI). Concomitant blood pressure measurements were also obtained in the supine and standing position. The subject was cleared for testing if cardiorespiratory response did not indicate any contraindications to exercise according to the ACSM guidelines for stress testing (American College of Sports Medicine, 1991).

The subject began the GXT with a one minute warm-up at 0% grade and 1.7 mph on a SensorMedics^R Series 1900 treadmill (SensorMedics Corporation, Yorba Linda, CA) and progressed through subsequent stages of exercise until he reached fatigue (or until he stopped the test by grabbing the front rail of the treadmill). ECG recordings, ratings of perceived exertion (RPE), and blood pressures were taken during the last 30 seconds of each stage during the exercise test and throughout each minute of recovery.

Ventilatory and metabolic expiratory values, i.e., aerobic power (VO_{2max}), ventilation (VE_{max}), and respiratory exchange ratio (RER), were determined breath by breath during exercise and throughout recovery with a calibrated SensorMedics^R 2900 metabolic measurement cart (SensorMedics Corporation, Yorba Linda, CA). The cart was autocalibrated using gases of known concentrations. V-slope method was used to determine the subject's anaerobic threshold (Beaver, Wasserman, & Whipp, 1986). This method notes the beginning of that intensity of work load or oxygen consumption in which

anaerobic metabolism is accelerated (Fox et al., 1989). The subject's maximal time (Time_{max}) on the treadmill was also recorded.

Anaerobic Power and Capacity

Anaerobic power and capacity were determined by having each subject perform a 30-second Wingate anaerobic test using a calibrated Monark^R 818E cycle ergometer (Monark AB, Varberg, Sweden) with integrated laser-based sensor and computer software (Sports Medicine Industries, Inc., St. Cloud, MN). Prior to test initiation, seat height was adjusted for the subject to ensure proper knee positioning at approximately 15° of knee flexion with the foot at the bottom of the pedal revolution and parallel to the floor. A warm-up consisted of 6 minutes of 30-second progressive workloads (i.e., 25%, 50%, 75% of test resistance), alternated with 30-second intervals of recovery (pedaling at 300 kpm/min or 1 kp). According to procedures described by Bar-Or (1987), the test resistance was calculated by multiplying the subject's body weight (kg) by .075 kp. At the initiation of each test, the investigator quickly increased the resistance to the calculated workload and simultaneously gave the cue for the subject to pedal with maximal exertion (Bouchard et al., 1991; Tharp, Newhouse, Uffelman, Thorland, & Johnson, 1985). Throughout the test, the investigator gave strong verbal encouragement. At the completion of the 30-second test, recovery was attained by having the subject continue to pedal at approximately 1 kp for 4 minutes, or until the individual was sufficiently cooled-down.

Variables included in the calculation of power output and rate of decline were the subject's performance and weight, the resistance added to the flywheel, the length of the test, and the circumference of the wheel. An electronic sensor counted the number of flywheel revolutions achieved during the test. Mean power (MP), peak power (PP), total

work output (TWO), and fatigue index (FI) were calculated according to accepted procedures (Ayalon, Inbar, & Bar-Or, 1974; Bar-Or, Dotan, & Inbar, 1977):

$$MP = \frac{\text{revs} \times \text{circum (6m)} \times \text{resistance (kg)} \times 2}{\text{body weight (kg)}} = \text{kgm} \cdot \text{min}^{-1} \cdot \text{kg}^{-1}$$

$$PP = \frac{\text{revs} \times \text{circum. (6m)} \times \text{resistance (kg)} \times 12}{\text{body weight (kg)}} = \text{kgm} \cdot \text{min}^{-1} \cdot \text{kg}^{-1}$$

These numbers were then converted to watts/kg as follows:

$$W \cdot \text{kg}^{-1} = \text{---} \text{ kgm} \cdot \text{min}^{-1} \cdot \text{kg}^{-1} \times \frac{1 \text{ watt}}{6.12 \text{ kgm} \cdot \text{min}^{-1}}$$

Where:	revs	=	# of revolutions of the wheel during the test
	circum (6m)	=	circumference of the wheel
	resistance (kg)	=	weight added to the flywheel as determined by the subject's weight
	2	=	constant which converts values based on a 30 second interval to one minute
	12	=	constant which converts values based on a 5 second interval to one minute
	6.12	=	regression number which allows for conversion from $\text{kgm} \cdot \text{min}^{-1}$ to watts

Total work output and fatigue index were calculated as follows:

$$TWO = \text{---} \text{ kgm/min/kg} \times \frac{1 \text{ watt}}{6.12 \text{ kgm} \cdot \text{min}^{-1} \cdot \text{kg}^{-1}} \times \frac{.06 \text{ kJ}}{1 \text{ watt}} \times \frac{1000\text{J}}{1 \text{ kJ}} = \text{---} \text{ J/kg}$$

$$FI \% = \frac{(\text{peak power} - \text{lowest power in 5 seconds})}{\text{peak power}} \times 100$$

Muscular (Leg) Power

Leg power was determined by having each subject perform a vertical jump test which included both squat and countermovement techniques. The squat jump consisted of a static hold of the body prior to take-off with the knees flexed to 90°, and the countermovement jump consisted of a dynamic knee bend to 90° of flexion from a

standing position just prior to jumping (Vandewalle, Peres, & Monod, 1987). The subject performed two practice jumps prior to testing to ensure proper jumping technique.

Prior to testing, the subject's standing height was marked on the wall. To accomplish this, the subject stood with his heels flat on the floor and his shoulders perpendicular to the wall. He then reached as high as possible with the wall-side hand to make a chalk mark on the wall. The subject then performed three trials of both jumps, each time placing chalk on his fingertips and making a mark on the wall at the height of each jump. He kept the hand used to mark the jump extended straight overhead, and the opposite hand placed in the small of the back. This was to ensure the use of muscles limited to the lower extremities (Johnson & Nelson, 1986). Jump height was determined using a measuring tape adhered to dark paper on which the subject's chalk prints were clearly evident. Power was calculated using both the Lewis (Semenick, 1984) and Harman (Harman, 1991) standardized regression equations:

$$\text{Power (Lewis)} = (4) \times (Wt) \times (\sqrt{Ht}) = \text{_____ ft-lbs/sec}$$

$$\text{Power (Harman)} = (61.9 \times Ht) + (36.0 \times Wt) - 1,822 = \text{_____ watts}$$

Where:	4	= value used for estimation of speed in jump performance
	$\sqrt{Ht}$	= square root of height in feet
	1.355	= regression number which allows for conversion from ft-lbs/sec to watts
	61.9	= regression coefficient for the variance in jump height due to gravity's effect on body mass
	Ht	= height of the jump in centimeters
	36.0	= regression coefficient for the variance of total body center of mass
	1,822	= regression coefficient for the variance in vertical ground reaction force
	Wt	= weight of subject in kilograms

The values for both the Lewis (Semenick, 1984) and Harman (Harman, 1991) nomograms were converted to W/kg for reporting and comparative purposes:

$$W/kg \text{ (Lewis)} = \frac{\text{ft-lbs/sec} \times 1.355}{Wt \text{ (kg)}}$$

$$W/kg \text{ (Harman)} = \frac{\text{watts}}{Wt \text{ (kg)}}$$

Agility

Agility was determined by having each subject complete a T-test (Semenick, 1990b) and a line drill test (Semenick, 1990a). The T-test, as shown in Figure 1, was conducted on a grass practice field using four cones, a stopwatch, and a recorder. The cones formed the shape of a T with the top three cones 5.45 meters apart, and the fourth cone (forming the base of the T) exactly 10.9 meters perpendicular to the center cone.

The test consisted of 5 minutes of warm-up and stretching of the subject's choosing, followed by one trial run and three timed runs. Upon starting, the subject ran from the base cone (A) to the center cone (B), shuffled left 5.45 meters to cone C, shuffled right 10.9 meters to cone D, shuffled left 5.45 meters back to cone B, and then backpedaled 10.9 meters to the start/finish line (cone A). The time of all three trials were recorded with the best time used for data analysis.

The line drill test, as shown in Figure 2, was conducted on a practice field using five cones and a timer with a stopwatch. The first cone (A) indicated the start/finish line, and the other four cones were placed in a straight line exactly 5.79 meters (cone B), 12.80 meters (cone C), 19.81 meters (cone D), and 25.60 meters (cone E), respectively, from the starting line. The subject performed four trials, running straight from the starting line to the second cone (B) and back, then to the third cone (C), fourth (D), and fifth (E) cones in a shuttle fashion, touching the line or respective cone with one hand each time. The course was completed by running back to the finish line from the fifth cone where a

tester stopped the time. The time was recorded for each trial with the average time of the four trials used for data analysis.

Figure 1. T-test

Adapted from Semenick, D. (1990b). The T-test. National Strength and Conditioning Association Journal, 12(1), 36-37.

Figure 2. Line Drill Test

Adapted from Semenick, D. (1990a). The line drill test. National Strength and Conditioning Association Journal, 12(2), 47-49.

Sport Skill

Sport skills specific to soccer were assessed using three procedures conducted on a grass practice field. The procedures used were the juggling test, to determine ball control (Baumgartner & Jackson, 1987), the Johnson wall volley, to assess kicking accuracy and trapping ability (Collins & Hodges, 1978), and the modified-Zelenka test, a circuit drill used to evaluate ball control, shooting ability, and the ability to maneuver oneself around or between defenders (Nettleton & Briggs, 1980).

The juggling test was conducted by having a subject drop a ball to one knee or foot, and then without the use of arms or hands, tap the ball in the air as many times as

possible within a 30-second time period. Any ball that hit the ground during the trial was not counted. Two trials were performed with the best trial recorded.

The Johnson wall volley, as shown in Figure 3, was completed by having a subject kick a soccer ball from behind a 4.57-meter restraining line to a stationary wall as many times as possible within a 30-second time period (Collins & Hodges, 1978). The size of the kicking area marked on the wall was 2.44 x 7.32 meters (8 x 24 feet), representing regulation soccer goal dimensions. Three soccer balls were available during the test, with 1 ball at the restraining line and the 2 extras 4.57 meters behind the restraining line. The subject was allowed to kick the ball from the air or ground, while avoiding the use of arms or hands. A few practice kicks were allowed, followed by three trials, with the sum number of kicks recorded for later analysis.

Figure 3. Johnson Wall Volley

Adapted from Collins, D. R., & Hodges, P. B. (1978). Soccer. In A comprehensive guide to sports skills and measurement (pp. 320-323). Springfield, IL: Charles C. Thomas.

A modified version of the Zelenka test (Nettleton & Briggs, 1980), as shown in Figure 4, was conducted by having each subject complete a circuit of drills incorporating various soccer skills. The subject was allowed one practice run, followed by two test runs

with a two minute recovery period between tests. The circuit consisted of a (1) power agility run (both with and without a soccer ball), (2) a sharp directional change, (3) jumping over and crawling under a hurdle, (4) dribbling a ball around a set of cones, and (5) kicking the ball 25 meters into a target 2 meters wide. Mean time of the two circuit trials as well as passing accuracy (judged by the ball passing through the target) were recorded (Nettleton & Briggs, 1980).

Figure 4. Modified-Zelenka Test

Adapted from Nettleton, B., & Briggs, C. A. (1980). The development of specific function tests as a measure of performance. *Journal of Sports Medicine and Physical Fitness*, 20, 47-54.

Flexibility

Joint ranges of motion (ROM) of the trunk, spine, hip, knee, and ankle were determined by goniometric technique, according to standard criteria (American Academy of Orthopaedic Surgeons, 1965). To ensure the greatest accuracy possible and reduce intratrester error, bony landmarks for each joint measurement were marked. Also, a firm surface was used in place of a cushioned surface to prevent undesired joint movement typically attributed to cushioning during measurement.

Trunk and spine measurements included trunk rotation, spine flexion and extension, and spine lateral flexion. The measurements of the hip involved flexion and extension, internal and external rotation in flexion, abduction and adduction, and abduction in flexion. Knee and ankle measurements included knee flexion and extension, and ankle dorsiflexion and plantarflexion. Three measurements for each joint ROM were obtained from each subject, and the highest value was recorded (Berg et al., 1985).

Statistical Analyses

A pilot study using eight individuals was initially conducted to determine test-retest reliability for identification of possible physiological response distortion. Data were analyzed using the General Linear Model (GLM) Procedure of SAS^R Proprietary Software Version 6.08 (SAS Institute, Carey, NC) running on a VAX/VMS platform. Intraclass correlation (R), which uses ANOVA to obtain the reliability coefficient, was the method chosen for the calculation of R values, since this method allows the tester to examine test performance from trial to trial (Thomas & Nelson, 1990).

Data collected were grouped by age and subregion. Data screening revealed no violations of assumptions related to sample size, bivariate linearity, multivariate normality and outliers, multicollinearity, singularity, or size of the correlations (Tabachnick & Fidell, 1989). Due to the large number of dependent variables required for this study in relation to the number of subjects, principal components factor analytical procedures (PCA) with subsequent varimax rotation were initially used for reduction of dependent variables and to identify strength of association among the aerobic, anaerobic, body composition, leg power, and field agility variables (Tabachnick & Fidell, 1989). Following the initial PCA, the correlation matrix revealed that 70% of the data were contained in four factors having eigen values > 1.0 (Tabachnick & Fidell, 1989). Only those variables with factor loadings

of .45 or greater (Tabachnick & Fidell, 1989) were retained for further analysis. Additional ANOVAs were performed at an alpha of .05 on three specific variables (HT, WT, Time_{max}) which were not included in the original analysis, but were later added due to their common inclusion in physiological studies of this type. Multivariate analysis of variance (MANOVA) using Wilks' Lambda criterion was performed on the 11 dependent variables that loaded sufficiently at each step in the PCA, i.e., LBM, FI, VE, TWO, PP VJS, VJC, WV, TT, BF, and TT. Least squared means were used due to unequal cell size in variables upon which comparisons were made. Univariate F s and Tukey's HSD post-hoc analyses were used to make specific comparisons when significant main effects were observed. Significance was determined at the .05 level of confidence. All data were reported as mean $\pm$ standard error of the mean (SEM).

Flexibility variables were not subjected to any statistical analysis because of inconsistent test-retest intertester and intratester reliabilities. Data are shown, however, for descriptive purposes only.

CHAPTER 4

RESULTS

Age

For descriptive purposes and comparison with traditional athletes, all data are presented by age group and subregion. Using Wilks' Lambda criterion, significant main effects were found ($E_{20,94}=4.2615; p = 0.0001$) across age groups.

Mean anthropometric and body composition of ODP soccer athletes by age group are shown in Table 1. Overall, results indicated the older athletes exhibited greater

Table 1. Mean Anthropometric and Body Composition By Age Group

Variable	Age Group ^a		
	81	80	79
Subjects (n)	20	19	20
Age (yr)	13.3±0.1	14.6±0.1	15.7±0.1
Height (cm)	163.9±0.4 ^f	176.1±0.3 ^g	177.1±0.3 ^g
Weight (kg)	49.9±0.4 ^{e,f}	62.8±0.3 ^{d,g}	68.6±0.4 ^{e,g}
Body density (kg·l ⁻¹)	1.1±0.0	1.1±0.1	1.1±0.1
Body fat (%)	7.8±0.3 ^b	7.7±0.5 ^b	9.0±0.4 ^c
Lean body mass (kg)	46.0±1.8 ^{b,f}	57.8±1.3 ^{b,g}	65.6±1.7 ^{c,g}

^a Mean±SEM

^{bc} $p < 0.05$

^{de} $p < 0.03$

^{fg} $p < 0.0001$

height, weight, percent body fat, and lean body mass than younger competitors. Athletes from the 79 and 80 groups were significantly taller and heavier ($p < 0.0001$) than the 81 players, and further, there was a significant difference in weight ($p < 0.03$) between the 79

and 80 athletes. Results also indicated 79 and 80 players both exhibiting significantly greater lean body mass ($p < 0.0001$) than 81 players, with the 79 athletes exhibiting significantly greater percent BF ($p < 0.05$) than the 80s and 81s, as well as greater LBM ($p < 0.05$) than the athletes in the 80 group.

Mean physiological responses of ODP soccer athletes are summarized by age group in Table 2. The older players exhibited a significant improvement in $\text{Time}_{\max}$ ($p < 0.004$) and $\text{VE}_{\max}$ ($p < 0.0001$) when compared with the younger athletes, with no significant differences ($p > 0.05$) observed in $\text{VO}_{2\max}$, $\text{HR}_{\max}$, $\text{AT}_{\max}$, or $\text{R}_{\max}$. Overall, these developmental soccer athletes exhibited similar aerobic responses across age groups.

Table 2. Mean Physiological Responses By Age Group

Variable	Age Group ^a		
	81	80	79
Subjects (n)	20	19	21
$\text{VO}_{2\max}$ ($\text{ml} \cdot \text{kg} \cdot \text{min}^{-1}$)	52.9 $\pm$ 1.2	54.5 $\pm$ 1.3	56.2 $\pm$ 1.5
$\text{HR}_{\max}$ (bpm)	192.4 $\pm$ 1.7	196.4 $\pm$ 1.7	195.0 $\pm$ 1.3
$\text{Time}_{\max}$ (min:sec)	14:06 $\pm$ 18 ^{d,f}	15:30 $\pm$ 18 ^e	16:06 $\pm$ 24 ^{e,g}
$\text{VE}_{\max}$ ($\text{l} \cdot \text{min}^{-1}$)	109.5 $\pm$ 5.4 ^{c,f}	138.9 $\pm$ 4.4 ^{b,g}	154.1 $\pm$ 4.5 ^{c,g}
$\text{R}_{\max}$	1.1 $\pm$ 0.0	1.2 $\pm$ 0.1	1.2 $\pm$ 0.0
$\text{AT}_{\max}$ (% VO_2)	65.9 $\pm$ 1.4	63.5 $\pm$ 2.5	61.2 $\pm$ 1.3
BP (mmHg)			
Rest systolic	108.8 $\pm$ 2.1	116.6 $\pm$ 2.0	111.3 $\pm$ 1.3
Rest diastolic	60.0 $\pm$ 2.7	60.4 $\pm$ 2.6	56.4 $\pm$ 1.7
Max systolic	168.6 $\pm$ 4.3	168.0 $\pm$ 3.9	166.7 $\pm$ 2.8
Max diastolic	71.0 $\pm$ 2.7	56.3 $\pm$ 1.9	52.0 $\pm$ 1.6

^a Mean $\pm$ SEM

^{bc} $p < 0.01$

^{de} $p < 0.005$

^{fg} $p < 0.0001$

Mean anaerobic responses of ODP soccer athletes by age group are shown in Table 3. Overall, there was a tendency for anaerobic power and capacity to increase with age. Players from the 80 and 79 groups exhibited significantly greater peak power

($p < 0.03$ and $p < 0.0003$, respectively) and fatigue ($p < 0.0008$ and $p < 0.005$, respectively) than 81 athletes. The 79 athletes also exhibited significantly greater total work output values than both the 80s ($p < 0.05$) and 81s ($p < 0.009$). There were no significant differences ($p > 0.05$) observed in mean power between the older and younger athletes, but values did increase slightly across age groups.

Results of the vertical jump tests indicated an overall tendency for power output to increase across age groups in both the squat and countermovement jumps. The 79 ($p < 0.0002$) and 80 ($p < 0.005$) athletes exhibited significantly greater power outputs in the countermovement jump when compared to the 81 group.

Table 3. Mean Anaerobic Response By Age Group

Variable	Age Group ^a		
	81	80	79
Subjects (n)	20	19	20
Peak power ($W \cdot kg^{-1}$)	$9.3 \pm 0.2^{b,j}$	10.0 ± 0.3^c	$10.5 \pm 0.2^{c,k}$
Mean power ($W \cdot kg^{-1}$)	8.0 ± 0.2	8.1 ± 0.2	8.7 ± 0.2
Total work output ($J \cdot kg^{-1}$)	$238.8 \pm 5.5^{b,d}$	243.8 ± 5.6^b	$259.7 \pm 5.2^{c,e}$
Fatigue index (%)	$27.1 \pm 1.9^{f,h}$	$36.8 \pm 1.9^{g,i}$	35.0 ± 1.9^g
Vertical squat jump ($W \cdot kg^{-1}$)	12.8 ± 0.4	13.5 ± 0.3	13.7 ± 0.3
Vertical countermove jump ($W \cdot kg^{-1}$)	$13.5 \pm 0.3^{f,h}$	14.6 ± 0.2^g	$15.0 \pm 0.3^{g,i}$

^a Mean $\pm$ SEM

^{bc} $p < 0.05$

^{de} $p < 0.01$

^{fg} $p < 0.005$

^{hi} $p < 0.002$

^{jk} $p < 0.0003$

Mean agility and sport skill response of ODP soccer athletes by age group are shown in Table 4. The 80 athletes exhibited significantly greater ($p < 0.003$) speed and agility during the T-test drill than both the 81 and 79 athletes, as well as greater ball control ($p < 0.02$) in the juggling test than the 81 athletes. In the Johnson wall volley test,

Table 4. Mean Agility and Sport Skill Response By Age Group

Variable	Age Group ^a		
	81	80	79
Subjects (n)	20	19	20
T-test (sec)	11.6±0.1 ^{g,i}	11.0±0.2 ^{f,h}	11.7±0.1 ^g
Line drill test (sec)	33.7±0.4	32.5±0.9	31.7±0.8
Juggling test (# of taps)	45.3±3.0 ^b	53.7±2.7 ^c	49.3±1.5
Wall volley (# of hits)	35.5±1.4 ^{d,h}	36.7±1.2 ^d	41.8±1.2 ^{e,i}
Modified-Zelenka Time (sec)	51.6±1.0	50.0±1.1	48.4±1.0
Modified-Zelenka Accuracy (# of misses)	3.7±0.1	3.4±0.2	3.5±0.2

^a Mean±SEM^{bc} $p < 0.02$ ^{de} $p < 0.008$ ^{fg} $p < 0.003$ ^{hi} $p < 0.002$

the athletes in the 79 group performed significantly more hits than the 80 ($p < 0.008$) and 81 ($p < 0.002$) athletes. No significant differences ($p > .05$) were observed between age groups in the line drill test (controlled directional change), or the modified-Zelenka circuit (ball control, shooting accuracy, and the ability to maneuver around or between defenders). Although nonsignificant ($p > .05$), the older athletes exhibited improved time and ball control when compared to the younger competitors.

Mean trunk and spine flexibility of ODP soccer athletes by age group are shown in Table 5. Overall, values were similar across age groups. Results in this study fall within normative ranges published for the general population by the American Association of Orthopaedic Surgeons (1965).

Mean hip flexibility values, as shown in Table 6, were also similar across age groups. Values for hip ROM were within normal limits, with the exception of internal and external rotation of the hip, which were 15° to 20° below accepted norms (AAOS, 1965). Symmetry, however, was observed between left and right sides across all age groups.

Table 5. Trunk and Spine Flexibility By Age Group

Variable	Age Group ^a		
	81	80	79
Subjects (n)	20	19	20
Trunk (deg)			
Right rotation	50.6±2.6	50.7±2.0	53.4±1.7
Left rotation	48.2±2.0	51.2±2.5	55.7±2.1
Spine (cm)			
Flexion	8.0±0.4	9.0±0.4	7.2±0.2
Extension	5.5±0.2	5.7±0.3	5.5±0.4
Right lateral flexion	1.1±0.1	1.4±0.3	1.0±0.1
Left lateral flexion	0.9±0.1	1.1±0.2	1.0±0.1

^a Mean±SEM

Table 6. Hip Flexibility By Age Group

Variable	Age Group ^a		
	81	80	79
Subjects (n)	20	19	20
Hip (deg)			
Right flexion	113.2±1.5	110.0±2.2	108.2±2.2
Left flexion	110.0±2.0	112.0±1.9	112.2±2.2
Right extension	21.0±1.6	23.0±1.2	20.3±0.9
Left extension	21.2±1.6	23.3±1.6	18.9±1.1
Right internal rotation	30.0±1.3	33.6±1.7	29.1±1.1
Left internal rotation	31.9±1.6	32.8±1.4	29.5±1.1
Right external rotation	29.8±1.5	31.3±1.7	24.2±0.9
Left external rotation	29.5±1.8	32.4±1.8	26.1±1.3
Right abduction	34.7±1.1	37.7±1.4	36.9±1.5
Left abduction	39.3±1.1	38.9±1.5	35.2±1.2
Right adduction	16.9±0.7	15.8±1.2	12.9±1.3
Left adduction	17.3±0.7	16.5±1.0	12.9±1.2
Right abduction in flexion	76.6±2.3	68.2±3.0	52.6±2.2
Left abduction in flexion	76.6±2.1	70.2±2.7	50.7±3.0

^a Mean±SEM

Mean knee and ankle flexibility of ODP soccer athletes by age group are shown in Table 7. Similarities were observed between ages across most variables. All lower leg values were within accepted normative ranges (AAOS, 1965) with no asymmetry noted.

Table 7. Knee and Ankle Flexibility By Age Group

Variable	Age Group ^a		
	81	80	79
Subjects (n)	20	19	20
Knee (deg)			
Right flexion	135.0±1.3	130.2±1.4	127.5±1.4
Left flexion	133.7±1.3	129.0±1.8	126.4±2.1
Right extension	179.4±0.5	179.0±0.5	178.1±0.4
Left extension	179.7±0.4	179.5±0.6	178.7±0.4
Ankle (deg)			
Right dorsiflexion	14.0±1.5	13.3±1.6	14.5±1.1
Left dorsiflexion	12.9±1.7	13.0±1.2	13.0±1.1
Right plantarflexion	52.1±2.4	53.5±2.9	52.8±1.3
Left plantarflexion	55.3±1.9	57.7±2.6	52.4±2.3

^a Mean±SEM

Subregion

MANOVA employing Wilks' Lambda criterion indicated no significant differences in any variable across subregions ($E_{20,94}=0.6985$; $p = 0.8184$). Mean anthropometric and body composition data for ODP soccer athletes by region are shown in Table 8. Results indicated no significant differences ($p>0.05$) in any variable across regions, although there was a trend for greater height, weight, and lean body mass in the groups of athletes that played more games per season.

Mean physiological response of ODP soccer athletes by subregion are shown in Table 9. No significant differences ($p>.05$) were noted between subregions for any variable. The athletes which played fewer games per season, however, did exhibit lower $VE_{\max}$ values.

Table 8. Mean Anthropometric and Body Composition By Subregion

Variable	Subregion ^a		
	A	B	C
Subjects (n)	18	20	21
Age (yr)	14.6±0.3	14.5±0.2	14.5±0.3
Height (cm)	174.5±2.3	172.9±1.9	170.0±2.3
Weight (kg)	66.3±3.0	59.2±2.2	56.1±2.4
Body density (kg·l ⁻¹)	1.1±0.0	1.1±0.0	1.1±0.0
Body fat (%)	8.4±0.5	8.3±0.5	7.9±0.4
Lean body mass (kg)	60.5±2.4	54.8±1.9	51.7±2.2

^a Mean±SEM

Table 9. Mean Physiological Responses By Subregion

Variable	Subregion ^a		
	A	B	C
Subjects (n)	18	21	21
VO _{2max} (ml·kg·min ⁻¹)	54.6±1.4	53.6±1.5	55.6±2.1
HR _{max} (bpm)	193.2±1.8	196.4±1.7	194.8±1.3
Time _{max} (min:sec)	15:35±:44	15:28±:36	15:32±:37
VE _{max} (l·min ⁻¹)	141.4±6.3	136.9±5.9	126.0±6.1
R _{max}	1.2±0.0	1.2±0.1	1.2±0.0
AT _{max} (%VO ₂)	63.5±1.8	63.9±2.1	63.2±1.4
BP (mmHg)			
Rest systolic	115.1±1.9	111.9±2.1	109.2±2.2
Rest diastolic	62.2±3.1	60.6±2.0	56.3±2.1
Max systolic	171.9±4.0	157.8±4.0	163.9±2.0
Max diastolic	59.9±3.9	59.3±2.3	59.9±2.9

^a Mean±SEM

Mean anaerobic response by subregion is shown in Table 10. Again, ODP soccer athletes exhibited no significant differences ($p>.05$) between subregions, although PP, FI, and both the VSJ and VCJ responses were lower for the athletes who played fewer games per season.

Table 10. Mean Anaerobic Response By Subregion

Variable	Subregion ^a		
	A	B	C
Subjects (n)	18	20	21
Peak power (W·kg ⁻¹)	10.1±0.3	9.9±0.2	9.7±0.2
Mean power (W·kg ⁻¹)	8.2±0.2	8.3±0.2	8.2±0.2
Total work output (J·kg ⁻¹)	247.2±6.3	248.1±5.5	247.1±5.8
Fatigue index (%)	36.7±2.5	32.5±1.7	30.0±2.0
Vertical squat jump (W·kg ⁻¹)	13.5±0.2	13.3±0.2	13.2±0.4
Vertical countermove jump (W·kg ⁻¹)	14.6±0.2	14.3±0.3	14.2±0.4

^a Mean±SEM

Mean agility and sport skill results are shown in Table 11. No significant differences ($p>.05$) were observed in any variables across subregions. However, the athletes who played a greater number of games per season exhibited improved ball control and shooting accuracy in the juggling test and the Johnson wall volley, respectively.

Table 11. Mean Agility and Sport Skill Response By Subregion

Variable	Subregion ^a		
	A	B	C
Subjects (n)	18	20	21
T-test (sec)	11.4±0.2	11.7±0.2	11.3±0.1
Line drill test (sec)	32.9±0.9	32.0±0.5	33.1±0.7
Juggling test (# of taps)	50.9±2.3	49.0±2.5	48.3±2.9
Wall volley (# of hits)	40.4±1.5	38.1±1.0	35.8±1.6
Modified-Zelenka Time (seconds)	48.5±1.2	47.8±1.2	50.6±0.9
Modified-Zelenka Accuracy (# of misses)	3.7±0.1	3.4±0.2	3.5±0.1

^a Mean±SEM

Mean trunk and spine flexibility values, as shown in Table 12, indicated similar ROM in athletes across subregions for most variables. Trunk and spine flexibilities were comparable to normatives published for the general population (AAOS, 1965). Symmetry was observed between left and right sides across subregions.

Table 12. Trunk and Spine Flexibility By Subregion

Variable	Subregion ^a		
	A	B	C
Subjects (n)	18	20	21
Trunk (deg)			
Right rotation	50.6±1.9	51.2±1.8	52.9±2.6
Left rotation	51.7±2.5	51.1±2.3	52.6±2.3
Spine (cm)			
Flexion	7.7±0.4	8.4±0.4	7.8±0.4
Extension	5.8±0.4	5.6±0.3	5.3±0.3
Right lateral flexion	1.0±0.1	1.3±0.3	1.2±0.1
Left lateral flexion	1.0±0.1	0.8±0.2	1.0±0.1

^a Mean±SEM

The mean hip flexibility data of ODP soccer athletes by subregion are shown in Table 13. Overall, athletes exhibited similar hip ROM, with values within normal limits (AAOS, 1965), and no asymmetry was noted. However, greater hip flexibility was observed in the athletes who played fewer games per season.

Mean knee and ankle flexibility are shown in Table 14. Overall, athletes exhibited similar knee and ankle ROM, with values comparable to those established for the general population (AAOS, 1965). Symmetry was observed between left and right sides across subregions.

Table 13. Hip Flexibility By Subregion

Variable	Subregion ^a		
	A	B	C
Subjects (n)	18	20	21
Hip (deg)			
Right flexion	108.1±1.7	110.8±1.1	112.1±2.7
Left flexion	108.7±2.3	112.3±1.7	113.0±2.1
Right extension	21.8±1.2	21.2±1.1	21.3±1.5
Left extension	20.9±1.5	20.7±1.3	21.5±1.7
Right internal rotation	29.4±1.3	32.6±1.2	30.4±1.6
Left internal rotation	30.6±1.5	32.1±1.1	31.3±1.6
Right external rotation	27.9±1.6	29.2±1.7	28.1±1.4
Left external rotation	29.1±1.7	29.9±1.8	29.8±1.6
Right abduction	34.9±1.3	37.3±1.5	36.8±1.5
Left abduction	39.6±1.3	38.1±1.2	35.9±1.3
Right adduction	14.3±1.0	16.0±1.3	15.2±1.0
Left adduction	14.2±0.9	16.0±1.3	16.3±0.9
Right abduction in flexion	63.2±3.2	68.5±2.9	65.4±3.9
Left abduction in flexion	63.7±3.4	68.1±3.6	65.3±3.8

^a Mean±SEM

Table 14. Knee and Ankle Flexibility By Subregion

Variable	Subregion ^a		
	A	B	C
Subjects (n)	18	20	21
Knee (deg)			
Right flexion	129.1±1.4	130.6±1.7	132.8±1.4
Left flexion	127.3±1.3	129.7±1.6	131.8±2.3
Right extension	178.7±0.6	179.5±0.5	178.3±0.5
Left extension	178.7±0.4	180.1±0.5	179.0±0.5
Ankle (deg)			
Right dorsiflexion	14.8±1.3	11.8±1.4	15.2±1.3
Left dorsiflexion	13.6±1.7	10.4±1.2	14.8±1.1
Right plantarflexion	52.1±2.7	50.8±2.2	55.2±2.4
Left plantarflexion	53.5±2.3	55.8±2.0	55.8±2.6

^a Mean±SEM

CHAPTER 5

DISCUSSION

The purposes of this study were to quantify physiological and sport-specific skill characteristics of Olympic Developmental soccer athletes by age group and region, as well as to compare this sample of athletes to published results observed in other field sport competitors. Several challenges to the study included: tests having to be ordered so as to comply with the camp schedule, the subject's young age, and their overall cooperation. The subjects were continually encouraged to adhere to their testing schedule and to perform at their maximal capability.

Anthropometric Status

As shown by previous research, developmental soccer athletes are comparable to athletes of similar age and ability. Between the older and younger age groups there was an increase in HT, WT, and LBM which correlates with the physical development which occurs during adolescence (Bale, Mayhew, Piper, Ball, & Willman, 1992; Baxter-Jones, Goldstein, & Helms, 1993; Malina, Meleski, & Shoup, 1982). The LBM values reported for U-16 Canadian soccer athletes of 57.9 kg, and 59.5 kg for U-19s from Hong-Kong (Chin et al., 1994; Leatt et al., 1987), correlate with the LBM of the 80 group tested and are lower than the 79s in this study.

ODP soccer teams have both higher and lower LBM than elite youth players from other intermittent-activity sports. When compared to Junior Olympic athletes (Thorland, Johnson, Fagot, Tharp, & Hammer, 1981), the players in the 80 group possessed similar

or greater LBM than middle distance runners, gymnasts, divers, and wrestlers, while athletes in the 79 group had a LBM similar to those exhibited by sprinters, hurdlers, jumpers, and vaulters. The older two groups of ODP athletes exhibited lower values than Dutch national speed skaters (Koning, Bakker, De Groot, & Van Ingen Schenau, 1994) and high school football athletes (Williford et al., 1994). Overall, the older two ODP teams had similar LBM to elite youth athletes from other intermittent-activity sports.

When comparing values of percent body fat, ODP athletes were similar to or slightly leaner than athletes of similar age. Athletes in this group exhibited percent body fat values similar to 13 to 17 year-old swimmers (Malina et al., 1982), and Junior Olympic middle distance runners, sprinters, hurdlers, jumpers, vaulters, gymnasts, and divers (Thorland et al., 1981), as well as professional soccer athletes (Golan, Verbitzky, & Sideman, 1995). Interestingly, ODP players displayed lower percent body fat than wrestlers (Thorland et al., 1981) and high school football athletes (Williford et al., 1994). When compared to junior national athletes in other countries, ODP athletes again possessed lower percent body fat than Dutch speed skaters (Koning et al., 1994), Canadian male judokas (Little, 1991), and Finnish cross-country skiers (Rusko, 1987). These findings indicate that developmental soccer athletes are comparable to other U.S. adolescent athletes (with the exception of football players) as well as professional soccer players. However, the ODP soccer players possess lower values than junior national athletes participating in intermittent and aerobic sports from other countries.

Aerobic Power

Increases in Time_{max} and VE_{max} across age groups are a result of greater physical development of the older athletes. A relationship has been shown to exist between minute ventilation and body size and training, which may be partially explained by an

increase in tidal volume (Bunc et al., 1987; Cumming, 1969; Fox et al., 1989). Neural stimuli are other factors influencing VE_{max} which are also related to body size (Fox et al., 1989; Slonim & Hamilton, 1971). These stimuli originate from messages which occur in higher brain centers, the lungs, muscles, joints, tendons, skin and respiratory passages. Examples of information provided by these stimuli include the amount of stretch of the lungs and the contraction or tension development of muscles and tendons to produce limb movement (Fox et al., 1989). Thus, in a larger individual, there will be an increased number of stimuli due to their greater mass which would require more force to move. Significant differences which were evident in ventilatory values, disappeared when body size was accounted for (Bunc et al., 1987; Cumming, 1969).

Several factors exist which explain the increase in $Time_{max}$ of the two older teams over the youngest team. The primary reason would be increased strength of the older athletes, as evidenced by their greater height, weight, and lean body mass (American College of Sports Medicine, 1993; Bale et al., 1992). The athletes of the 80 and 79 groups exhibited similar $Time_{max}$ values which reflects their similarity in physical maturity and physiological response in this study.

Another possibility is that the older athletes were more willing to work to exhaustion because they may have been more competitive in nature, more knowledgeable about their level of physical tolerance, and thus more willing to push themselves. Greater adaptability to the equipment of the older athletes was another factor. Younger athletes will sometimes perform an unfamiliar task, i.e., running uphill on a treadmill, in a mechanically inefficient way (American College of Sports Medicine, 1993). This inefficiency increases the energy cost of the exercise, causing the athletes to fatigue more quickly, thereby influencing their overall performance.

As has been found previously by some investigators regarding VO_{2max} values in adolescent athletes (Bale et al., 1992; Daniels & Oldridge, 1971; Daniels, Oldridge, Nagle, & White, 1978; Krahenbuhl, Skinner, & Kohrt, 1985), no differences were observed between age groups of the ODP athletes when the values were expressed relative to body mass. Researchers agree that significant changes occur in aerobic power during growth under the influences of training (Bale et al., 1992; Murase, Kobayashi, Kamei, & Matsui, 1981; Sundberg & Elovainio, 1982); however, the amount of change in VO_{2max} values reported for junior male athletes are equivocal. Some report no change in VO_{2max} when it is expressed relative to body mass, and others report a significant change whether VO_{2max} is expressed in absolute or relative values (Bale et al., 1992; Daniels & Oldridge, 1971; Daniels et al., 1978; Krahenbuhl et al., 1985; Murase et al., 1981; Sundberg & Elovainio, 1982). In one study, in which the effects of physical maturity on the relationship between age and physical performance in 13 to 18 year-olds were examined, the results indicated an increase in aerobic power with age. Results also indicated these differences disappeared when VO_{2max} was reported relative to body mass (Bale et al., 1992). Krahenbuhl, Skinner, and Kohrt (1985), in a comprehensive review, concluded from previously reported data that VO_{2max} does increase proportionally to body size and mass in adolescents. Thus, when VO_{2max} was reported in relative rather than absolute terms, no differences were evident.

The VO_{2max} values the ODP athletes exhibited must be adjusted 4-6% higher than their actual performance values due to the altitude at which the tests were performed. When VO_{2max} values in this study are adjusted by 4-6% to offset the effects of altitude, results indicate that ODP athletes exhibited similar to higher VO_{2max} values than intermittent-activity sport athletes, but lower values than endurance athletes. The VO_{2max} values reported for the ODP players were similar to hockey players (Cunningham, 1979),

speed skaters (Koning et al., 1994), gymnasts, swimmers, and tennis players (Baxter-Jones et al., 1993). Aerobic responses from these soccer players were higher than those exhibited by football players (Williford et al., 1994), but lower than those of both junior and adult endurance athletes such as runners (Crielgaard & Pirnay, 1981; Ghosh et al., 1987; Maud & Shultz, 1984; Ready, 1984; Sundberg & Elovainio, 1982; Withers et al., 1977), cross-country skiers (Rusko, 1987), and triathletes (O'Toole & Douglas, 1995).

The comparison of the ODP soccer players' aerobic values to soccer players and national or professional athletes of other intermittent-activity sports proves interesting. Our results indicate that the ODP soccer players had higher VO_{2max} values than those reported for rugby, basketball (Maud & Shultz, 1984) and baseball athletes who exhibited values of 40 to 50 $ml \cdot kg^{-1} \cdot min^{-1}$ (Hagerman et al., 1989). VO_{2max} values were very similar to those reported for both junior and national soccer athletes (Tumilty, 1993), players from the National Hockey League (Cox, Miles, Verde, & Rhodes, 1995), and the Canadian national judo team (Thomas et al., 1989), but were lower than values reported for field hockey athletes from several countries (Reilly & Borrie, 1992).

Anaerobic Power and Capacity

The differences observed across age group in anaerobic power and capacity can be attributed to ongoing muscular development which occurs in adolescence (American College of Sports Medicine, 1993; Bale et al., 1992). These factors do not explain, however, the resemblance of TWO between the 81 and 80 athletes. As previously discussed, the maturational characteristics indicate a significant increase in development of the 80 athletes over the 81s. Unlike anaerobic power, differences in anaerobic capacity cannot be explained solely by body size or lean body mass (Bale et al., 1992; Inbar & Bar-Or, 1986).

Comparisons of the power outputs expressed by ODP athletes in this study to other athletes indicate lower PP and MP values than intermittent-sport competitors, but higher outputs than endurance athletes. ODP athletes exhibited higher PP output than sprinters and marathoners (Crielaard & Pirnay, 1981; Tharp, Johnson, & Thorland, 1984), but power comparable to elite middle distance runners and alpine skiers (Bacharach & Duvillard, 1995; Crielaard & Pirnay, 1981). The ODP soccer players' PP output was lower, however, than junior Dutch national speed skaters (Koning et al., 1994), NHL players (Cox et al., 1995), Canadian judo athletes (Thomas et al., 1989), and the Brazilian 1994 World Cup soccer team (Gomes, Monteiro, Santos, Maciel, & Soares, 1995). Our results also indicate developmental soccer players MP outputs were higher than high school athletes (Nindl et al., 1995), similar to elite U.S. soccer players (Mangine, Noyes, Mullen, & Barber, 1990) and elite alpine skiers (Bacharach & Duvillard, 1995), but lower than Dutch national speed skaters (Koning et al., 1994). Comparison of TWO reveals developmental soccer players had lower power outputs than national judo athletes (Thomas et al., 1989), and the FI of the two older squads was similar to the value reported for elite alpine skiers (Bacharach & Duvillard, 1995), but lower than those of NHL athletes (Cox et al., 1995). Overall, these results and the norms created for the Wingate test by Maud and Shultz (1989) indicate that ODP soccer players' power outputs are considered average.

Muscular (Leg) Power

The increase in explosive power produced by the older athletes over the younger, as observed in the countermovement technique, can be ascribed to the continuing increase in muscular development which occurs in adolescence (American College of Sports Medicine, 1993; Bale et al., 1992). The difference in power produced by the

athletes resembles the findings of the Wingate test, in that the 80 and 79 athletes exhibited greater power than the 81 group in both tests, explained by older athletes greater muscular development.

ODP soccer athletes exhibited similar to lower power outputs when compared to junior and adult athletes of aerobic and intermittent-activity sports. The developmental soccer players expressed similar values to national amateur track and field athletes (Hollings & Robson, 1991), high school football placekickers (Meyers, Marley, Duhon, Ingram, & Sterling, 1995), South Australian national and professional soccer athletes (Cochrane & Pyke, 1976; Green, 1992), and endurance athletes such as runners and road cyclists (Vandewalle et al., 1987). The ODP soccer athletes power outputs were lower, however, than those reported for Canadian national U16 and U18 soccer teams (Leatt et al., 1987), athletes from the North American Soccer League (Raven et al., 1976), rugby (Maud & Shultz, 1984), judo (Thomas et al., 1989), hockey and tennis players, as well as sprinters and track cyclists (Vandewalle et al., 1987). These results indicate the power outputs exhibited by the ODP athletes in the vertical jump test are appropriate to their age and sport.

Agility and Sport Skill

The improved performances observed in the results of the agility and sport-specific skills tests can likely be attributed to the length of time an athlete has played the game, since athletes who have participated longer in soccer would likely possess greater sport-specific skills. The only exception to this explanation are those skills tests which the athletes from the 80 group performed better on than the 79s. The athletes from the 80 group performed better on the T-test and the juggling test, while the 79s performed better on the Johnson wall volley. It is possible that the training of oldest group of

athletes focused more on game-like situations instead of concentrating on the separate pieces.

Results reported for the modified-Zelenka test and Johnson wall volley indicate that ODP soccer players displayed similar or better performances than collegiate soccer athletes. In comparison to values reported for the modified-Zelenka test from collegiate soccer athletes (Nettleton & Briggs, 1980), results indicated that developmental soccer athletes were several seconds faster in their times. The grading scale created by Johnson for the wall volley test (Collins & Hodges, 1978) indicated that the younger two squads of the soccer players ranked in the average category, while the oldest ranked in the good category. Several of these tests, or variations thereof, are frequently used for skill and agility training, but few studies have reported their findings. Thus, further comparison to other athletic populations is restricted.

Flexibility

Flexibility is a crucial component of an athlete's fitness regimen. Inflexibility of tissues surrounding a joint will cause a decrease in joint ROM, and is a causative factors of injuries (Burkett, 1970; Chandler, Kibler, Uhl, Wooten, Kiser, & Stone, 1990; Ekstrand & Gillquist, 1982). As indicated in prior studies, inflexibility is a common problem observed in soccer players (Chin et al., 1992; Green, 1992; Kirkendall, 1985). More than one study has even indicated that soccer training contributes to the decrease in ROM (Moller, Oberg, & Gillquist, 1985) and that an intrinsic aspect of soccer may actually create muscular inflexibility (Chin et al., 1992; Ekstrand & Gillquist, 1982).

The data collected in this study indicated flexibility values were within normal limits, as evidenced by the normatives produced by the American Association of Orthopaedic Surgeons (1965), however, the norms were produced from flexibility values

of primarily working class adults (Clark, 1920). Therefore, one must question whether the flexibility exhibited by the ODP athletes is truly sufficient since they were youths as well as athletes. As has been indicated in prior studies, youths are typically more flexible than adults (American College of Sports Medicine, 1993), and the demands placed on the body of an athlete requires that they have greater flexibility than the average population in order to prevent injury (Chandler et al., 1990; Ekstrand & Gillquist, 1982). Thus, the fact that these athletes were within the normal limits established for the average population could indicate a predisposition for injury.

It seems that neither coaches nor players are aware of the increased risk created by inflexibility, thus little emphasis is placed on the importance of flexibility and stretching. However, flexibility will decrease without stretching, especially during adolescence when there is increased muscular development.

Summary

In summary, this investigation has shown that there are physiological and sport-specific skill differences among young developmental soccer athletes. When compared by age group, significant differences were found in one or more variables associated with anthropometric status, aerobic power, anaerobic power and capacity, leg power, and agility and sport skill. No significant differences were found, however between athletes across subregions. These results pose an interesting question since they seem to indicate that the number of games played per season does not have an effect on the characteristics tested, both in the laboratory and on the field. There are a few possible explanations for this finding. The first is that coaches share and use similar training techniques, resulting in uniformity of training regimens. Coaches from those regions in which the athletes are not able to play as long or as frequently may subsequently use

alternative training/increased number of practices to supplement the lack of actual games played. Athletes from the subregions where there are fewer games may also participate in pick-up games or become involved in other sports to maintain and improve their fitness level and skill.

The findings of this study indicate that ODP soccer players were similar to athletes of traditional field sports in several variables, while exhibiting values slightly below them in a few others. When compared to other intermittent-activity sport competitors, ODP soccer players were similar in anthropometric status, aerobic power, agility and flexibility, but lower in anaerobic power/capacity and leg power. Improvements in anaerobic power, agility, sport skill, and flexibility should be addressed.

Conclusions

Information provided by this study may be useful to high school and club soccer coaches for evaluating physiological and sport-specific skill strengths and/or deficiencies. This information may aid in enhancing the development and subsequent selection of young soccer athletes through improved training and conditioning regimens. It is hoped that these results may also serve as a point of reference for further studies conducted with soccer athletes of this skill level.

With regard to future investigations, one question which should be considered is, "Do those who do well in the laboratory setting, play as well on the field, i.e., during the game?" It is one thing to have adequate physiological conditioning and sport-specific skill when performing tests in a laboratory or around stationary field cones, but does that ability translate to the actual environment of a game situation. Anyone with strong aerobic conditioning could likely do well on a treadmill test, and an athlete with good ball control skills could perform well on a wall volley test. However, to perform these and

other similar skills well in the midst of a field of opponents requires talent and experience. The combination of these characteristics enhances the opportunity to improve an athlete, ultimately resulting in better match play.

There are several investigations which should be considered in continuing this line of inquiry. A study such as this one should be conducted which includes subjects across all U. S. Youth Soccer regions. Other investigation possibilities would be to evaluate ODP athletes of younger and older ages. A standardized group of tests should be created for investigations of this manner which would be conducted to develop a larger database for the purposes of athlete improvement, evaluation, and selection. With the use of a standardized group of tests, result comparison could be more easily made and normatives could be established.

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APPENDICES

APPENDIX A
FORMS USED IN THE PRESENT STUDY

**SUBJECT CONSENT FORM
FOR
PARTICIPATION IN HUMAN RESEARCH
MONTANA STATE UNIVERSITY**

Physiological and Sport Skill Characteristics of U-81- U-79 Soccer Athletes

1. You are being asked to participate in a study to:

- a. Investigate the general physiologic and sport skill characteristics of U-81- U-79 Olympic Development Program soccer athletes
- b. Develop a health status profile to evaluate physiological fitness, and athletic performance potential

The subject for this study is _____. This subject exhibits no known cardiovascular or pulmonary disease, metabolic disorders (i.e., diabetes), or contraindications to exercise.

2. Participant time requirements:

If you agree to participate, the amount of total time that you will be asked to participate should be approximately 2 hours. The tests will be performed in four settings at no cost to you. This will be scheduled either during mornings, afternoons, or evenings.

3. The participant discomforts and risks:

a. Hydrostatic weighing- Each subject's body fat percentage and lean body mass will be determined via hydrostatic (underwater) weighing procedures. The underwater weight will be determined in a weighing tank which requires the subject to sit in a chair in water while they are weighed using an overhead scale. When instructed, the subject will expel all air from their lungs while submerged 5-8 seconds. This procedure will be repeated 5-6 times. Associated risks are less than those encountered in a closely supervised swimming situation. (Time involved: approximately 10 minutes)

b. Skinfold measurements- These measurements will be made via calipers using the seven site protocol. No associated risks accompany this test. However, minor discomfort might be caused by the calipers. (Time involved: approximately 5 minutes)

c. Maximal aerobic power- Expiratory gases will be collected from the subject while walking and/or running on a treadmill. The speed and grade of the treadmill will increase steadily during the test until the subject reaches exhaustion. Cardiac responses will be monitored through an electrocardiograph device (ECG). Where appropriate, the preparatory phase for the ECG will involve removing small amounts of chest hair with a dry-shave razor, where the electrodes will be placed. The surface of the chest will be prepared by roughing the skin with a piece of gauze and alcohol in order to optimize adhesion and conduction of the electrodes. A pre-exercise screening will be given involving resting supine (laying down), hyperventilation (rapidly breathing deeply for 20 seconds), and standing ECGs and blood pressures. The preparation for the ECG may cause slight discomfort in

the areas of electrode placement which may sting slightly, similar to a rug burn, but the discomfort should subside within two days. Some risks/discomforts may be associated with the testing procedure and may include occasional abnormal blood pressure response, syncope (light-headedness), dysrhythmia (disturbance in normal heart rhythm), severe dyspnea (shortness of breath), and in rare instances, heart attack. Every effort will be made to minimize these risks inherent in this procedure through preliminary examination and observations during testing by trained personnel according to the American College of Sports Medicine guidelines for testing procedures. Given the age and fitness level of the subject, the overall procedural risks in this study are minimal. (Time involved: approximately 20-30 minutes)

d. Anaerobic power test- The subject will be asked to perform a 30-second power test on a cycle ergometer with the resistance set according to the subject's body weight. Following a six minute warm-up, the subject will be directed to immediately pedal as fast as possible. Pedal repetitions will be counted and data assessed by computer software, followed by a four minute recovery pedaling without any resistance. Heart response will be monitored via ECG throughout the test. This test involves explosive power which involves the associated discomforts typically encountered during strenuous physical and competitive sports events. Some risks/discomforts which may accompany the testing procedures include muscle soreness or muscle strain, and cardiovascular problems (abnormal blood pressure, syncope, dysrhythmia, dyspnea, and in rare instances, heart attack. In addition, some subjects may display slight weakness or light-headedness (hypoglycemia) post-test; however, the subject will be given a carbohydrate drink (fruit juice) following the test to avoid such an occurrence. (Time involved: 12 minutes)

e. Muscular strength- This test involves three trials of two types of vertical jump (squat and countermovement). The subject will be asked to place chalk dust on his fingertips so as to mark the height of his jump, and will also be asked to hold the position of knee flexion momentarily for standardization of the starting position for the squat jump. Associated risks are minimal since these movements are experienced in competitive sports events; however, tests will be performed in a controlled situation. Given the nature of the subject, and activity prior to testing, the risks are minimal. (Time involved: approx. 20-30 minutes; depends on number of measurements)

e. Agility and sport skill assessment- Each subject will be asked to complete a battery of widely accepted, agility (ability to make a quick change of direction) and sport skill tests. Each of the tests will be completed on a grass practice field. Before the subjects begin the tests, a five minute warm-up and stretching routine will be required. (Time involved: 20-25 minutes) This battery will include:

T-test - Reveals the ability to change directions quickly without losing speed and while maintaining balance.

Line drill test - Reveals the ability to maintain a maximum level of performance throughout the duration of an anaerobic activity.

Juggling test - Evaluates the subject's level of ball sensitivity and control.

Johnson test - Evaluates kicking accuracy and ball control.

Modified Zelenka test - Evaluates fitness and overall skill ability of the athlete.

4. The benefits expected:

All measures obtained from this subject can be used as indices of physiological fitness and athletic performance potential. Results of this study should provide the subject with information related to their physical well-being and sport skill, and may aid the subject in making the decision to enhance activity or sport-specific training.

5. Statement of understanding:

I, _____ (please print), should benefit from this study by receiving information related to my physiological fitness and agility/sport skill ability. I understand that the procedures are those which will offer the minimal amount of risk to me while allowing the collection of significant and relevant data.

If I desire, copies of the consent form and all final results will be made available to me and my parent/guardian(s). I have been offered an answer to any inquiries concerning the procedures prior to signing voluntarily this consent form and I expect that future inquiries will be answered to my satisfaction. I understand there will be no monetary compensation for my participation in this study.

I understand that I am free to withdraw my consent and to discontinue my participation in this study at any time and for any reason. Should I choose to do so, this will be without prejudice and what results were obtained will still be reported to me upon request.

I understand that participation in this study is voluntary and have been assured that steps will be taken to ensure the confidentiality of my individual results which will not be shared with anyone or will not affect my status on any team. The only information available to individuals other than myself will be in average and statistical form. Neither my name nor any other personal descriptor will be associated with publication or presentation of the results of this study.

I have not been requested to waive or release the institution, its agents, or sponsors from liability for the negligence of its agents or employees.

In the event my participation in this research directly results in injury to myself, medical treatment consisting of a comprehensive evaluation of the reported condition will be available, but there is no compensation for such injury available. Further information about this treatment may be obtained by contacting the researcher listed below.

I, the undersigned, have understood the above explanations and give my consent to my voluntary participation in this research project.

If I have additional questions about my rights as a subject or the manner in which this research is conducted I can contact the Department Head, Department of Health and Human Development at 406-994-4001.

Please sign the application form.

Participant Signature: _____ Witness Signature: _____
(must be unrelated to subject)

Parent/Guardian Signature: _____

Date: _____

Please contact the following individual if you have further questions.

Michael C. Meyers, PhD, MS, FACSM
Assistant Professor, Exercise Physiology
Department of Health & Human Development
Montana State University
Bozeman, MT 59717-0336
(406) 994-6324

CONSENT COVER LETTER

**Department of Health
and Human Development**

Marga Hosaeus Health
and Physical Education Complex
MSU • Bozeman
Bozeman, MT 59717-0336
Telephone (406) 994-4001
Fax (406) 994-6314

Date

Dear Parents:

I am pleased to inform you that for the first time, free physiological and sport skill testing will be available as part of a soccer study, during the ODP camp held here in Bozeman, MT. Subjects for the study will be chosen from the participants involved the ODP camp.

I must tell you, regrettably everyone will not be able to participate in the study due to time and funds available. However, each week 21 volunteers will be selected to participate in the study. If you are interested in learning about your son's physical/competitive potential, please fill out and return the enclosed form (i.e. - consent form) to me as soon as possible.

There is one form:

1. Consent form - This form contains information concerning the expectations and procedures of the study.

All information will be treated with the strictest confidence. No one but myself and my instructor, will see this form.

If you have any questions concerning the study, please feel free to call me at the number listed below. Thank you for your time and cooperation in this matter. I look forward to working with your son this summer.

Sincerely,

Lydia Vanderford, ATC
Graduate Student

Ec: consent form

Please mail the completed form to:

Lydia Vanderford, ATC
Montana State University
Department of Health and Human Development
Marga Hoseas Complex
Bozeman, MT 59715
(406) 994-6266 (Office)

SUBJECT INSTRUCTIONS**Instructions for Testing Procedures:**

1. Wear comfortable, cool clothing and running shoes.
2. Do not eat a large meal prior to testing.
3. Do not consume soft drinks containing caffeine or prior to testing.
4. Get a good night's sleep prior to testing.
5. Abstain from any strenuous physical activity prior to testing.
6. Report to location at appointed time.
7. For meals other than those affected by testing, eat plenty of carbohydrates with some fat and protein to aid your body in the refueling process.

PATIENT CHECKLIST

	TEST	COMPLETED	TECHNICIAN
1.	Informed Consent	_____	_____
2.	Medical History	_____	_____
3.	Questionnaire	_____	_____
4.	Height & Weight	_____	_____
5.	ECG Prep	_____	_____
6.	Rest/Hyper/Stand	_____	_____
7.	Strength	_____	_____
8.	Body Comp/VC	_____	_____
9.	Anaerobic: Wingate	_____	_____
10.	Psychological	_____	_____
11.	Flexibility	_____	_____
12.	Vertical Jump	_____	_____
13.	Field Tests	_____	_____
14.	GXT: Bruce	_____	_____
15.	Final Checkout	_____	_____

Mr. Ms. Miss Mrs. Dr.

Sex	M	F
-----	---	---

Address			
Number and Street	City, State	Zip	

Phone () - - SSN - - - - - DOB / / Today's Date / /

Dr. _____ Phone (____) _____

Address _____
Number and Street City, State Zip

Marital Status ☐ Single ☐ Married ☐ Divorced ☐ Widowed ☐ Separated

Education: (Check highest level attained)
☐ Grade School ☐ Jr. High ☐ High School ☐ 2-yr college (or 4-yr not completed)

☐ College Graduate ☐ Postgraduate School

Occupation _____ Employer _____

Employer Address	City, State	Zip	Phone
------------------	-------------	-----	-------

☐ Currently pregnant (if yes: _____ weeks)
☐ Taking oral contraceptives
☐ Menstrual problems (comment below if yes)
☐ Recurrent itching/discharge
☐ Childbirth complication (comment below if yes)
☐ Breast discharge/lumps
☐ Urinary incontinence

No. of pregnancies _____
 No. of children _____
 1st day of last menstruation _____
 Date last pelvic exam _____
 results: _____ nl. _____ abnl.

Comments: _____

List any prescribed *and* any self-prescribed medications and dietary supplements you are taking:

Date of last complete physical examination: _____
results: _____ nl. _____ abnl. (please comment: _____)

Date of last chest x-ray (if ever): _____
results: _____ nl. _____ abnl. (please comment: _____)

Date of last electrocardiogram (if ever): _____
results: _____ nl. _____ abnl. (please comment: _____)

Date of last dental examination: _____
results: _____ nl. _____ abnl. (please comment: _____)

List any other medical or diagnostic tests you have had in the past 5 yrs:

List hospitalizations (include dates and purpose for hospitalization):

List any drug or food allergies:

Please explain the purpose for your visit to this laboratory:

- ☐ To participate in a research study
- ☐ To determine current level of fitness/receive recommendations for an exercise program
- ☐ Other (please explain): _____

Present Health

Check only those conditions that apply to you. Makes comments below if further explanation needed.

- ☐ High blood pressure
- ☐ Low blood pressure
- ☐ Chest pain
- ☐ "Thumping" or "racing" of the heart
- ☐ Heart skips a beat or seems to have extra beats
- ☐ Ankles that tend to swell
- ☐ Hands and feet that are often cold even in warm weather
- ☐ Leg cramps
- ☐ Difficulty breathing
- ☐ Shortness of breath
- ☐ Out of breath while sitting or laying down
- ☐ High cholesterol
- ☐ Chronic or recurrent morning cough
- ☐ One or more episodes of coughing up blood
- ☐ Anxiety or depression
- ☐ Chronic fatigue, difficulty sleeping, and/or increased irritability
- ☐ Migraine or recurrent headaches
- ☐ My joints are swollen, stiff, or painful
- ☐ Leg pain even after walking only a short distance
- ☐ Back pain
- ☐ Men only: Prostate trouble
- ☐ Stomach or intestinal problems (heartburn, ulcers, constipation, diarrhea, etc.)
- ☐ Vision or hearing problems
- ☐ Recent change in a wart or mole

Comments: _____

Please indicate if you've had any history of the following conditions:

☐ Heart attack	
☐ How long ago? _____	
☐ Heart murmur	☐ Injuries to back, arms, legs, joints
☐ Diseases of the arteries	☐ Broken bones
☐ Other heart problems (please comment in space provided)	☐ Jaundice or gallbladder problems
☐ Varicose veins	☐ Kidney or urinary problems
☐ Arthritis in legs or arms	☐ Polio
☐ Diabetes or abnl. blood sugar test	☐ Epilepsy or seizures
☐ Phlebitis	☐ Stroke
☐ Dizziness or fainting spells	☐ Diphtheria
☐ Thyroid problems	☐ Scarlet Fever
☐ Pneumonia	☐ Infectious Mononucleosis
☐ Bronchitis	☐ Anemia
☐ Asthma	☐ Nervous or emotional problems
☐ Abnl. chest x-ray	
☐ Other lung diseases (please comment in in space provided)	

Comments: _____

Family Medical History

Father: _____ Alive → current age: _____ yrs general health: _____ excellent _____ good _____ fair _____ poor
 Deceased → at age: _____ yrs cause of death: _____
 Mother: _____ Alive → current age: _____ yrs general health: _____ excellent _____ good _____ fair _____ poor
 Deceased → at age: _____ yrs cause of death: _____

Siblings: No. of brothers: _____ No. of sisters: _____ Age range: _____
 Health problems: _____

If your parents, siblings, grandparents, aunts, or uncles have had any of the following, please indicate with a check mark and comment below as needed:

☐ Heart attacks under age 50 ☐ Congenital heart disease

☐ Strokes under age 50 ☐ Heart operations

☐ High blood pressure ☐ Glaucoma

☐ Elevated cholesterol ☐ Obesity (20 or more lbs. overweight)

☐ Diabetes ☐ Leukemia or cancer under age 60

☐ Asthma or hay fever

Comments:

Additional Cardiac Risk Factor Assessment

SMOKING

Have you ever smoked (cigarettes, cigars, or a pipe)? yes no (go to WEIGHT section)

Do you currently smoke? yes no

If you do/did smoke, how many per day? _____ cigarettes cigars pipe Age started: _____
(circle one)

If you have quit smoking, when was your last (month/year)? _____

WEIGHT

What do you consider a good weight for yourself? _____ lbs.

What is the most you've ever weighed (indicate if it is pregnancy weight)? _____ lbs. @ age _____

Current weight: _____ lbs.; Weight 1 yr. ago: _____ lbs.; Weight @ age 21: _____ lbs.

NUTRITIONAL INTAKE

The following is a food frequency list. Please indicate the average number of times you consume each food item per week.

_____ Eggs	_____ Beef	_____ Pork	_____ Fowl
_____ Fish	_____ Fried foods	_____ Desserts	_____ Coffee/Tea
_____ Whole milk	_____ Low fat milk	_____ Skim milk	

What is your usual intake of the following alcoholic beverages?

Are you a regular drinker of the following alcoholic beverages?

Beer	☐ none	☐ occasional	☐ often (no. per week: _____)
Wine	☐ none	☐ occasional	☐ often (no. per week: _____)
Hard liquor	☐ none	☐ occasional	☐ often (no. per week: _____)

Has your intake of alcoholic beverages changed recently? _____

EXERCISE

Are you currently involved in a regular exercise program? ____ yes ____ no

Do you regularly walk or run one or more miles continuously? yes no

If yes, average no. of miles you walk/run per workout or day: _____

Average time per mile (if known): _____

Do you lift weights or do calisthenics? yes no

Are you involved in an aerobic exercise program (e.g. an aerobics class)? ☐ yes ☐ no

Have you recently taken any "fitness tests?" yes no

If yes, please describe (include results): _____

Do you frequently participate in competitive sports? ☐ yes ☐ no

If yes, please list (include frequency): _____

Please list any high school or collegiate sports in which you participated: _____

What activities would you prefer in an exercise program for yourself?

Please comment on any other medical conditions:

Thank You!

HYDROSTATIC WEIGHING

Name _____ Date _____
 Age _____ Sex _____
 Weight _____ (lbs) _____ (kg) Height _____ (in)

I. Vital Capacity (VC)*

Trial 1 _____ L
 Trial 2 _____ L
 Trial 3 _____ L

*Choose largest of 3 trials

II. Residual Volume

A. RV_{actual}

$$RV = [VC (L) \times \text{BTPS conversion factor}] \times .24$$

$$= [\quad (L) \times \quad] \times .24$$

$$= \quad L$$

B. $RV_{\text{predicted}}$

$$RV = 0.017 (\text{age}) + 0.06858 (\text{height}) - 3.477$$

$$= 0.017 (\quad) + 0.06858 (\quad \text{in}) - 3.477$$

$$= \quad L$$

III. Underwater Weight**

A. Trials

1. _____ kg 6. _____
 2. _____ 7. _____
 3. _____ 8. _____
 4. _____ 9. _____
 5. _____ 10. _____

**Choose heaviest trial

B. Tare Weight

_____ kg (under water weight of chair, weight belt, and chains)

C. Net Underwater Weight

$$\text{underwater wt. (kg)} - \text{tare wt. (kg)} = \text{net underwater wt. (kg)}$$

$$\quad \text{kg} - \quad \text{kg} = \quad \text{kg}$$

IV. Body Density

$$D_b = \frac{\text{wt of subject in air (kg)}}{[\text{wt. in air (kg)} - \text{net underwater wt. (kg)}] - (RV + 0.1 L)}$$

$$\quad \text{density of the water}$$

$$= \quad$$

V. Body Fat Percentage

$$\% \text{ body fat} = \frac{4.570}{D_b} - 4.142 \times 100 = \quad \%$$

Brozek, J., Grande, F., Anderson, T., & Keys, A. (1963). Densitometric analysis of body composition: Revision of some quantitative assumptions. Annals of the New York Academy of Science, 110, 113-140.

Goldman, H.I., & Becklake, M.R. (1959). Respiratory function tests: Normal values of medium altitudes and the prediction of normal results. American Reviews of Tuberculosis and Respiratory Disease, 79, 457-467.

Wilmore, J.H. (1969). The use of actual, predicted and constant residual volumes in the assessment of body composition by underwater weighing. Medicine and Science in Sports, 1, 87-90.

SKINFOLD MEASUREMENT

Name _____ Date _____ Age _____
 Sex _____
 Weight _____ lbs _____ kg
 Height _____ in _____ cm

I. Frame size measurement

_____ cm ----> S M L

II. Seven-site skinfold

	Trial 1	Trial 2	Trial 3	Average
1. Chest	_____	_____	_____	_____
2. Axilla	_____	_____	_____	_____
3. Triceps	_____	_____	_____	_____
4. Subscapular	_____	_____	_____	_____
5. Abdominal	_____	_____	_____	_____
6. Suprailium	_____	_____	_____	_____
7. Thigh	_____	_____	_____	_____

Sum of seven skinfolds _____ mm

III. Generalized Regression Equation

A. Body density (D_b)

Male: $1.112 - 0.00043499[\text{sum of seven}(\text{_____})] +$
 $0.00000055[\text{sum of seven}^2(\text{_____})^2] - 0.00028826[\text{age}(\text{_____})]$
 $= \text{_____ } D_b$

Female: $1.0970 - 0.00046971[\text{sum of seven}(\text{_____})] +$
 $0.00000056[\text{sum of seven}^2(\text{_____})^2] - 0.00012828[\text{age}(\text{_____})]$
 $= \text{_____ } D_b$

B. Body fat percentage

% body fat = $\frac{4.570}{D_b} - 4.142 * 100 = \text{_____} \%$

IV. Circumferential Measurement

Weight (WT) _____ lbs Conversion factor (CF) _____

Waist _____ inches Conversion factor (CF) _____

Weight CF _____ - Waist CF _____ = _____ CF

CF _____ + (98.42 for males) = _____ Lean Body Weight (LBW)
 (76.76 for females)

Weight _____ - LBW _____ = _____ Fat Weight (FW)

FW _____ / LBW _____ * 100 = _____ % Body fat

BRUCE PROTOCOL

Name _____ No. _____ Date ____ / ____ / ____ Time ____ :

Age ____ Sex ____ Height ____ in ____ cm Weight ____ lb ____ kg

Predicted Max Heart Rate ____ bpm 85% Max HR ____ bpm Activity Status _____

Medications/Other Considerations _____

Pre-exercise lactate ____ mmol Post-exercise lactate ____ mmol

STAGE	HR	BP	RPE	VO ₂	RPP	COMMENTS
Rest/Supine		/	////////			
Rest/hypervent		/	////////			
Rest/standing		/	////////			
1. 1.7 mph 10% grade		/				
2. 2.5 mph 12% grade		/				
3. 3.4 mph 14% grade		/				
4. 4.2 mph 16% grade		/				
5. 5.0 mph 18% grade		/				
6. 5.5 mph 20% grade		/				
7. 6.0 mph 22% grade		/				
Recovery: minute 1	_____	____/____		_____		
minute 2	_____	____/____		_____		
minute 3	_____	____/____		_____		
minute 4	_____	____/____		_____		
minute 5	_____	____/____		_____		

MAX VALUES: HR ____ BP ____ / ____ RPE ____ VO₂ ____ RPP ____ Time ____ Stage ____

Reason for termination: _____

Findings/Conclusions: _____

Supervisor Signature: _____

ELECTROCARDIOGRAPHY REPORT

RESTING ECG:

Supine:

Rate _____ PR Interval _____ QRS Duration _____
 QT Interval _____ Axis _____ Rhythm _____ ST Segment _____
 Remarks _____

Hypervent:

Rate _____ PR Interval _____ QRS Duration _____
 QT Interval _____ Axis _____ Rhythm _____ ST Segment _____
 Remarks _____

Standing:

Rate _____ PR Interval _____ QRS Duration _____
 QT Interval _____ Axis _____ Rhythm _____ ST Segment _____
 Remarks _____

IMPRESSION: Normal _____ Equivocal _____ Abnormal _____

EXERCISE ECG:

Protocol _____ MAX BP _____ / _____ MAX HR _____
 Duration of test _____

IMPRESSION:

_____ Normal
 _____ Inconclusive test
 _____ Submaximal _____ Drug Effect (Name) _____
 _____ Mechanical Failure _____ Other _____
 Remarks _____

_____ Equivocal
 _____ ST Segment Depression/Elev(.5-1mm Amp, $\geq .08$ sec)
 _____ PVCs (10-20%/min)
 _____ Excessive Hypertension
 _____ T Wave Changes
 _____ Other: _____

_____ Abnormal
 _____ ST Changes ≥ 1 mm _____ Elevation
 _____ Depression _____ Leads _____ Downslope
 _____ Horizontal _____ Upslope
 _____ Angina
 _____ LBBB (induced)
 _____ Hypotension
 _____ R on T PVCs: number/min _____
 _____ Exercise Induced 2 or 3 degree Block _____
 _____ Uniform PVCs (>20-30%)
 _____ A Couplet (with known CHD)
 _____ Multifform PVCs: number/min _____
 _____ Ventricular Tachycardia
 _____ RBBB (Induced)
 _____ Supraventricular Tachycardia
 _____ Other _____

REMARKS: _____

Supervisor's Signature _____ Date _____

Physician's Signature _____ Date _____

WINGATE ANAEROBIC POWER TEST **NAME:** _____

Procedures:

1. Warm-up: Adjust the seat height for subject. Cycle for 30 seconds at 300 kpm/min (1 kg), followed by 30 seconds of rest for total of 6 min.
2. Workload: Set workload according to subject's body weight (kg). The normal range of resistance for subjects is 3.4-6.0 kg.

$$\text{_____ kg} \times 0.075 = \text{_____ kg}$$

3. The Test: Set ergometer resistance within 2-3 seconds so the subject can overcome initial flywheel resistance. On the command "START", subject begins pedaling as fast as possible. Count number of full revolutions for every 5 seconds up until the 30-second stopping point.

4. Warm-down: Workload resistance is reduced to approximately 100 kpm/min while the subject continues to pedal for 4 minutes.

Data: :05 :10 :15 :20 :25 :30 Total Revs
 (revs/5 sec) _____ _____ _____ _____ _____ _____ = _____

Calculations:

1. **Total mean anaerobic output** for 30 seconds (AN 30):

$$\text{TMAO 30} = \frac{\text{revs} \times \text{circum. (6 m)} \times \text{resistance (kg)} \times 2}{\text{body weight (kg)}} = \text{_____ kgm/min/kg}$$

2. Convert kgm/min/kg to watts/kg: _____ kgm/min/kg $\times \frac{1 \text{ watt}}{6.12 \text{ kgm/min}}$ = _____ watts/kg

3. Calculate **peak anaerobic output** for each 5 sec interval (PAO 5):

$$\text{PAO 5} = \frac{\text{revs} \times \text{circum. (6 m)} \times \text{resistance (kg)} \times 12}{\text{Body weight (kg)}} = \text{_____ kgm/min/kg}$$

$$\text{PAO 10} = \text{_____} \quad \text{PAO 20} = \text{_____} \quad \text{PAO 30} = \text{_____}$$

$$\text{PAO 15} = \text{_____} \quad \text{PAO 25} = \text{_____}$$

4. Convert the interval output in kgm/min/kg to watts/kg.

5. Calculate **total power output** in J/kg:

$$\text{TPO} = \frac{\text{_____ kgm/min/kg} \times \frac{1 \text{ watt}}{6.12 \text{ kgm/min/kg}} \times \frac{.06 \text{ kJ}}{1 \text{ watt}} \times \frac{1000 \text{ J}}{1 \text{ kJ}}}{1} = \text{_____ J/kg}$$

6. Divide _____ J/kg by 2 in order to account for the 30 seconds:

$$\text{TPO 30} = \frac{\text{J/kg}}{2} = \text{_____ J/kg}$$

7. Calculate **fatigue index:** $\frac{(\text{peak PAO} - \text{lowest PAO in 5-s}) \times 100}{\text{peak PAO}} = \text{_____ \%}$

VERTICAL JUMP

Name _____

Date _____

Age _____ Sex _____ Ht _____ cm

Wt _____ kg

I. Standing (Reach) Height _____ cm

II. Squat Jump

Ht (cm)	Time (sec)
Trial 1 _____	_____
Trial 2 _____	_____
Trial 3 _____	_____

- * 2 practice jumps
- * 30 sec rest between jumps

III. Countermovement Jump

Ht (cm)	Time (sec)
Trial 1 _____	_____
Trial 2 _____	_____
Trial 3 _____	_____

- * 2 practice jumps
- * 30 sec rest between jumps

Lewis Nomogram:

Power (ft-lbs/sec) = 4 x _____ body weight (kg) x _____ sq. root of ht (ft)

Power (W/kg) = $\frac{\text{ft-lbs/sec} \times 1.355}{\text{body weight (kg)}}$

Harman Nomogram:

Power (watts) = $[61.9 \times \text{height (cm)}] + [36.0 \times \text{weight (kg)}] - 1,822$ Power (W/kg) = $\frac{\text{watts}}{\text{weight (kg)}}$

FIELD TESTS

Name _____

Date _____

Age _____ Sex _____ Ht _____ cm

Wt _____ kg

I. Agility**T-Test** Time

Trial 1 _____

Trial 2 _____

* 1 practice run

* 1 min rest between trials

Line Drill Test Time

Trial 1 _____

Trial 2 _____

Trial 3 _____

Trial 4 _____

* 1 practice run

* 2 min rest between trials

II. Sport-Specific Skill**Juggling** # taps

Trial 1 _____

(30 sec/trial)

Trial 2 _____

* 30 sec rest between trials

Wall Volley # kicks

Trial 1 _____

(30 sec/trial)

Trial 2 _____

Trial 3 _____

* 30 sec rest between trials

Modified Zelenka Time

Kicking Accuracy (hit/miss)

Trial 1 _____

Trial 2 _____

* 2 min rest between trials

**** Initial warm-up prior to all field tests is 5 min light jog.**

JOINT FLEXIBILITY

Name _____

Date _____

Age _____ Sex _____ Height _____ cm

Wt _____ kg

I. Spine

Trunk Rotation

R _____

L _____

Lateral Flexion(cm)

R _____

L _____

Flexion (cm)

Extension (cm)

II. Hip

Flexion

R _____

L _____

Extension

R _____

L _____

Internal Rotation

R _____

L _____

External Rotation

R _____

L _____

Abduction

R _____

L _____

Adduction

R _____

L _____

Abduction in Flexion

R _____

L _____

III. Knee

Flexion

R _____

L _____

Hyperextension

R _____

L _____

IV. Ankle

Dorsiflexion

R _____

L _____

Plantarflexion

R _____

L _____

**Physiological and Sport Skill Norms, Subject Scores,
and Rankings Data Sheet**

<u>Variables</u>	<u>Personal</u>	<u>Norms</u>	<u>Status</u>		
Aerobic Capacity					
VO _{2max} (ml/kg-min)		46 - 54			
HR _{max} (bpm)		191 - 221			
VE _{max} (L/min)		140 -160			
R _{max}		1 -1.10			
AT _{max} (%VO2)		55 - 80			
Bp _{rest} systolic (mmHg)		90 -120			
BP _{rest} diastolic (mmHg)		60 - 80			
Bp _{max} systolic (mmHg)		200 - 250			
Bp _{max} diastolic (mmHg)		80 - 120			
Anaerobic Power					
Peak power (W/kg)		9.9 -11.5			
Mean power (W/kg)		7.0 -7.74			
Fatigue index (%)		40 -44			
Total work output (J/kg)		231 -268			
Body Composition					
Body fat (%)		6.6 -11			
Leg Power					
Squat jump (W/kg)		16.9 -29.7			
Countermovement jump (W/kg)		14.3 -18.0			
Agility/Skills Tests					
T-test (sec)		10.84 - 12.77			
Line drill test (sec)		27.41 - 40.75			
Juggling test (# of taps)		38 - 58			
Wall volley test (# of hits)		37 -42			
Zelenka time test (sec)		42.17 - 58.67			
Zelenka goal test (# of misses)		1 - 4			
Flexibility					
	<i>Right/Left</i>				
Trunk rotation (deg)		30 - 45			
Lateral flexion (cm)		.2 - 2.5			
Spine flexion (cm)		8 - 12			
Spine extension (cm)		2 - 10			
Hip flexion (deg)		110 - 120			
Hip extension (deg)		20 - 30			
Hip internal rotation (deg)		40 - 50			
Hip external rotation (deg)		40 - 50			
Hip abduction (deg)		40 - 55			
Hip adduction (deg)		20 - 45			
Hip abduction (deg) in flexion		45 - 60			
Knee flexion (deg)		120 - 145			
Knee extension (deg)		165 - 175			
Ankle dorsiflexion (deg)		15 - 20			
Ankle plantarflexion (deg)		40 - 50			
Summary:					
Aerobic	Excellent	Good	Average	Fair	Poor
Anaerobic	Excellent	Good	Average	Fair	Poor
Body Composition	Excellent	Good	Average	Fair	Poor
Leg Power	Excellent	Good	Average	Fair	Poor
Agility/Skill	Excellent	Good	Average	Fair	Poor
Flexibility	Excellent	Good	Average	Fair	Poor
Overall	Excellent	Good	Average	Fair	Poor

DATA COVER LETTER

**Department of Health
and Human Development**

Marga Hosaeus Health
and Physical Education Complex
MSU • Bozeman
Bozeman, MT 59717-0336

Telephone (406) 994-4001
Fax (406) 994-6314

Date

Name
Address
City/State Zip

Dear,

First of all I want to thank you so much for your participation in the physiological study conducted this summer at the ODP camp. Your generosity with your time and work is much appreciated. I trust that these results from your tests will be informative and helpful to you in your continued pursuits in soccer.

Included is a brief description of your results, which are listed on the following page. Also included is a list of each of the variables and their definitions. If any of you would like further information on a specific value, ways to improve a certain value, or training principles, send me a self-addressed stamped envelope and I will get that information to you as soon as possible.

Thanks again for your cooperation and time.

Sincerely,

Lydia Vanderford, ATC

ec - definitions and summary

25% COTTON

APPENDIX B

ANOVA TABLES

ANOVA Table for Lean Body Mass by Age Group

Source	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Between Groups	2	2912.82	1456.41	27.54
Within Groups	56	2961.33	52.88	$p=.0001$
Total	58	5874.15		

ANOVA Table for Body Fat by Age Group

Source	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Between Groups	2	20.37	10.19	2.76
Within Groups	56	206.65	3.69	$p=.0719$
Total	58	227.03		

ANOVA Table for Minute Ventilation by Age Group

Source	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Between Groups	2	22966.97	11483.48	19.04
Within Groups	57	34371.09	603.00	$p=.0001$
Total	59	57338.06		

ANOVA Table for Peak Power by Age Group

Source	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Between Groups	2	15.58	7.79	7.74
Within Groups	56	56.32	1.01	$p=.0011$
Total	58	71.89		

ANOVA Table for Total Work Output by Age Group

Source	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Between Groups	2	4745.19	2372.59	4.07
Within Groups	56	32673.46	583.45	$p=.0224$
Total	58	37418.64		

ANOVA Table for Fatigue Index by Age Group

Source	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Between Groups	2	1044.70	522.35	7.23
Within Groups	56	4045.86	72.25	$p=.0016$
Total	58	5090.57		

ANOVA Table for Vertical Squat Jump by Age Group

Source	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Between Groups	2	8.84	4.42	2.24
Within Groups	56	110.77	1.98	$p=.1164$
Total	58	119.61		

ANOVA Table for Vertical Countermovement Jump by Age Group

Source	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Between Groups	2	25.23	12.61	8.57
Within Groups	56	82.43	1.47	$p=.0006$
Total	58	107.66		

ANOVA Table for T-Test by Age Group

Source	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Between Groups	2	5.24	2.62	7.20
Within Groups	56	20.36	0.36	$p=.0016$
Total	58	25.60		

ANOVA Table for Juggling Test by Age Group

Source	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Between Groups	2	693.89	346.95	2.87
Within Groups	56	6779.63	121.06	$p=.0653$
Total	58	7473.53		

APPENDIX C

FACTOR ANALYSES TABLES

Physiological Variables and Factor Scores

SUB	LBM	BF	VE	PP	TWO	FI	VJS	VJC	TT	JT	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
1	37.6	4.9	115.2	8.1	218	16.3	12.9	12.9	11.88	54	-1.71	-0.22	-1.20	-0.41
2	49.9	6.2	153.1	11.9	290	37.7	14.5	14.2	11.81	54	-0.34	-0.20	1.88	-0.47
3	64.2	7.7	172.6	10.2	255	32.8	13.4	14.5	10.66	64	0.44	0.08	0.14	-0.65
4	51.9	8.7	153.2	10.1	253	30.4	12.8	13.3	11.66	56	-0.27	-0.63	0.36	-0.03
5	55.4	11.1	162.2	7.8	195	40.0	13.0	14.0	11.99	29	0.53	-0.05	-2.15	1.05
6	49.4	9.5	164.1	8.3	231	14.7	12.4	13.9	10.99	47	-0.81	0.19	-0.97	0.45
7	43.7	7.6	116.7	10.3	254	33.1	12.3	12.9	10.87	65	-0.79	-1.12	0.53	-0.19
8	45.7	5.2	121.1	9.9	256	26.8	13.3	13.6	10.96	60	-1.09	-0.23	0.27	-1.02
9	40.7	8.6	127.2	9.4	245	23.3	11.8	12.4	12.68	51	-1.13	-1.04	0.12	0.67
10	44.9	9.4	116.6	9.9	231	34.8	12.7	12.7	11.96	58	-0.47	-1.18	-0.04	-0.53
11	40.6	6.0	90.2	8.3	231	19.3	14.2	14.1	12.58	60	-1.89	0.77	-1.05	0.01
12	42.9	7.4	112.0	8.5	231	20.5	13.6	13.5	12.60	17	-1.38	0.10	-0.66	1.39
13	58.9	7.4	164.9	8.8	222	32.0	13.5	14.7	11.65	39	0.28	0.40	-1.14	0.40
14	57.4	6.4	154.9	10.2	255	34.3	14.6	15.8	11.09	32	0.08	0.86	0.16	0.05
15	38.8	9.3	122.0	8.0	194	35.8	6.0	8.5	11.87	29	-0.04	-4.51	-1.09	0.82
16	35.2	7.9	67.2	9.9	277	15.4	12.6	13.2	11.99	36	-2.40	-0.40	1.12	0.73
17	35.7	7.5	96.0	8.7	216	35.0	13.7	14.0	11.71	37	-1.16	-0.05	-1.10	-0.37
18	43.0	7.2	110.5	8.2	220	24.5	13.5	14.3	11.65	33	-1.18	0.41	-1.26	0.31
19	40.4	8.4	113.9	9.3	240	24.6	12.6	13.9	11.05	43	-1.17	-0.27	-0.20	-0.25
20	43.2	8.7	135.4	9.2	261	10.5	13.3	13.3	11.20	42	-1.76	0.14	0.26	0.49
21	66.2	7.2	162.0	12.0	273	55.9	15.8	16.2	10.13	57	1.16	0.62	1.06	-1.65
22	68.5	10.8	168.3	7.9	204	27.4	14.7	16.1	11.41	57	0.54	1.66	-2.24	0.34
23	60.9	7.9	163.7	10.7	260	38.0	12.1	13.3	10.10	58	0.53	-1.06	0.67	-0.96
24	55.7	6.8	131.9	11.8	288	36.6	14.5	16.1	9.81	59	-0.17	0.59	1.56	-1.55
25	55.6	6.3	129.9	10.9	265	39.2	14.6	15.1	11.28	60	-0.13	0.37	0.68	-0.92
26	63.1	11.0	173.8	9.9	237	44.5	13.3	14.7	11.60	50	1.01	-0.06	-0.39	0.31
27	66.5	3.7	205.5	10.7	254	40.2	13.8	15.4	10.78	59	1.14	0.33	0.19	-1.02
28	54.8	5.1	167.5	10.2	232	44.6	12.4	14.2	11.27	47	0.82	-0.79	-0.19	-0.77
29	59.0	11.1	158.0	10.6	265	33.3	11.5	13.2	11.22	51	0.33	-1.15	0.90	0.43
30	57.6	8.9	184.4	9.0	204	45.1	12.7	14.4	10.00	55	1.11	-0.42	-1.55	-1.30
31	55.6	7.7	127.3	9.2	233	30.1	11.9	12.4	12.31	30	-0.18	-1.10	-0.28	1.02
32	56.5	10.3	157.7	9.7	242	32.1	14.2	15.2	12.00	37	0.10	0.59	-0.23	0.83
33	60.1	6.9	156.0	8.5	211	32.2	12.3	13.7	10.80	65	0.33	-0.32	-1.53	-0.86
34	58.0	6.8	159.0	11.3	250	48.7	13.7	15.3	11.36	66	0.94	-0.20	0.53	-1.29
35	47.0	6.9	121.5	10.6	274	27.2	14.5	15.0	10.60	79	-1.16	0.66	0.74	-1.57
36	46.1	4.7	107.4	8.8	213	33.8	12.9	14.1	10.66	63	-0.59	-0.23	-1.27	-1.73
37	53.5	9.9	159.0	9.7	236	36.0	14.1	14.6	11.06	38	0.10	0.16	-0.35	-0.04
38	58.1	5.7	138.9	9.1	234	32.9	12.9	13.6	11.79	46	-0.06	-0.22	-0.66	0.16
39	56.0	9.4	172.7	9.3	257	20.8	14.8	15.7	11.49	44	-0.55	1.50	-0.26	0.82
40	80.5	6.8	191.8	9.9	220	53.2	12.1	14.9	11.25	38	2.56	-0.50	-0.84	0.18
41	70.9	7.1	205.3	11.1	270	42.8	13.4	14.9	11.47	53	1.36	-0.02	0.80	0.17
42	56.8	12.0	142.9	11.0	251	44.2	13.5	15.2	12.77	39	0.72	-0.16	0.68	0.96
43	71.3	12.9	175.6	10.9	256	43.5	12.9	13.9	12.32	43	1.42	-0.69	0.71	1.26
44	70.7	9.6	192.0	9.2	231	32.5	13.3	14.8	11.91	58	1.00	0.45	-0.89	0.64
45	67.1	7.5	214.1	10.3	248	33.6	13.1	14.4	12.59	38	1.18	-0.10	0.22	1.21
46	56.2	8.2	181.0	9.8	241	41.1	14.2	15.3	11.20	53	0.48	0.57	-0.48	-0.35
47	62.1	11.6	185.2	10.6	263	36.1	15.6	17.5	11.34	53	0.59	1.87	0.22	0.30
48	63.0	9.4	192.5	11.8	318	30.3	13.9	15.7	11.44	47	0.12	0.78	2.20	1.11
49	60.4	10.2	162.3	10.7	264	32.5	13.6	15.0	12.30	50	0.32	0.23	0.74	0.81
50	58.9	7.5	180.8	10.9	260	35.3	13.7	14.9	11.84	54	0.53	0.07	0.69	-0.04
51	60.4	8.1	173.7	8.9	238	23.3	15.2	16.2	11.88	49	-0.15	1.80	-0.96	0.62
52	60.0	9.3	158.9	11.2	282	32.2	13.4	14.1	11.77	48	0.08	-0.25	1.43	0.56
53	73.5	9.7	199.9	10.9	256	41.1	15.4	16.4	10.94	57	1.39	1.16	0.24	-0.32
54	61.6	10.2	190.4	10.1	257	29.7	13.4	14.7	11.57	52	0.41	0.27	0.23	0.59
55	55.3	8.6	173.8	9.6	260	19.9	14.2	14.8	11.78	58	-0.57	0.90	0.40	0.48
56	49.9	6.9	152.9	9.8	256	27.1	11.0	11.8	11.80	44	-0.45	-1.58	0.51	0.53
57	53.3	10.1	136.1	11.6	308	22.6	15.6	16.0	11.57	42	-1.03	1.34	2.07	0.73
58	56.7	9.3	146.4	11.6	270	41.5	12.4	14.8	11.41	54	0.60	-0.65	1.35	-0.25
59	62.5	4.8	177.1	9.9	244	36.8	14.7	14.8	10.84	55	0.41	0.52	-0.35	-0.89
60			157.6											

Principal Components Factor Pattern^a

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
LBM	.75	.52	.08	.11	-.17	.01
FI	.54	.54	.40	-.14	.40	.001
VE	.65	.50	.09	.14	-.29	.01
VJS	.65	.36	.54	-.14	.17	.02
VJC	.81	.12	.48	-.10	.13	-.02
TWO	.58	.64	.26	.38	-.13	-.001
PP	.77	.30	.48	.24	.11	.003
TT	.35	.05	.20	.54	.13	.01
BF	.08	.19	.14	.46	.03	-.02
JT	.37	.19	.18	-.46	-.20	-.004

^aFactor values resulting from principal factors extraction which was used to obtain maximum orthogonal variance, as well as to analyze common variance without the interference of unique and error variance.

Varimax Rotation Factor Loadings^a

Variable	Factor 1	Factor 2	Factor 3	Factor 4
LBM	.86 *	.31	.10	.05
FI	.80 *	-.15	.11	-.29
VE	.79 *	.27	.06	.11
VJS	.04	.90 *	.19	-.14
VJC	.34	.86 *	.19	-.12
TWO	-.06	.26	.94 *	-.01
PP	.34	.11	.90 *	-.19
TT	-.18	-.11	-.07	.64 *
BF	.20	.05	.07	.48 *
JT	.09	.17	.18	-.59 *

*Factors loading above .45

^aResulting factor loadings across variables following varimax rotation to maximize the variance of the loadings within the factors.

R-Squares of the Variables with each Factor

Factor	R ²
Factor 1	.93
Factor 2	.93
Factor 3	.97
Factor 4	.68

APPENDIX D

TEST-RETEST CORRELATION COEFFICIENTS

TEST-RETEST RELIABILITY CORRELATION COEFFICIENTS
FOR TEST VARIABLES

<u>TEST</u>	<u>r</u>
Anthropometric	
BF	.92
LBM	1.00
BD	.92
Aerobic	
VO ₂	.52
HR	.91
VE	.94
AT	.66
RER	.02
Anaerobic	
PP	.83
MP	.78
TWO	.78
FI	.58
Leg Power	
VJS	.86
VJC	.88
Agility	
TT	.65
LDT	.82
JT	.94
WV	.35
MZT	.86
MZA	-.46
Flexibility	
TRR	.53
TRL	.58
SF	.63
SE	.90
SLFR	.39
SLFL	.05

Flexibility - continued

r

HFR	.76
HFL	.81
HER	.93
HEL	.82
HIRR	.72
HIRL	.81
HERR	.04
HERL	.17
HABR	.81
HABL	.83
HADR	.20
HADL	.27
HABFR	.77
HABFL	.78
KFR	.90
KFL	.60
KER	.67
KEL	.86
ADFR	.80
ADFL	.74
APFR	.76
APFL	.82