The Effect of Seasonal Training on Selected Physical and Physiological Variables of Junior Male Alpine Ski Racers

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ABSTRACT

TITLE OF THESIS: The Effect of Seasonal Training on Selected Physical and Physiological Variables of Junior Male Alpine Ski Racers.

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The purpose of this study was threefold: 1) to investigate the effect of seasonal training on anthropometry, muscular strength and power, motor ability, flexibility, aerobic power, and anaerobic power and capacity, 2) to investigate the relationship between physical and physiological variables in slalom (SL) and giant slalom (GS) performance, and 3) to establish a regression equation to predict SL and GS performance for junior male Alpine ski racers.

A group study research design was employed, which involved pre-season and post-season tests. Measurements of SL and GS performance were taken immediately after each test session. Twenty one junior male Alpine ski racers were assessed for: i) anthropometry following the International Biological program (Weiner and Lourie, 1969); ii) muscular strength, power, and endurance of quadricep and hamstring muscle groups using the Dual

Channel Cybex II isokinetic unit and a Stoeling hand dynamometer and also using vertical jump, box jump, and hexagonal jump tests; iii) flexibility using the Leighton Flexometer and a sit and reach test; iv) pulmonary function using the autospirometer AS-700 (Minato Medical Science); v) aerobic power using a cycle ergometer protocol (MacDougall, Wenger, and Green, 1982); vi) anaerobic power and capacity using a cycle ergometer (Bar Or, Dotan, and Inbar, 1977); and vii) anaerobic threshold determined by locating an increase in the ventilatory equivalent for O_2 without an increase in ventilatory equivalent for CO_2 and an increase in FEO_2 at the peak point of $FECO_2$.

Three methods of statistical analyses were used to investigate the results of the study: 1. Paired t-test of pre- and post-season results, 2. Pearson Product-Moment correlation for both pre- and post-season results, and 3. Stepwise multiple regression analyses of pre-season SL and GS performance and post-season SL and GS performance.

The paired t-test indicated that slalom performance and hip rotation degree significantly ($p<.05$) improved after the season, and fatigue index for the hamstring muscle group in the left leg showed a significant decline between pre- and post-season tests.

The Pearson Product-Moment correlation coefficient revealed several significant ($p<.05$) relationships between skiing performance (SL & GS) and selected variables as well as several significant intercorrelations between the variables.

The stepwise multiple regression analyses revealed that age and hexagonal jump accounted for a large percentage of the variability for both pre-and post-season SL and GS performance.

Additional stepwise multiple regression analyses were applied to pre- and post-season SL and GS performance with the independent variable "age" removed to investigate what other predictors would account for the variation in the absence of the age variable. In general, isometric quadricep strength in the right leg accounted for most of the variance in 2 out of the 4 analyses and hexagonal jump accounted for most of the variance in the remaining 2 analyses.

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INTRODUCTION

Statement of the Problem

The purpose of this study was threefold: 1) to investigate the effect of seasonal training on anthropometry, muscular strength and power, motor ability, flexibility, aerobic power, and anaerobic power and capacity, 2) to investigate the relationships between physical and physiological variables in slalom (SL) and giant slalom (GS) performance, and 3) to establish the regression equations to predict SL and GS performance for junior male Alpine ski racers.

Significance

Competitive Alpine skiers endure many physical demands associated with the sport. Elite performance is achieved through systematic training that is designed according to well founded scientific laws and principles. Therefore, training towards elite performance requires a complex blend of many physical, physiological, biomechanical, and environmental components (Song, 1982).

Physiological profiles of elite Alpine skiers reveal the importance of a wide range of variables such as muscular strength and power, motor ability, flexibility, aerobic power, and anaerobic power and capacity (Andersen and Montgomery, 1988; Atkins and Hagerman, 1984; Brown and Wilkinson, 1983; Hagerman, Davis, Stone, and Rozenek, 1978; Haymes and Dickinson, 1978; Haymes and Dickinson, 1980A; Haymes and Dickinson, 1980B; Song, 1982). The high-intensity work associated with ski racing requires a high level of muscular strength as well as superior anaerobic power (Karlsson, Eriksson, Fosberg, Karlberg, and Tesch, 1978; Tesch, Larsson, Eriksson, and Karlsson, 1978; Haymes and Dickinson, 1980B).

The energy demand of SL and GS can only be partially fulfilled by aerobic metabolism, since the duration of either event is not long enough to attain a steady state and the intensity is higher than the maximum aerobic power (Saibene, Cortili, Gavazzi, and Magistri, 1985). For these reasons there are relatively few studies available that have investigated the energy systems involved in Alpine skiing.

In theory, an athlete should be at peak physical condition at the time of competition. However, the competitive ski season may last for four months or longer. Physiologically it is not possible to maintain peak condition for this length of time (Haymes and Dickinson, 1978). Although it is highly individualized it is thought that peak condition can be maintained for seven to ten days when an athlete is properly physically prepared throughout the year. A maximum of two to three peakings of seven to ten days may result within a one to two and a half month period (Bompa, 1983; Dick, 1980; Matveyev, 1981; Sharkey, 1986). Therefore, realistically an elite Alpine skier can aim to peak for short durations only two or three times in a one to two and a half month period within the competitive ski season.

Maintaining an elite level in Alpine skiing involves a year-round physical conditioning process. However, the demands of the sport require athletes to travel, train, and compete for a minimum of nine months each year. Therefore, there are only three months during the off-season that Alpine skiers can be assured access to "state of the art" facilities that other sportsmen use year-round (Haymes and Dickinson, 1978). The results of pre-season and post-season testing, therefore, largely depend upon the athletes ability to follow an effective training program with a minimum of training facilities.

Considering that physiological changes must take place during the competitive ski season, very few studies have investigated these changes and in particular changes in junior male Alpine ski racers. This study has attempted to determine specific physical and physiological parameters for junior male Alpine ski racers.

The results of this study should assist in the preparation of seasonal training programs and ultimately contribute to a more effective annual training plan. Since this investigator is a National level coach and former ski racer, there is a personal interest in investigating the effects of seasonal training on selected physical and physiological variables of junior male

Alpine ski racers. Results of this study should help to improve the knowledge and coaching skills of this investigator.

Delimitations

1. The subjects of this study were 21 junior male Alpine ski racers, ranging from 11 to 16 years of age, who are members of the Lake Superior Ski Division.
2. Selected physical and physiological variables were strength and flexibility of legs, trunk, and hips; aerobic power; anaerobic power and capacity; motor ability; and anthropometric measurements.
3. Diurnal variations were avoided by testing the subjects at the same time of day each testing session.
4. The investigative period was from early November 1986 to late March 1987.

Limitations

1. The subjects in this study participated on a voluntary basis.
2. It was assumed that the subjects exerted maximum effort on all tests.
3. A level of .05 has been established as the level of significance for statistical testing.

Definitions

Aerobic Power: also called maximal oxygen uptake ($\dot{V}O_2$ max). The greatest amount of oxygen (O_2) a person is able to utilize during maximal effort. It can be reported as absolute $\dot{V}O_2$ (L/min) or relative $\dot{V}O_2$ max (ml/kg/min).

Agility: the ability of the body or parts of the body to change directions rapidly and accurately.

Anaerobic Capacity: the total amount of anaerobic energy that may be produced independent of time, depends on the supply of ATP and CP and the maximal amount of blood lactic acid.

Anaerobic Power: the rate of anaerobic energy production depends on the velocity of phosphagen splitting and the rate of blood lactate formation.

Anaerobic Threshold: the point of curvilinear increase of ventilation during graded exercise (Wasserman, Whipp, Koyal, and Beaver, 1973). It is identified by a change from linearity of the $\dot{V}E$ and $\dot{V}CO_2$ relative to $\dot{V}O_2$, FEO_2, and $FECO_2$.

Flexibility: the range of motion about a joint or series of joints.

Forced Vital Capacity: the vital capacity performed with expiration as forceful and as rapid as possible.

Maximum Heart Rate: the greatest number of ventricular contractions by the heart in one minute.

Mixed Expired Oxygen (FEO_2): the concentration of O_2 in the expired air.

Mixed Expired Carbon Dioxide ($FECO_2$): the concentration of carbon dioxide (CO_2) in the expired air.

Motor Ability: a present aptitude for physical skills as they appear in everyday motor habits.

Muscular Endurance: the ability to persist when performing a repetitive task. Measured as the repetitions of submaximal contractions or submaximal holding time.

Muscular Power: the time rate at which strength is transferred into work (force x velocity).

Muscular Strength: the maximal force that can be exerted in a single voluntary contraction.

Respiratory Exchange Ratio: the ratio of the volume of CO_2 expired per minute ($\dot{V}CO_2$) to the volume of O_2 consumed during the same time interval ($\dot{V}O_2$).

Ventilation ($\dot{V}E$): the volume of air expired per minute.

Chapter 2

REVIEW OF LITERATURE

At the 1988 Olympic games, Alpine skiing included five events: slalom (SL), giant slalom (GS), super-giant slalom (SG), downhill (DH), and Alpine combined. Skiers frequently compete in more than one Alpine event and are often separated into one of two categories; either the "technical" events, SL and GS, or the "speed" events, SG and DH. This study is primarily concerned with the SL and GS events.

Though GS is more technical than SL, SL requires more agility. The average speed of a GS race is approximately 75 km/hr and is typically 60 to 90 seconds in duration. SL has a lower average speed than GS and ranges from 45 to 60 seconds per run (Canadian Ski Coaches Federation, 1983). The relatively short duration of both events involves mostly high-intensity work from movements that are not repetitive and not reproducible in laboratory conditions.

Anthropometry

The earliest studies on Alpine skiers (Knoll, 1948; Dubs, 1954; and Saller, 1966) described them as small in body size, with strongly developed thigh muscles. Arnold (1933, 1956) stated that weight more than height plays an important role in Alpine skiing. More recently Karlsson (1984) described Alpine skiers as average in height and mass. Anthropometric data collected over a ten year period revealed that the successful skier is now taller and heavier than his predecessors (Karlsson, 1984). Song (1982) found that most competitive Alpine skiers are thin, small, and have well developed muscles compared to athletes in other physically demanding sports. During the last 15 years, mean heights in male elite Alpine skiers ranged from 172.5 to 179.0 cm, and mean weights ranged from 69.3 to 77.6 kg (Orvanová, 1987). National calibre skiers have a higher lean body mass than divisional or club skiers (Brown and Wilkinson, 1983). Slalom skiers tend to be leaner than skiers in other events (Haymes and Dickinson, 1980A: Ross and Day, 1972), while downhill skiers appear to be the heaviest (Haymes and Dickinson, 1980A). Ross and Day (1972) found a significant negative relationship between height and performance in junior Alpine skiers, and they noted that shortness in competitive skiing may be an advantage because a lower centre of gravity increases stability. These results were further supported by Song (1982) where the length of the lower leg was significantly correlated with performance, and Chovanová (1976) where the best performers were shorter than the less skilled ones although the difference was not significant.

Haymes and Dickinson (1978) found a significant increase in both body weight and % body fat from the beginning of on-snow training to the end of the competitive season among members of the National women's ski team. Anderson and Montgomery (1988) stated that there was no significant difference in the sum of skinfolds among male divisional skiers from the beginning to end of the competitive season.

Orvanová (1987) reported the range of mean endomorphic, mesomorphic, and ectomorphic components in elite adult and junior male Alpine skiers: endomorphic was 2.1 to 2.6 in adult males and 1.5 to 2.3 in junior males, mesomorphic was 5.5 to 6.2 in adult males and 4.3 to 5.0 in junior males, and ectomorphic was 1.9 to 2.6 in adult males and 2.7 to 4.1 in junior males. These results were supported by Song (1982) who characterised junior male racers as 1.8 in endomorphy, 4.3 in mesomorphy, and 2.7 in ectomorphy using the Heath-Carter method of somatotyping. However, Chovanová (1976) compared elite Alpine skiers with less skilled skiers and found that the more skilled skiers had significantly smaller values in endomorphy, higher values in mesomorphy, and lower values in ectomorphy.

Brown and Wilkinson (1983) indicated that Alpine ski racers have a low percent body fat. This was supported by Haymes and Dickinson (1980B) who reported that percent body fat also appeared to be an important factor. Smaller and leaner men performed better in SL, whereas skiers with more body fat performed better in DH. Percent body fat, weight, lean body mass, and power correlated significantly with FIS points for the males (Haymes and Dickinson, 1980B). Orvanová (1987) reported the range of mean percentage of fat and lean body mass in male and female Alpine skiers: percent body fat was 9.7 to 14.1% in male skiers and 16.2 to 20.6% in female skiers, and lean body mass was 60.8 to 67.7kg in male skiers and 42.1 to 46.6kg in female skiers.

Subcutaneous fat of Alpine skiers was compared to that of ice hockey players, ski jumpers, and Nordic combined skiers (Chovanová, 1976). It was found that ice hockey players had significantly more subcutaneous fat than any of the skiers. However, Alpine skiers had a greater amount of subcutaneous fat than ski jumpers and Nordic combined skiers. The leanest of all groups were cross-country skiers.

Muscular Strength and Power, and Motor Ability

Alpine skiing requires rapid movements with repeated maximal contractions. The elite Alpine skiers are characterized by extremely high maximal isometric strength in their leg skeletal muscles (Agnevik and Saltin, 1966; Astrand and Rodahl, 1986; Eriksson, Nygaard, and, Saltin, 1977A; Haymes and Dickinson, 1978; Haymes and Dickinson, 1980A; Karlsson, Eriksson, Fosberg, Karlberg, and Tesch, 1978; Thorstensson, Larsson, and Tesch, 1977). Agnevik and Saltin (1966) suggested that this was caused by the need to hold a correct body position while controlling their direction of momentum at high speeds. Thorstensson et al. (1977) stated that the crouched posture maintained by skiers for prolonged periods of time contributes to high isometric leg strength. Skiers also have extremely strong quadricep muscles which contributes to agility (Foss and Garrick, 1978). Astrand and Rodahl (1986) measured isometric strength of the leg extensor muscles of the Swedish Alpine team which averaged 2900N compared to athletes from other sports whose mean value was approximately 2500N. They reported that the Swedish ski racer, Ingemar Stenmark, who specialized in SL and GS and held the title of World Champion in these events for five consecutive years, had the highest value of 3430N. Ski racers repetitively apply forces of several thousand newtons when competing and, therefore, a high level of leg strength is necessary (Astrand and Rodahl, 1986).

High values were also obtained for Alpine ski racers in respect to dynamic strength at different speed of contractions compared with values found in endurance athletes and ordinary subjects (Eriksson, Forsberg, Nilsson, and Karlsson, 1978). Alpine skiers have a significantly greater isokinetic leg strength at 30°/sec and 180°/sec compared with other athletes (Brown and Wilkinson, 1983) as well as both cross-country and Nordic combined skiers (Haymes and Dickinson, 1980A). However, volleyball players, sprinters, and high jumpers displayed greater dynamic muscle strength than the elite Alpine skiers (Eriksson et al., 1978) probably because of greater demands on explosive strength in the former sports. These results indicate that ski racers perform better the slower the velocity of the muscle contraction. Therefore, although high speeds are reached in competition, the contractions where most muscle tension is developed may still be quite slow (Eriksson, Tesch, and Karlsson, 1977B).

Skiers with the greatest relative strength are able to perform at a lower percentage of maximal strength (Song, 1982) and occlusion of blood flow to the leg muscles is less at lower percentages of maximal strength, which delays the onset of fatigue (Haymes and Dickinson, 1980A).

Studies on muscle fiber composition have revealed that athletes performing sports that demand a high aerobic capacity possess a high proportion of slow twitch (ST) fibers. These fibers are known to be high oxidative and fatigue resistant. (Gollnick, Armstrong, Saltin, Saubert, Sembrowich, and Shephard, 1973). Eriksson et al. (1977B) found that 12 competitors from the Swedish National Alpine ski team had 57% ST fibers in their thigh muscles (the individual variation was quite large). Following a training session, histochemical staining of both ST and fast twitch fibers (FTa and FTb) revealed that there was a pronounced glycogen depletion of ST and FTa fibers, whereas FTb fibers showed little or no reduction. FTa fibers are known to have reasonably high oxidative and glycolytic capacity, whereas FTb fibers have the lowest oxidative potential and a high glycolytic capacity (Gollnick et al., 1973). It was found that the only situation where there was a selective loss of glycogen from FTb fibers was in maximal voluntary contractions (Eriksson, Ekholm, Hultén, Karlsson, and Karlsson, 1976; Secher and Nygaard, 1976). Together, this evidence indicates that elite ski racers on the whole exert relatively slow dynamic submaximal contractions and maximal isometric contractions during SL and GS.

Haymes and Dickinson (1978) reported an increase in leg strength, relative strength, power, and vertical velocity during the competitive season but could not confirm how much of these increases were due to the exercise program and how much to the ski training. Haymes and Dickinson (1980A) used a step-wise multiple regression analysis to identify the significant physical measurements that best estimated ski racing success for males and females in SL, GS, and DH. They found that the single most important factor influencing performance in the Alpine events was leg strength either total or relative to body weight. Total isometric strength was more important for females in DH whereas strength/weight was more important to males in SL. These findings were further supported by Gettman (1974) where total leg strength correlated significantly with performance in all three events for females and in DH and GS for males among a group of junior Alpine skiers. Song (1982) found that grip strength was the only strength variable that was significantly correlated with performance in DH and GS, and the strength of the elbow, hip and trunk were significantly correlated with GS alone. Thorstensson et al. (1977) demonstrated that elite downhill skiers have high levels of both isometric and dynamic strength. However, dynamic strength of Alpine skiers at 180°/sec was lower than that of sprinters and jumpers.

Haymes and Dickinson (1980A) stated that vertical jump was useful in predicting success in SL for men, and Gettman (1974) indicated significant correlations between vertical jump and success in all Alpine events for junior male skiers.

Flexibility

The movement of any body segment with respect to another segment is universal for all parts of the body (Leighton, 1966). Flexibility is an important component of an athlete's physiological make-up.

There are few studies that have investigated the flexibility of Alpine skiers. However, it is generally well known that flexibility is an important component for success in athletic performance. National, divisional, and club Alpine skiers proved to be more flexible than non-athletes in the flexibility scores for sit and reach, trunk extension, trunk flexion, trunk lateral flexion and hip ad-abduction (Brown and Wilkinson, 1983). Scott (1974) indicated that 20% of performance in Alpine skiing depends on flexibility/agility. Song (1982) measured the flexibility of 5 joints in junior Alpine skiers and found that the skiers had significantly greater flexibility on only the hip flexion-extension test compared to age-matched control subjects. However, none of the flexibility measurements were significantly correlated with performance.

Effective flexibility programs for Alpine skiers might reduce the risk of injury (Karlsson, 1984) and allow the performance of optimal technique (Brown and Wilkinson, 1983). It appears that above a minimum level of flexibility, performance ability of Alpine ski racing is not associated with further development of flexibility (Brown and Wilkinson, 1983; Song, 1982). Agility can be improved with exercises in flexibility that have a speed component (Song, 1982).

Pulmonary Function

The rhythmic inspiration and expiration of air in and out of the lungs is known as pulmonary ventilation. Ventilation ($\dot{V}E$) increases during exercise and is directly proportional to increases in the O_2 consumed and CO_2 produced by the working muscle (Mathews and Fox, 1981). Under maximal exercise VE is regulated more to the need for CO_2 removal than to O_2 consumption (Sutton and Jones, 1979). $\dot{V}E$ does not normally limit the capacity of the cardiorespiratory system (Mathews and Fox, 1981). Athletes, especially endurance athletes, tend to have lower $\dot{V}E$ during exercise at given work loads or O_2 consumptions and at given CO_2 productions (Mathews and Fox, 1981). Though not entirely known, it has been suggested that the physiological reason for this is related to diminished peripheral chemoreceptor function (Byrne-Quinn, Weil, Sodal, Filley, and Grover, 1971; Martin, Weil, Sparks, McCullough, and Grover, 1978), and genetic familial influences (Collins, Scoggin, Zwillich, and Weil, 1978; Scoggin, Doekel, Kryger, Zwillich, and Weil, 1978). It has been suggested that the low ventilatory response to exercise may be linked to outstanding endurance athletic performance (Martin, Sparks, Zwillich, and Weil, 1979).

Forced Vital Capacity (FVC) is the vital capacity (VC) performed with expiration as forceful and rapid as possible. The absolute volume of FVC is important in that it is an index of the state of the elastic properties of the respiratory system. The rate of exhalation from the lungs predominately reflects flow-resistive properties (Cherniack, 1977). Most testing of pulmonary function assess flow resistance by an analysis of the volume of air expired in a particular time, usually in one second ($FEV_{1.0}$). Other commonly used analyses involve estimates of the rate of air flow during the middle half of the forced expired vital capacity. Many investigators of pulmonary function are interested in the flow-volume relationship. This is the rate of air flow as well as volume change during the forced expiratory manoeuvre (Cherniack, 1977).

During exercise there are two major changes in VE. Firstly, there is a rapid increase in VE within a few seconds after the start of exercise. This is mainly a result of nervous stimulation (Mathews and Fox, 1981). Secondly, this rapid increase is replaced by a slower increase, which in submaximal exercise tends to reach a steady state. In maximal exercise, VE continues to increase until the exercise is terminated. These changes are thought to be stimulated by chemical stimuli, mainly from the CO_2 in the blood produced during exercise (Mathews and Fox, 1981).

Song (1982) reported mean VC for junior Alpine skiers as 3.96 liters. However, the result was not significantly correlated with performance.

Brown and Wilknson (1983) studied $\dot{V}E$ max values of National and club male Alpine ski racers. They reported differences of 156 l/min for National skiers and 149 l/min for club skiers. Haymes and Dickinson (1980B) found $\dot{V}E$ max values of elite male and female Alpine ski racers were 173 l/min and 112 l/min, respectively, and that of the elite male and female cross-country skiers were 200 l/min and 124 l/min, respectively.

Aerobic Power

In assessing an individual's capacity for prolonged work the determination of his maximal oxygen uptake ($\dot{V}O_2$ max) per unit time has a fundamental importance and is an excellent indicator of aerobic fitness (Astrand and Rodahl, 1986). An increase in aerobic metabolism will occur after approximately 2 minutes of maximal exercise which will be reflected by a similar increase in $\dot{V}O_2$ max (McArdle, Katch, and Katch, 1986). The effects of training on the amount of oxygen that can be consumed per minute during maximal exercise has been studied extensively; there is little doubt that it is increased with training (Astrand and Rodahl, 1986; Eriksson, et al., 1977A; Saltin and Astrand, 1967).

Elite Alpine skiers have a high aerobic power compared to a "normal" population (Brown and Wilkinson, 1983; Karlsson, 1984; Karlsson, et al., 1978; Rusko, Havu, and Karvinen, 1978). Eriksson et al. (1977A) stated that the aerobic demands of competitive Alpine skiing may approach the maximal aerobic power of the athlete. This is supported by the maximal heart rates and high oxygen uptake observed on completion of a race (Haymes and Dickinson, 1978; Haymes and Dickinson, 1980B; Karlsson et al., 1978). Karlsson et al. (1978) reported that elite ski racers performing in GS have reached 95% of $\dot{V}O_2$ max, whereas less skilled skiers never exceed 65 to 75% of $\dot{V}O_2$ max (Tesch et al., 1978). A skiers heart rate may reach 160 beats/min in the start gate which is attributed to emotional and nervous factors (Astrand and Rodahl, 1986). When the race begins, the heart rate accelerates rapidly and maximal values are achieved in the latter part of the course (Karlsson et al., 1978; Veicsteinas, Ferretti, Margonato, Rosa, and Tagliabue, 1984).

Elite male ski racers from the Finnish National team showed an average $\dot{V}O_2$ max of 63.8 ml/kg/min (Rusko et al., 1978). The Swedish National team reported a similar value of 70 ml/kg/min (Eriksson et al., 1977A), and the U.S. National team averaged 60.1 ml/kg/min (Haymes and Dickinson, 1980A). Ingemar Stenmark, a World Cup champion, had a $\dot{V}O_2$ max of 70 ml/kg/min. The high $\dot{V}O_2$ max values shown by elite Alpine skiers may reflect aerobic endurance training by the athletes and not the actual demands of the sport (Karlsson, 1984). However, ski racers with high oxygen uptakes can work aerobically longer without depending entirely on energy from anaerobic metabolism and can exert strong, powerful contractions, endure sustained work, and recover quickly from high intensity tasks (Song, 1982). This may be of more benefit during prolonged training bouts than on the race day. However, Haymes and Dickinson (1980A) used a battery of tests that included aerobic power, isometric leg extension strength, leg muscular power, leg response time, balance, agility, and body composition to assess the US Alpine ski team. They reported that $\dot{V}O_2$ max was the single most important factor in predicting performance in DH for females and was significantly correlated with SL performance for men. These results were supported by Song (1982) who also found that $\dot{V}O_2$ max was significantly correlated with performance in DH. $\dot{V}O_2$ max also correlated significantly with FIS points (Federation International de Ski) for SL performance of female members of the US Alpine ski team (Haymes and Dickinson, 1980A).

Tesch et al. (1978) observed a higher contribution of aerobic metabolism associated with a higher recruitment of ST fibers in skilled skiers. Unskilled skiers recruited relatively fewer ST fibers. Gollnick et al. (1973) indicated the FT fibers produce more lactate than ST fibers. This appears to indicate that aerobic sources play an important role in supplying energy for skillful skiing (Tesch et al., 1978).

Karvonen, Rauhala, Chwalbinska-Moneta, and Hänninen (1985) studied changes in aerobic power during the competitive season. The results of three months of SL training increased $\dot{V}O_2$ max from 38.0 to 41.2 ml/kg/min in women but remained unchanged for the men. Haymes and Dickinson (1978) performed pre-season tests on ten members of the US women's Alpine ski team in August and post-season tests in April. There was little emphasis made by coaches on cardiorespiratory training during the season and consequently $\dot{V}O_2$ max decreased from 53.1 to 48.6 ml/kg/min (Haymes and Dickinson, 1978). It was suggested that the 7.5% decline in $\dot{V}O_2$ max amongst the US National ski team over the eight month period was attributed to a lack of opportunity to train aerobic fitness. On-snow training that consists of free-skiing, running gates, and exercise courses does not place a great enough demand on the cardiorespiratory system to maintain $\dot{V}O_2$ max throughout the ski season. On-snow training decreases the time available for dryland training and specifically aerobic training.

Anaerobic Power and Capacity, and Energy Sources

Studies pertaining to the physiological effects of training on the anaerobic system (ATP-CP, Lactic Acid) cite four main adaptations. First of all, there is an increase in the resting levels of ATP-PC, free creatins, and glycogen (McArdle et al., 1986). Secondly, there is an increase in the quantity and activity of the enzymes that are responsible for controlling the anaerobic phase of glucose breakdown (Sharkey, 1986; McArdle et al., 1986). Thirdly, there is an increase in muscle capacity to withstand greater amounts of lactic acid before fatigue sets in and, finally, there is an increase in the size of muscle fibers (McArdle et al., 1986; Mathews and Fox, 1981).

Energy systems for various types of activities, such as rowing, swimming, running, and bicycling, have been analyzed in detail in the laboratory using specially adapted ergometers

(Astrand, and Rodahl, 1986). However, for sports such as Alpine ski racing, that involve a great variety of movements of almost every muscle group, proper laboratory ergometers have yet to be developed (if, in fact, they can be developed). Therefore, any accurate physiological study of the energy systems utilized in Alpine skiing will have been carried out on the mountain. The problems arising from this have prevented extensive research in the field and, therefore, there are relatively few studies that can be used for reference.

However, Alpine skiing has been classified as an anaerobic activity as each of the four Alpine disciplines lasts for up to 1.0 minutes and no more than 2.5 minutes (Tesch et al., 1978). Each discipline places close to maximal demands on the circulatory system (Karlsson et al., 1978; Eriksson et al., 1978). The skill of turning around poles, absorbing gravitational and centrifugal forces, and coping with undulations in the terrain, mostly involves isometric contraction of the leg musculature throughout the entire duration of the event.

According to Veicsteinas et al. (1984) the percentage input of each energy system that corresponds to elite performance in both SL and GS is approximately 40% aerobic, 40% lactic and 20% alactic metabolism. Saibene et al. (1985) indicated a higher aerobic energy yield of approximately 46%, reducing lactic metabolism to 26% and increasing alactic metabolism to 28%. Therefore, the overall anaerobic contribution (alactic plus lactic acid) to energy metabolism amounts to approximately 55 to

65%. This high anaerobic contribution may be due, in part, to intense static work of some muscle groups (Tesch et al., 1978).

Improvements in anaerobic power following training can be attributed to increases in the ATP-CP concentration in the muscle (Karlsson, Nordesjo, Jorfeldt, and Saltin, 1974). As a result of increased alkaline reserves (Mathews and Fox, 1981) an athlete is able to tolerate increases in oxygen debt and blood lactate concentration (Cunningham and Faulkner, 1969).

Blood lactate concentration appears to vary between 10 to 13 mM/L of blood after performing either SL or GS. As SL is approximately 20 seconds shorter than GS, Veicsteinas et al. (1984) estimated the rate of LA accumulation to be 1.5 times higher in SL than GS. However, the energy expenditure during SL and GS may vary substantially from one subject to the next. In fact, small changes in snow formation around the SL and GS poles, and differences in skill, technique, and mechanical work, even in elite ski racers, results in large differences in energy expenditure. These findings, however, indicate that SL at an elite level is more demanding than GS anaerobically, even though it is a shorter duration event.

Eriksson et al. (1978) claimed that demands on the circulatory system (derived from heart rate recordings) was maximal or nearly maximal during GS competition. However, Saibene et al. (1985) indicated that increased muscle tone, which takes place almost rhythmically every turn, seems to impede oxygen delivery. As a consequence, anaerobic metabolism is increased.

Anaerobic Threshold

The importance of anaerobic threshold (AT) and its role in competitive sports has been known to coaches, sports scientists, and athletes for some time. However, though AT is an accepted physiological principle, the method of identification has become one of the most controversial issues of exercise physiology to date. Nevertheless, to the coach the notion of a "performance threshold" is a very real entity (Brooks, 1985).

Wasserman, Whipp, Koyal, and Beaver (1973) define AT as the point at which blood lactate begins to accumulate. More recently, however, Brooks (1985) has commented on the mechanisms of lactate production, accumulation, and removal. Brooks (1985) states that AT is not necessarily due to a sudden increase in production of lactate but to a difference between the rate of removal and rate of accumulation of lactate. Therefore, AT is defined as the level of work of oxygen consumption just below the onset of metabolic acidosis. In other words, AT is the point during exercise whereby the workout intensity is increased and anaerobic metabolism is required to supply energy at which point lactate accumulation increases beyond the rate of lactate removal (Brooks, 1985; Duvillard, 1988).

The concept of AT is closely related to the percentage of $\dot{V}O_2$ max that can be maintained for a long period of time. AT can be closely estimated by means of respiratory gas exchange measures, especially changes in pulmonary ventilation ($\dot{V}E$), carbon dioxide production ($\dot{V}CO_2$), and ventilatory equivalent of oxygen ($\dot{V}E/\dot{V}O_2$). As these parameters deviate from linearity this signifies the onset of AT, while the increase of level of work remains linear (Davis, 1985; Wasserman et al., 1973). AT is most often referred to as a percentage of $\dot{V}O_2$ max. The onset of AT in Alpine skiing expressed in percent of $\dot{V}O_2$ max indicates the transition from aerobic to anaerobic metabolism. Well conditioned athletes will reach the onset of AT at a higher $\dot{V}O_2$ than poorly conditioned or sedentary individuals (Duvillard, 1988).

It is important that AT should not be confused with "intensity" threshold. Intensity threshold is established as a percent of $\dot{V}O_2$ max which a ski racer can maintain for a prolonged time. The higher the intensity of exercise the shorter the duration. In other words, the higher the intensity threshold the greater demand is put on the anaerobic metabolism and consequently the duration of exercise is shortened (Duvillard, 1988). A high intensity threshold is also desirable as the ski racer will be able to rely on a relatively higher aerobic metabolism before switching over to anaerobic metabolism.

Summary

Besides the difficulty of assessing the relative contribution of the different energy sources from the studies cited, it appears that there is a need to train aerobic energy systems as well as anaerobic lactic systems more or less equally. Agility appears to be a necessary component in overall fitness and can be improved with flexibility and strength exercises that have an agility (speed) component. Muscular strength and power are considered highly important especially in both isometric and dynamic strength in knee extensors and quadricep muscles. As a result, ski racers should concentrate on improving the production of force and neuro-muscular coordination in order to obtain better results in SL and GS (Pedersen, 1978A). Exercises should be as specific to skiing performance as possible for maximum effect (Pedersen, 1978B).

Anaerobic threshold is simply an indicator of metabolic change from aerobic to anaerobic metabolism (Duvillard, 1988). Workloads or intensity threshold workouts below the AT level are less likely to produce a valuable training effect in competitive Alpine skiing.

Chapter 3

METHODS AND PROCEDURES

Research Design

A group study approach was employed to explore the effects of seasonal training on anthropometry, muscular strength and power, motor ability, flexibility, aerobic power, and anaerobic power and capacity.

The Subjects

The subjects in this study were 21 male junior ski racers ranging in age from 11 to 16 years, all members of the Lake Superior Ski Division. The subjects were familiarized with the experimental procedures prior to their participation. Both written and verbal consent were obtained from the subjects and their parents.

All the subjects had competed in local and provincial level races and selected older members (15 and 16 years old) had competed in national level races. The characteristics of subjects are shown on Table 1.

Investigative Period

The investigative period was from early November 1986 to late March 1987.

Table 1

Characteristics of Subjects

Subject (# & initials)	Age (yrs)	Height (cm)	Weight (kg)
1. TB	16	177.2	66.6
2. SC	14	155.5	44.8
3. JC	16	174.7	70.5
4. GC	16	155.3	44.9
5. SD	14	176.5	50.6
6. TD	12	163.5	52.2
7. RD	14	168.0	53.6
8. JF	12	142.5	35.9
9. WF	12	151.5	41.6
10. WC	11	147.0	39.7
11. JG	13	154.3	47.6
12. CH	16	179.5	77.3
13. SH	15	179.5	62.7
14. WJ	15	174.0	64.3
15. JL	13	152.7	43.1
16. MM	16	175.3	65.9
17. SM	14	178.9	65.7
18. RP	16	179.0	59.0
19. RR	13	171.0	63.3
20. DR	15	171.3	66.0
21. JY	15	168.0	50.9
Mean	14.2	166.4	55.5
Standard Deviation	1.6	12.0	11.6
Range	11 - 16	142.5 - 179.5	35.9 - 77.3

Training Schedule and Procedure

The training schedule was developed and administered by the coaches of Lake Superior Ski Division.

Each Tuesday and Thursday evenings were designated as dry land fitness training sessions (early November to late March). All methods of fitness training were recorded (see Appendix A). Most weekends throughout the season (December to March) were reserved for competitions, the remainder being used for on-snow technical training. Wednesday afternoons (2 to 3 hours) and Friday evenings (2 to 3 hours) were also used for on-snow technical training. Competitions and on-snow training were recorded for each subject (see Appendix B). The training procedures followed an outlined annual training plan (see Appendix C).

Testing Schedule

Each subject visited the Human Performance Laboratory at Lakehead University on two separate occasions: pre-season testing (early November) and post-season testing (late March). The subjects were tested at the same time and day of the week to avoid diurnal variations.

Pre- and Post-Season Testing Procedures

For both testing sessions subjects were asked to report to the laboratory prepared for the tests. The subjects were instructed to avoid any vigorous activity for at least twenty four hours before testing and to refrain from eating, taking medication, or drinking anything except water for the two hours prior to the VO_2 max testing.

Upon arrival at the laboratory each subject's age, weight, and height were recorded.

Anthropometeric Measurements

Anthropometry was assessed following the International Biological program (Weiner and Lourie, 1969). Weight was measured to the nearest one-tenth of a kilogram using a balance scale (Continental Scale Corporation, Bridgeview, Illinois). The subject was dressed in shorts and a t-shirt, without footwear. Height was measured to the nearest .5 cm. Skinfold measurements were taken using a Harpenden Skinfold Caliper. The contact surfaces of the caliper exerted a calibrated constant pressure of approximately 10 gm/mm^2. Percentage body fat was estimated from the skinfold thickness using the method of Durnin and Wormersley (1974), where four sites (bicep, tricep, subscapular, and suprailiac) are added together to give the total skinfold thickness.

Muscular Strength and Power, and Motor Ability

Muscular strength and power were evaluated using the Dual Channel Cybex II isokinetic unit. This analysis provided a comparison of individual left to right leg strength levels. A graph recorder registered a readout in absolute foot-pounds of torque for muscular contractions at pre-selected, controlled velocities. Each of these variables was then subdivided into values equivalent to absolute and per kilograms of body weight. Two repetitions of isometric contraction recorded strength of the quadricep muscle group, 0°/sec and at 90° flexion, and fifty repetitions of torque setting 180°/sec recorded endurance strength of quadricep and hamstring muscle groups in both right and left legs.

Grip strength was measured using a Stoeling hand dynamometer. The dynamometer was placed in the subject's palm, dial up, fingers curled over, and the second and third knuckles touching the grip. The subjects arm was kept by their side, away from the body throughout the test. The subject was instructed to contract against the apparatus with a maximum effort. The best out of three attempts was recorded.

Motor ability was tested using two vertical jump tests. One test followed the protocol developed by Sargent (1921), the second was modified as subjects wore ski boots to measure vertical jump with the restriction of ankle flexion.

The high box jump and hexagonal jump developed by Kornexl (1977) were used to measure muscular power and motor ability. The high box jump protocol required the subject to jump up onto a 40 centimeter high box and down to the floor. The total number of complete jumps was recorded. The hexagonal jump protocol required the subject to jump around a hexagon built with loosely mounted plastic pipes which were placed at various heights. The subject completed three revolutions of the hexagon and the total time taken was recorded. The techniques used to measure vertical jump, high box jump and hexagonal jump are described in greater detail in Appendix D.

Flexibility

The sit and reach test was used to measure hamstring flexibility. Each subject was given three attempts prior to three measurements. The best result of three trials was recorded.

The Leighton Flexometer (Leighton, 1966) was used to measure ankle and knee flexion and extension, trunk lateral flexion, and hip rotation. Each subject was given three attempts prior to three measurements. The best result of three trials was recorded. The reliability coefficeint of the Leighton's flexometer for 21 subjects ranged from .92 to .99. The techniques used to measure flexibility are described in Appendix E.

Pulmonary Function

Pulmonary function was determined using the autospirometer AS-700 (Minato Medical Science). Three attempts were made, and the highest FVC value reading was recorded.

Measuring $\dot{V}O_2$ max

The test protocol for measuring $\dot{V}O_2$ max was taken from

Physiological Testing of the Elite Athlete, (McDougall, Wenger, and Green, 1982). A Monark mechanically braked cycle ergometer was used to measure $\dot{V}O_2$ max. The initial work load (300 - 600 kpm), varied depending upon age and sex and increased by .5kp every two minutes until the point of exhaustion. A metronome was set at 120bpm (60 revolutions/min) and this rhythm was maintained throughout the test by the subject. Each subject was given strong verbal encouragement to help attain maximum effort during the test.

Criteria for Attaining $\dot{V}O_2$ max:

1. As the work load increased the subjects $\dot{V}O_2$ reached a plateau or began to decrease.
2. The RER value had to be greater than 1.10.
3. The observed heart rate (HR) had to be close to the subject's personal maximum or the anticipated age maximum.
4. The subject became volitionally exhausted.

Criteria for Termination of Test:

1. Unusual or intolerable fatigue.
2. Facial expression signifying disorders (strained or blank facies).
3. Cyanosis or pallor (facial or elsewhere).
4. Dizziness.
5. Intolerable claudication or pain.

Gas Analysis:

Expired air samples were collected continuously and analyzed every 15 seconds, using a pre-calibrated, computerized Sensormedics Metabolic Measurement Cart (MMC II). Along with the continuous presentation of time, $\dot{V}O_2$, $\dot{V}E$, RER, and HR was displayed every 15 seconds on the system's visual read out screen and was printed. As well, the values for $\dot{V}EO_2$, $\dot{V}ECO_2$, $\dot{V}O_2$/kg/min, FEO_2, $FECO_2$, and time were printed every 15 seconds until the test was completed.

Heart Rate:

Heart rate (HR) was monitored continuously with a three lead (Cambridge, VS4 model) electrocardiograph, integrated via digital analog to the Sensormedic MMC II system.

Anaerobic Power and Capacity

Anaerobic power and capacity was determined according to the test protocol developed by Bar Or, Dotan, and Inbar (1977). The subject was instructed to pedal a cycle ergometer as fast as possible at a fixed work load for a 30 second duration. The work load varied depending on the age and weight of the subject; under 15 years of age the workload was 35g/kg body weight, 15 years of age and over the workload was 75g/kg body weight. The resistance was adjusted in the first 2 or 3 sec and at that time the electronic, computerized counter, as well as a mechanical counter connected to the ergometer's flywheel were activated.

The number of pedal revolutions were recorded every 5 sec. A television monitor connected to the electronic counter provided visual feedback to the subject by displaying the number of revolutions recorded after each 5 sec interval. Upon completion of the test each subjects results were printed.

Anaerobic power was calculated using the 5 sec interval with the highest number of pedal revolutions recorded. This was then multiplied by resistance (kpm) and the circumference of the flywheel (6m), divided by body weight, and expressed as watts/kg.

Anaerobic capacity was calculated using the total number of revolutions for 30 seconds, multiplied by resistance and circumference of the flywheel (6m), divided by body weight, and expressed as joules/kg.

Determination of the Anaerobic Threshold

Two criteria were used to locate each subjects AT: an increase in the ventilatory equivalent for O_2 without an increase in ventilatory equivalent for CO_2 and an increase in FEO_2 at the peak point of $FECO_2$. These are identical criteria to those recommended by Davis, Frank, Whipp, and Wasserman (1979) whose findings reported a correlation coefficient of .95. Anaerobic threshold was determined by averaging analyses of two investigators using the above criteria (three analyses per investigator).

Data Analysis

Means and standard deviations were obtained for all variables, and paired t-tests were used. The Pearson Product-Moment correlation coefficient was used to establish the relationship between SL and GS and independent variables. Stepwise multiple regression analyses was performed using the variables which were significant ($p<.05$) and the regression equations of SL and GS were established.

Chapter 4

RESULTS

The general characteristics of each subject are presented in Table 1. The results of pre-season and post-season testing, and the mean and standard deviation were computed for each variable using a paired t-test. Table 2 presents a comparison of the pre- and post-season test results as well as the percentage change and probability level for each variable. The results showed that there was a statistically significant improvement in SL performance. A significant improvement in hip rotation degree and a significant drop in endurance strength of the left hamstring was also revealed.

Pearson Product-Moment Correlation Analyses

Significant ($p<.05$) correlations coefficients were found between performance and the selected variables during pre- and post-season testing and the results are presented in Tables 3 to 6. A correlation coefficient (r) of .37 was required for significance at the .05 level.

Table 2

Ski Performance, Anthropometry, Muscular Strength and Power, Motor Ability, Flexibility, Pulmonary Function, Aerobic Power, Anaerobic Power and Capacity, and Anaerobic Threshold

Variables	Pre-season	Post-season	% Change	Probability
Slalom (sec)	44.8 ± 4.8+	41.1 ± 3.2	8.24↓	.006**
Giant SL (sec)	29.6 ± 2.2	28.8 ± 1.3	2.57↓	.177
% Body Fat	18.9 ± 4.6	18.5 ± 4.3	2.12↓	.768
Skinfold (mm)	30.8 ± 11.9	34.0 ± 14.0	10.39↑	.431
VJ With Boots (cm)	29.5 ± 8.6	31.7 ± 8.2	7.46↑	.415
VJ Without Boots (cm)	46.7 ± 9.0	48.3 ± 9.0	3.43↑	.552
Hexagonal Jump (sec)	22.6 ± 5.1	21.5 ± 4.2	5.00↓	.437
High Box Jump (rep)	59.4 ± 12.5	62.5 ± 14.9	5.22↑	.465
Grip Strength Right (kg)	39.2 ± 10.8	40.9 ± 12.3	4.34↑	.643
Grip Strength Left (kg)	36.7 ± 11.0	38.5 ± 11.9	4.91↑	.610
Quadricep "0°" Right (Nm)	177.0 ± 56.1	181.0 ± 54.7	2.26↑	.816
Quadricep "0°" Left (Nm)	174.5 ± 52.9	175.9 ± 55.0	8.02↑	.934
Fatigue Index Quad. Right (%)	54.3 ± 11.5	53.1 ± 10.6	2.21↓	.708
Fatigue Index Quad. Left (%)	52.1 ± 8.6	51.6 ± 8.8	0.96↓	.860

+ : mean ± SD.

** : $p<.01$

↑ : increase ↓ : decrease

SL = Slalom Quad. = Quadricep
VJ = Vertical Jump Ham. = Hamstring

Skinfold = Σ of bicep, tricep, subscapula, & suprailliac skinfolds (Durnin and Wormersley, 1974).

Table 2 Continued

Variables	Pre-season	Post-season	% Change	Probability
Fatigue Index Ham. Right (%)	68.4 ± 14.4+	63.2 ± 13.2	7.60↓	.230
Fatigue Index Ham. Left (%)	67.1 ± 12.9	59.3 ± 11.2	11.62↓	.044*
Sit & Reach (cm)	14.5 ± 6.7	15.5 ± 7.5	6.70↑	.650
Ankle Flex. & Extens. Degree	64.5 ± 7.4	68.7 ± 8.1	6.51↑	.085
Knee Flex. & Extens. Degree	152.2 ± 6.6	149.8 ± 7.8	1.58↓	.282
Trunk Lateral Flexion Degree	112.2 ± 19.8	113.3 ± 13.4	0.98↑	.842
Hip Rotation Degree	92.1 ± 12.7	117.3 ± 15.0	27.36↑	.000***
Forced Vital Capacity (L)	3.4 ± 0.9	3.7 ± 1.0	6.40↑	.469
$\dot{V}O_2$ max (l/min)	3.1 ± 0.7	3.3 ± 0.8	6.52↑	.384
$\dot{V}O_2$ max (ml/kg/min)	54.3 ± 6.2	57.0 ± 4.5	4.97↑	.105
Anaerobic Threshold (%)	69.4 ± 6.0	73.2 ± 6.5	5.48↑	.054
Anaerobic Power (watt/min/kg)	8.5 ± 2.6	8.1 ± 2.6	5.04↓	.602
Anaerobic Cap. (joules/min/kg)	419.9 ± 105.0	407.5 ± 112.8	2.95↓	.715

+ : mean ± SD.

* : $p<.05$ *** : $p<.001$

↑ : increase ↓ : decrease

Flex. = Flexion
Extens. = Extension
Cap. = Capacity

As can be seen in Table 3, eight significant correlations were found between pre-season performance and anthropometric variables. Age, weight, and height were correlated significantly (r=-.88,-.73, and -.70, respectively) with SL and (r=-.87,-.64, and -.64, respectively) with GS. Percent body fat and skinfold measurements correlated significantly (r=.40 and .37, respectively) with GS alone.

Ten significant correlations were found between post-season performance and anthropometric variables (see Table 5). Age, weight, height, percent body fat, and skinfold were correlated significantly (r=-.85,-.66,-.64, .46 and .44, respectively) with SL and (r=-.83,-.61,-.57, .42, and .39, respectively) with GS.

For pre-season muscular strength and power variables and SL performance (see Table 3), 8 out of 12 were significantly correlated (p<.001). The same 8 variables also correlated significantly (p<.001 for 7 variables and p<.01 for 1 variable) with GS. Only 1 out of 5 flexibility variables correlated significantly (r=.42) with both SL and GS performance from pre-season tests (see Table 4). Post-season tests for muscular strength and power showed that the same variables correlated with SL and GS performance as with pre-season tests, though the r values were not the same.

Anaerobic power and capacity correlated significantly (p<.001) with SL and GS performance for both pre- and post-season tests (see Tables 4 and 6). Forced vital capacity correlated significantly with SL and GS (r=-.71 and r=-.67, respectively) for the pre-season tests and (r=-.75 and r=-.68) for the post-season tests (see Tables 4 and 6).

The results of both pre- and post-season tests showed that $\dot{V}O_2$ max (l/min) correlated significantly (p<.001) with SL and GS performance, whereas $\dot{V}O_2$ max (ml/kg/min) correlated significantly (p<.05) with pre-season GS performance alone (see Tables 4 and 6).

Furthermore, many significant intercorrelations between the 30 variables were found (see appendices H and I).

Significant Intercorrelations Among Variables

Five significant intercorrelations occurred among anthropometric measures. As would be expected with this age group (11 to 16), age, weight, and height were highly correlated (p<.001) with each other. Percent body fat also correlated with age.

Forty seven out of a possible sixty six significant intercorrelations were recorded among twelve muscular strength and power variables. This suggests a general strength factor exists between the legs and grip strength. Fatigue index of quadricep and hamstring muscle groups showed few intercorrelations with other variables. It appears from the results that the individual muscle groups primarily in the legs of Alpine skiers may show some close relation, i.e., a degree of strength in one muscle group results in a similar degree of strength in the other muscle groups.

Table 3

Significant Correlation Coefficients Between Pre-season Performance & Selected Variables

Performance	Variables	r
	Anthropometry	
Slalom	Age	-.88***
	Weight	-.73***
	Height	-.70***
Giant Slalom	Age	-.87***
	Weight	-.64**
	Height	-.63**
	% Body Fat	.40*
	Skinfold	.37*
	Muscular Strength & Power	
Slalom	Vertical Jump With Boots	-.68***
	Vertical Jump Without Boots	-.79***
	Hexagonal Jump	.70***
	High Box Jump	-.72***
	Grip Strength Right	-.71***
	Grip Strength Left	-.68***
	Quadricep "0" Degree Right	-.80***
	Quadricep "0" Degree Left	-.76***
Giant Slalom	Vertical Jump With Boots	-.60**
	Vertical Jump Without Boots	-.72***
	Hexagonal Jump	.70***
	High Box Jump	-.74***
	Grip Strength Right	-.73***
	Grip Strength Left	-.68***
	Quadricep "0" Degree Right	-.78***
	Quadricep "0" Degree Left	-.69***

* $p<.05$, ** $p<.01$, *** $p<.001$

Table 4

Significant Correlation Coefficients Between Pre-season Performance & Selected Variables

Performance	Variables	r
	Flexibility	
Slalom	Sit & Reach	$-.52^{**}$
Giant Slalom	Sit & Reach	$-.53^{**}$
	Anaerobic Power & Capacity	
Slalom	Anaerobic Power	$-.67^{***}$
	Anaerobic Capacity	$-.67^{***}$
Giant Slalom	Anaerobic Power	$-.67^{***}$
	Anaerobic Capacity	$-.67^{***}$
	Pulmonary Function	
Slalom	Forced Vital Capacity	$-.71^{***}$
Giant Slalom	Forced Vital Capacity	$-.67^{***}$
	Aerobic Power	
Slalom	$\dot{V}O_2$ max (l/min)	$-.75^{***}$
Giant Slalom	$\dot{V}O_2$ max (l/min)	$-.69^{***}$
	$\dot{V}O_2$ max (ml/kg/min)	$-.40^{*}$

* $p<.05$, ** $p<.01$, *** $p<.001$

Table 5

Significant Correlation Coefficients Between Post-season Performance & Selected Variables

Performance	Variables	r
	Anthropometry	
Slalom	Age	-.85***
	Weight	-.66**
	Height	-.64**
	% Body Fat	.46*
	Skinfold	.44*
Giant Slalom	Age	-.83***
	Weight	-.61**
	Height	-.57**
	% Body Fat	.42*
	Skinfold	.39*
	Muscular Strength & Power	
Slalom	Vertical Jump With Boots	-.51**
	Vertical Jump Without Boots	-.64**
	Hexagonal Jump	.80***
	High Box Jump	-.69***
	Grip Strength Right	-.73***
	Grip Strength Left	-.68***
	Quadricep "0" Degree Right	-.78***
	Quadricep "0" Degree Left	-.74***
Giant Slalom	Vertical Jump With Boots	-.46*
	Vertical Jump Without Boots	-.59**
	Hexagonal Jump	.80***
	High Box Jump	-.65**
	Grip Strength Right	-.68***
	Grip Strength Left	-.62**
	Quadricep "0" Degree Right	-.76***
	Quadricep "0" Degree Left	-.69***

* $p<.05$, ** $p<.01$, *** $p<.001$

Table 6

Significant Correlation Coefficients Between Post-season Performance & Selected Variables

Performance	Variables	r
	Flexibility	
Slalom	Sit & Reach	$-.65^{**}$
	Trunk Lateral Flexion	$-.63^{**}$
Giant Slalom	Sit & Reach	$-.68^{***}$
	Trunk Lateral Flexion	$-.60^{**}$
	Anaerobic Power & Capacity	
Slalom	Anaerobic Power	$-.74^{***}$
	Anaerobic Capacity	$-.75^{***}$
Giant Slalom	Anaerobic Power	$-.74^{***}$
	Anaerobic Capacity	$-.74^{***}$
	Pulmonary Function	
Slalom	Forced Vital Capacity	$-.75^{***}$
Giant Slalom	Forced Vital Capacity	$-.68^{***}$
	Aerobic Power	
Slalom	$\dot{V}O_2$ max (l/min)	$-.70^{***}$
Giant Slalom	$\dot{V}O_2$ max (l/min)	$-.65^{**}$

* $p<.05$, ** $p<.01$, *** $p<.001$

No significant intercorrelations between flexibility measures were found. This indicates that there is no general flexibility factor between sit and reach, ankle and knee flexion and extension, trunk lateral flexion, and hip rotation but that each joint has its own characteristic flexibility.

Twenty six significant positive correlations and six negative correlations were found between anthropometry and muscular strength variables. The negative correlations indicate an inverse relationship between the percent body fat and skinfold variables and the muscular strength variables. The results suggest that the age, weight, and height variables in particular relate closely to Alpine skiers' muscular strength.

Forced vital capacity was correlated with age, weight, and height which may suggest that greater age, weight, and height contributes to a greater potential FVC. FVC also correlated with 8 out of 12 muscular strength variables. In general, this implies that muscular strength assists in forceful expiration of air from the lungs.

Maximum oxygen uptake (l/min) significantly correlated with FVC and 8 out of 12 muscular strength variables.

As would be expected 19 out of 24 muscular strength variables were significantly correlated with anaerobic power and capacity. This implies that a strong relationship exists between muscular strength and anaerobic power and capacity.

Stepwise Multiple Regression Analyses

Separate analyses on SL and GS performance times were examined at pre- and post season tests with physical and physiological variables as the predictors. Fifteen variables that were found to be significantly correlated ($p<.05$) with SL and GS performance using the Pearson Product-Moment correlation analyses were selected for inclusion in stepwise multiple regression analyses. Using stepwise multiple regression, an equation was generated that would minimize the sum of squares deviations by using a weighted linear combination of predictors. A significant equation indicates that the equation provides a better than chance prediction. The higher the variance (R^2) accounted for, the stronger the relationship between SL and GS performance and physical and physiological variables. The stepwise regression analyses are most useful in describing the sample. However, the ratio of independent variables to subjects is not large enough to produce stable regression analyses.

In general, the stepwise multiple regression analyses revealed that age and hexagonal jump accounted for a large percentage of the variability for both pre- and post-season SL and GS performance (see Tables 7, 9, 11, and 13). Other variables with a significant ($p<.05$) correlation to performance accounted for the remaining variability.

The regression equation for pre-season SL performance revealed that age and hexagonal jump were the significant predictors at the $p<.05$ level of confidence and trunk lateral flexion was added at the $p<.10$ level of confidence (see Table 7). The regression equation for pre-season GS performance was significant, and the significant predictors were age and hexagonal jump (see Table 9).

The post-season SL performance regression equation was significant and revealed that, though age was still the dominant predictor, sit and reach accounted for more variability than hexagonal jump (see Table 11). The regression equation for post-season GS performance was significant and included 3 predictors, age, hexagonal jump, and trunk lateral flexion (see Table 13).

The independent variable "age" was removed from the stepwise multiple regression analyses for pre- and post-season SL and GS performance (see Tables 8, 10, 12, and 14) to investigate what other predictors would account for the variation. In general, isometric quadricep strength in the right leg accounted for most of the variance in 2 out of the 4 analyses (see Tables 8 and 10) and hexagonal jump accounted for most of the variance in the remaining 2 analyses (see Tables 12 and 14). Anaerobic power was the second most powerful predictor in pre-season SL and GS performance analyses (see Tables 8 and 10). With the age variable removed, trunk lateral flexion accounted for a small percentage or the variance in pre- and post-season SL performance and post-season GS performance analyses (10.1, 6.1, and 10.1%, respectively [see Tables 8, 12, and 14]). Percent body fat also accounted for some variance in post-season SL and GS performance analyses (5.6 and 8.7%, respectively [see Tables 12 and 14]). In the post-season GS performance analysis with the age variable removed, anaerobic capacity accounted for 3.7% of the variance.

Table 7

Stepwise Multiple Regression for Pre-season Slalom Performance

Step #	Variables in Equation	R	R^2	ß ($p<.10$)	ß ($p<.05$)
1	Age	.8771	.7692	-2.002	-2.156
2	Hexagonal Jump	.9075	.8235	.338	.271
3	Trunk Lateral Flexion			.047	-
	Constant			60.33	69.25

Note: $F(3,17) = 33.82$.

Table 8

Stepwise Multiple Regression for Pre-season Slalom Performance with Age Variable Removed

Step #	Variables in Equation	R	R^2	ß ($p<.10$)	ß ($p<.05$)
1	Quadricep "0" Degree Right	.8033	.6452	-.043	-.069
2	Anaerobic Power	.8396	.7049	-.580	-
3	Trunk Lateral Flexion	.8974	.8054	.085	-
4	Hexagonal Jump	.9154	.8380	.246	-
	Constant			42.23	57.06

Note: $F(4,16) = 20.69$.

Table 9

Stepwise Multiple Regression for Pre-season Giant Slalom Performance

Step #	Variables in Equation	R	R^2	ß ($p<.10$)	ß ($p<.05$)
1	Age	.8744	.7645	-.951	-.951
2	Hexagonal Jump	.9054	.8197	.121	.121
	Constant			40.36	40.36

Note: $F(2,18) = 40.93$.

Table 10

Stepwise Multiple Regression for Pre-season Giant Slalom Performance with Age Variable Removed

Step #	Variables in Equation	R	R^2	ß ($p<.10$)	ß ($p<.05$)
1	Quadricep "0" Degree Right	.7832	.6134	-.023	-.030
2	Anaerobic Power	.8271	.6842	-.273	-
	Constant			35.94	34.91

Note: $F(2,18) = 19.50$.

Table 11

Stepwise Multiple Regression for Post-season Slalom Performance

Step #	Variables in Equation	R	R^2	ß (p<.10)	ß (p<.05)
1	Age	.8513	.7247	-1.186	-1.186
2	Hexagonal Jump	.9072	.8231	.316	.316
	Constant			51.36	51.36

Note: $F(2,18) = 41.86$.

Table 12

Stepwise Multiple Regression for Post-season Slalom Performance with Age Variable Removed

Step #	Variables in Equation	R	R^2	ß (p<.10)	ß (p<.05)
1	Hexagonal Jump	.7963	.6341	.338	.338
2	Quadricep "0" Degree Right	.8674	.7523	-.016	-.016
3	Percent Body Fat	.8989	.8081	.219	.219
4	Trunk Lateral Flexion	.9320	.8687	-.068	-.068
	Constant			40.42	40.42

Note: $F(4,16) = 26.45$.

Table 13

Stepwise Multiple Regression for Post-season Giant Slalom Performance

Step #	Variables in Equation	R	R^2	ß (p<.10)	ß (p<.05)
1	Age	.8255	.6815	-.375	-.375
2	Hexagonal Jump	.8939	.7991	.134	.134
3	Trunk Lateral Flexion	.9177	.8422	-.024	-.024
	Constant			34.04	34.04

Note: $F(3,17) = 30.24$.

Table 14

Stepwise Multiple Regression for Post-season Giant Slalom Performance with Age Variable Removed

Step #	Variables in Equation	R	R^2	ß (p<.10)	ß (p<.05)
1	Hexagonal Jump	.8014	.6422	.144	.188
2	Trunk Lateral Flexion	.8619	.7429	-.035	-.038
3	Percent Body Fat	.9109	.8297	.071	.094
4	Anaerobic Capacity	.9310	.8668	-.003	-
	Constant			29.69	27.38

Note: $F(4,16) = 26.03$.

Chapter 5

DISCUSSION

The purpose of this study was to investigate the effects of seasonal training on selected physiological variables, and the relationship between these variables and SL and GS performance. A paired t-test revealed a significant improvement in hip rotation degree and a significant drop in endurance strength of the left hamstring. There were improvements in 19 out 27 variables between pre- and post-season testing, though the majority were not statistically significant.

It was also the purpose of this study to establish the regression equations to predict SL and GS performance for junior male Alpine ski racers. In general, the stepwise multiple regression analyses revealed that age and hexagonal jump accounted for a large percentage of the variability for both pre- and post-season SL and GS performance. Other variables with a significant ($p<.05$) correlation for performance accounted for the remaining variability. An analysis and discussion of the data are presented in this chapter under the headings of each selected physical and physiological variable.

Anthropometry

There are many studies that research anthropometry of elite athletes. An athletes physical build and muscular endowment can be related to performance in specific sports. Research has been performed on body size of elite athletes to determine what height and weight is optimal for specific sports (Orvanová, 1987). Ross and Day (1972) reported a significant negative relationship between height and performance of young Alpine skiers. They stated that shortness in competitive Alpine skiing may be an advantage due to the low centre of gravity which enhances stability. These findings were supported by Song (1982), where shorter leg length significantly correlated with DH performance and Chovanová (1976), where the best performers in Alpine skiing were shorter than the less skilled ones although the difference was not significant.

The average age of the subjects in this study (14.2 years) is lower in comparison to other studies on Alpine skiers. This most probably accounts for the smaller mean values for height and weight (166.4 cm and 55.5 kg, respectively) compared to the results found by Orvanová (1987) where elite Alpine skiers ranged from 172.5 to 179.0 cm in height and 69.3 to 77.6 kg in weight. In comparison to a study of ordinary Canadians of the same age by Nutrition Canada (1980), the subjects in this study were 7.3 cm taller and 7.8 kg heavier. These values support the findings of Karlsson (1984) who revealed that the successful skier is now taller and heavier than his predecessors. Andersen and Montgomery (1987) found that 10 divisional Alpine skiers, with an average age of 15.7 years, had a mean height of 175.8 cm and mean weight of 65.3 kg. The difference in age of the subjects in this study (1.5 years) would most likely account for the differences in height and weight.

Comparing the sum of four skinfolds of this study to percentile scores of the Canadian population (Canadian Fitness Survey, 1981) of the same age, resulted in an average score of between 55 and 60%. The predicted mean percent body fat for the pre-season test was 18.9% and the post-season test was 18.5%, respectively. When compared to other studies of elite Alpine skiers, the percent body fat is generally greater. However, the younger age of the athletes in this study may account for this difference as younger boys have approximately 4% higher body fat than adult males (Durnin and Rahman, 1967).

The stepwise multiple regression revealed that in each pre- and post-season SL and GS performance analyses age was the dominant predictor (see Tables 7, 9, 11, and 13). With a group of subjects ranging in age from pre- to post-puberty (11 to 16), this result was expected. However, a variety of other variables account for some of the variance and with the age variable removed an anthropometric variable, percent body fat, was accepted into the regression equation. Percent body fat became the third predictor for post-season slalom and post-season giant slalom performance (see Table 13).

Muscular Strength and Power, and Motor Ability

The results of this study indicated that all muscular strength and power variables were significantly correlated ($p < .001$) with SL and GS performance and were generally greater than that of subjects in a similar age group. These findings agree with others who have stated that muscular strength and power are considered important in Alpine skiing (Agnevik and Saltin, 1966; Astrand and Rodahl, 1986; Haymes and Dickinson, 1978; Haymes and Dickinson, 1980A; Karlsson et al., 1978; Song, 1982; Thorstensson et al., 1977) and that competitive Alpine skiers have a very high maximal isometric strength in their leg skeletal muscles (Eriksson et al., 1977A).

According to Thorstensson et al. (1977) elite sprinters, jumpers, and Alpine skiers had higher torque values than race walkers, orienteers, and sedentary men. When expressed relative to bodyweight, the Alpine skiers had the greatest peak torque (3.9 Nm/kg) during isometric contraction. The mean peak torque of the subjects in this study was 3.2 Nm/kg for the right quadricep muscle group and 3.1 Nm/kg for the left quadricep muscle group during isometric contraction. Thorstensson et al. (1977) stated that the crouched posture maintained by skiers for prolonged periods of time contributes to high isometric leg strength. This suggests that increases in isometric leg strength of the subjects in this study may be caused in part by skiing itself during the ski season.

Brown and Wilkinson (1983) reported club skiers with an average age of 17.1 had a mean vertical jump of 48.3 cm, divisional skiers 18.6 years old jumped 52.2 cm, and National skiers 21.9 years old jumped 54.2 cm. The skiers in this study are division level skiers but were 2.9, 4.4, and 7.7 years younger, respectively. They had a mean vertical jump of 48.3 cm which shows greater muscular strength for their age. McGinnis, Piper, and Dillman (1981) reported mean values for junior male Alpine skiers of the same age group for vertical jump, high box jump, and hexagonal jump (43.7cm, 70.5 reps, and 24.44 secs, respectively). In this study vertical jump (48.3 cm) and hexagonal jump (21.5 secs) were higher and high box jump (62.5 reps) was lower. However, this evidence shows that the explosive strength of the subjects in this study was above average for their age. Gettman (1974) reported significant correlations between vertical jump and SL and GS performance among junior male Alpine skiers, and Haymes and Dickinson (1980B) found that vertical jump was useful in predicting success in SL competitions. The regression analyses from this study show that hexagonal jump was useful in predicting SL and GS performance (see Tables 7 to 14) and the isometric strength in the right quadricep muscle group was useful in predicting SL performance for the post-season test, with the age variable removed (see Table 12). These findings support research by Shea (1983) who reported that the high box jump and hexagonal jump were the only motor assessment tests related to competitive Alpine skiing performance and that jump and reach, high box jump, Berg und Tal, and hexagonal jump tests can accurately predict GS performance 93% of the time.

Foss and Garrick (1978) reported that Alpine skiers have strong quadricep muscles compared to other sportsmen and agility can be improved through muscle strength. Song (1982) stated that skiers with the greatest relative strength work at a lower percentage of their maximal strength while skiing. With greater agility and less fatigue especially towards the end of a SL or GS competition, an elite Alpine skier may maintain a higher skill level where others may fatigue and become less efficient. The results of this study support the research by Foss and Garrick (1978) and Song (1982) as the subjects were generally stronger than those in a similar age group, and all the muscular strength and power variables showed 2.3 to 8.0% improvement between pre- and post-season tests.

The muscular endurance variables which were the fatigue index (FI) of right and left quadricep and hamstring muscle groups, were not statistically significant and showed a 2.2% decline in the FI of the right quadricep muscle group and a 0.96% decline in the FI of the left quadricep muscle group. This may be a result of pre-season dry-land muscular endurance training that is discontinued following the commencement of the competitive season. Alpine ski technique places equal demands on muscular endurance of both right and left legs. Though the FI of the right quadricep muscle group shows a greater decline than the left, the difference is not significant. The effects of dominance of muscular strength between right and left legs are controlled by the nature of dry-land and on-snow training.

Flexibility

It is generally well known that flexibility is an important component for success in athletic performance. Scott (1974) indicated that 20% of performance in Alpine skiing depends on flexibility/agility. Song (1982) measured the flexibility of 5 joints in junior Alpine skiers and found that the skiers had significantly greater flexibility on only the hip flexion-extension test compared to age-matched control subjects. In this study sit and reach was the only flexibility variable that was significantly correlated ($p<.01$) with SL and GS performance for both pre- and post-season tests. Trunk lateral flexion was also significantly correlated ($p<.01$) with SL and GS performance for the post-season test alone. Increases in the mean scores of sit and reach and trunk lateral flexion during the season agree in part with a study by Brown and Wilkinson (1983) who stated that National, divisional, and club Alpine skiers proved to be more flexible than non-athletes in the flexibility scores for sit and reach, trunk lateral flexion, trunk extension, trunk flexion, and hip ad-abduction. Comparing the flexibility scores of this study reveals that, though sit and reach showed a percent improvement between pre- and post-season tests, the mean was still 2.4 cm less than club Alpine skiers. However, trunk lateral flexion was 2.0 degrees greater than National Alpine skiers.

The stepwise multiple regression analyses revealed that trunk lateral flexion was useful in predicting SL and GS performance (see Tables 7, 8, 12, 13, and 14). This may be due to the trunk and hip flexibility required for skiing performance. Song (1982) reported that skiers had greater hip flexion-extension than age-matched control subjects. Though flexibility contributes to agility it is believed that flexibility is not very important for Alpine skiers total fitness (Song, 1982).

Pulmonary Function

The absolute volume of FVC is important in that it is an index of the state of the elastic properties of the respiratory system, whereas the rate of exhalation from the lungs predominately reflects flow-resistive properties (Cherniack, 1977).

Forced vital capacity was significantly correlated ($p<.001$) with SL and GS performance for both pre- and post-season tests. Though not significant, there was a 6.4% improvement between pre- and post-season tests.

The values of FVC in this study were lower than that of marathon runners (McArdle et al., 1986) and wrestlers (Song and Cipriano, 1984; McArdle et al., 1986). However, McArdle et al. (1986) stated that although some measures of lung function are sensitive indices of the severity of obstructive lung disease, they are of little use in predicting fitness or performance, provided that the values fall within the normal range. The mean values of FVC in this study were within the normal range.

Aerobic Power

Elite Alpine skiers have high aerobic power compared to a "normal" population (Brown and Wilkinson, 1983; Karlsson, 1984; Karlsson, et al., 1978; Rusko et al., 1978). Eriksson et al. (1977A) stated that the aerobic demands of competitive Alpine skiing may approach the maximal aerobic power of the athlete. This is supported by the maximal heart rates and high oxygen uptake observed on completion of a race (Haymes and Dickinson, 1978; Haymes and Dickinson, 1980B; Karlsson et al., 1978). Karlsson et al. (1978) reported that elite ski racers performing in GS have reached 95% of $\dot{V}O_2$ max, whereas less skilled skiers never exceed 65 to 75% of $\dot{V}O_2$ max (Tesch et al., 1978). Elite male ski racers from the Finnish National team showed an average $\dot{V}O_2$ max of 63.8 ml/kg/min (Rusko et al., 1978). The Swedish National team reported a similar value of 70 ml/kg/min (Eriksson et al., 1977A), and the U.S. National team averaged 60.1 ml/kg/min (Haymes and Dickinson, 1980A). The mean $\dot{V}O_2$ max (ml/kg/min) for this study was 57 ml/kg/min, which shows above average results for this age group compared to reports by Andersen (1988), Veicsteinas et al. (1984), and Haymes and Dickinson (1980A) on junior male and elite Alpine skiers.

Maximal oxygen uptake (l/min) proved to be significantly correlated ($\underline{p}<.01$) with SL and GS performance for both pre- and post-season tests. $\dot{V}O_2$ max (ml/kg/min) was significantly correlated ($\underline{p}<.05$) with GS for the pre-season test alone. In this study these results support the findings of Haymes and Dickinson (1980A) who reported that $\dot{V}O_2$ max was the single most important factor in predicting performance in DH for females and was significantly correlated ($p<.05$) with SL performance for men. Song (1982) also found that $\dot{V}O_2$ max was significantly correlated with performance in DH.

Karvonen et al. (1985) found no change in $\dot{V}O_2$ max in elite Alpine skiers after three months of SL training during the competitive season. This study found that after a four month period the percent increase in $\dot{V}O_2$ max (l/min) proved to be 6.5% and in $\dot{V}O_2$ max (ml/kg/min) proved to be 5.0%, though neither were significant. These improvements throughout the season may reflect long durations of repetitive skiing each day rather than the effect of limited dry-land training that did not include many aerobic endurance sessions.

Anaerobic Power and Capacity

Energy systems for various types of activities, such as rowing, swimming, running, and bicycling, have been analyzed in detail in the laboratory using specially adapted ergometers (Astrand, and Rodahl, 1986). However, for sports such as Alpine ski racing, that involve a great variety of movements of almost every muscle group, proper laboratory ergometers have yet to be developed (if, in fact, they can be developed). Therefore, any accurate physiological study of the energy systems utilized in Alpine skiing will have been carried out on the mountain. The problems arising from this have prevented extensive research in the field and, therefore, there are relatively few studies that can be used for reference.

Alpine skiing places demands on anaerobic power and capacity as well as aerobic power. It has been classified as an anaerobic activity as DH, the longest of the Alpine skiing events, usually lasts from 2 to 2.5 minutes at the elite level (Tesch et al., 1978). Karlsson et al. (1978) and Eriksson et al. (1978) reported that each discipline places close to maximal demands on the circulatory system . The skill required when turning, absorbing gravitational and centrifugal forces, and coping with undulations in the terrain, mostly requires isometric and slow isokinetic contractions of the leg musculature throughout the entire duration of the event.

Song (1982) stated that Alpine skiing is more dependent on the anaerobic lactate energy system and, therefore, anaerobic tests should last at least 30 seconds to fully challenge this energy system. Erikson et al. (1977) reported that the highest blood lactate concentration was recorded in GS, which indicates that aerobic demands are greatest in this event.

In this study, both anaerobic power and capacity proved to be significantly correlated ($p<.001$) with SL and GS performance for pre- and post-season tests. However, anaerobic power and capacity decreased, though not significantly, throughout the competitive season. This may have been the result of i) a decrease in anaerobic dryland training following the start of the competitive season, and ii) the duration of SL courses and some GS courses used for training that were often shorter than 30 seconds from start to finish would not have allowed an anaerobic training effect to take place.

The stepwise multiple regression analyses with the age variable removed, revealed that anaerobic power was useful in predicting pre-season SL and GS performance, and that anaerobic capacity was a predictor for post-season GS performance (see Tables 8, 10, and 14). These results agree with Karlsson et al. (1978) and Eriksson et al. (1978) who classified skiing as an anaerobic activity.

Anaerobic Threshold

The importance of anaerobic threshold (AT) and its role in competitive sports has been known to coaches, sports scientists, and athletes for some time. The concept of AT is closely related to the percentage of $\dot{V}O_2$ max that can be maintained for a longer period of time. AT can be closely estimated by means of respiratory gas exchange measures, especially changes in pulmonary ventilation ($\dot{V}E$), carbon dioxide production ($\dot{V}CO_2$), and ventilatory equivalent of oxygen ($\dot{V}E/\dot{V}O_2$). AT is most often referred to as a percentage of $\dot{V}O_2$ max. The onset of AT in Alpine skiing expressed in percent of $\dot{V}O_2$ max indicates the transition from aerobic to anaerobic metabolism. Well conditioned athletes will reach the onset of AT at a higher $\dot{V}O_2$ than poorly conditioned or sedentary individuals (Duvillard, 1988). Though not significant, the results of this study show a 5.5% increase in AT between pre-season (69.4%) and post-season

(73.2%) tests. These improvements throughout the season may reflect long durations of repetitive skiing during on-snow training rather than the effect of dry-land training.

Chapter 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this study was threefold: 1) to investigate the effect of seasonal training on anthropometry, muscular strength and power, motor ability, flexibility, aerobic power, and anaerobic power and capacity, 2) to investigate the relationships between physical and physiological variables in slalom (SL) and giant slalom (GS) performance, and 3) to establish the regression equations to predict SL and GS performance for junior male Alpine ski racers.

A group study research design was employed, which involved pre-season and post-season tests. Measurements of SL and GS performance were taken immediately after each test session. Twenty one junior male Alpine ski racers were assessed for: i) anthropometry following the International Biological program (Weiner and Lourie, 1969); ii) muscular strength, power, and endurance of quadricep and hamstring muscle groups using the Dual Channel Cybex II isokinetic unit and a Stoeling hand dynamometer and also using vertical jump, box jump, and hexagonal jump tests; iii) flexibility using the Leighton Flexometer and a sit and reach test; iv) pulmonary function using the autospirometer AS-

700 (Minato Medical Science); v) aerobic power using a cycle ergometer protocol (MacDougall et al., 1982); vi) anaerobic power and capacity using a cycle ergometer (Bar Or, Dotan, and Inbar, 1977); and vii) anaerobic threshold determined by locating an increase in the ventilatory equivalent for O_2 without an increase in ventilatory equivalent for CO_2 and an increase in FEO_2 at the peak point of $FECO_2$.

In general, stepwise multiple regression analyses revealed that age and hexagonal jump accounted for a large percentage of the variability for both pre-and post-season SL and GS performance.

Three methods of statistical analyses were used to investigate the results of the study: 1. Paired t-test of pre- and post-season results, 2. Pearson Product-Moment correlation for both pre- and post-season results, and 3. Stepwise multiple regression analyses of pre-season SL and GS performance and post-season SL and GS performance, and each analyses performed with the age variable removed from the regression equation.

Conclusions

Based upon the results obtained and within the limitations and delimitations of the research in this study, the following conclusions appear justified regarding the effect of seasonal training on selected physical and physiological variables of junior male Alpine ski racers:

1. The paired t-test indicated that slalom performance and hip rotation degree significantly ($p<.05$) improved after the season, and fatigue index for the hamstring muscle group in the left leg showed a significant decline between pre- and post-season tests.

2. The Pearson Product-Moment correlation coefficient revealed several significant ($p<.05$) relationships between skiing performance (SL & GS) and anthropometry, muscular strength and power, motor ability, flexibility, anaerobic power and capacity, pulmonary function, and aerobic capacity as well as several significant intercorrelations between the variables.

3. In general, stepwise multiple regression analysis revealed that age and hexagonal jump accounted for a large percentage of the variability for both pre-and post-season SL and GS performance.

An additional four stepwise multiple regression analyses were applied to pre- and post-season SL and GS performance with the independent variable "age" removed to investigate what other predictors would account for the variation in the absence of the age variable. In general, isometric quadricep strength in the right leg accounted for most of the variance in 2 out of the 4 analyses and hexagonal jump accounted for most of the variance in the remaining 2 analyses.

Recommendations

1. The use of a control group would help to support differences between "normal" subjects within the same age group and Alpine skiers thereby reducing the limitations of the study.

2. A larger number of subjects would support the results by providing a larger cross-section of Alpine skiers.

3. A more specific age range would reduce the large variation of results caused by maturation.

4. A better ratio of subjects to physical and physiological variables would stablize the regression equation thereby providing more reliable results to predict performance.

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Appendix A

Fitness Training

Fitness training was restricted to Tuesday and Thursday night sessions each week throughout the season. Each session lasted approximately 2½ hours and consisted of a warm-up, flexibility, circuit training, endurance or speed training, and a warm-down.

Warm-up: (approximately 15 mins)
Slow jog, changing direction occasionally and performing various ski related exercises, such as sideways shuffle, kicking up heels, running backwards, hopping, two footed jumps and foot to foot jumps from side to side, skipping stride, and a few short sprints to finish. Each exercise is described under the heading of low impact aerobics.

Flexibility: (approximately 10 mins)

Fifteen general stretching exercises were selected to i) prepare the body for upcoming physical stress, ii) increase the range of motion about the joints, enabling better skill performance, and iii) reduce the risk of injury and muscular stiffness and soreness.

The exercises were chosen to ensure all the body joints were mobilized before starting the circuit training.

Stretching Exercises:

1. Neck stretch, push head from side to side and forward. Do not circle head.

2. Side-ways stretch, feet apart reach down side-ways with hand passed knees, both sides.

3. Hip stretch, with hands on hips, rotate hips around in a circle.

4. Touch toes, standing position with feet apart. **

5. Touch alternate toes, standing position with feet apart. **

6. Touch toes, sitting position with legs at 90°, push stomach, then shoulders, then arms and head toward toes. **

7. Calf stretch, standing with foot on a step or against the wall push hips forward and knee backward. *

8. Thigh stretch, standing, bend at knee till heel touches buttock and hold ankle, push knee backward. *

9. Runners stretch, step left foot onto table approximately 3 ft high push left knee and hips forward and right knee backward.

10. Buttocks and trunk stretch, sitting with left leg flexed and over right leg, rotate trunk to the left, pull against flexed leg with right arm.

11. Inside leg stretch, with legs wide apart, push one knee forward. *

12. Arm and shoulder stretch, stand facing the wall, place an outstretched arm against the wall and rotate the body away from the arm. *

13. Tricep stretch, place left arm behind the head, with right hand pull arm further behind the head. *

14. Chest stretch, extend arms back behind the body, have a partner lift and close arms slowly. *

15. Ankle stretch, carefully role foot over until there is a little pressure on the outside of the ankle.

* Should be performed with pelvic tilt to protect lower back and assist stretching.

** Should be performed with slight knee flexion if there is undue pressure behind the knee. This will transfer the pressure to the muscle which assists stretching.

Where an instruction is given for only the right or left side, the opposite side should also be stretched.

Circuit Training:

Abdominal and back circuit - consisted of approximately 20 trunk exercise of which 8 to 12 exercises were chosen to make up an abdominal circuit session. Exercises were developed to strengthen rectus abdominis, external oblique, quadratus lumborum, sacrospinalis, lower back extensors, and latissimus dorsi muscle groups.

Abdominal and back exercises:

Sit Ups: On back with knees flexed, heels 1 ft from buttocks, hands clasped behind head:

1. sit up until elbows touch knees.
2. sit up and touch right elbow to left knee, then left elbow to right knee, alternately.

3. repeat 2. and lift left knee to right elbow, then right knee to left elbow, alternately.

4. with hands on thighs, sit up slowly until hands touch knees.

5. repeat 1. with feet held.

6. repeat 2. with feet held.

7. repeat 4. with feet held.

8. repeat 3. and lift both knees to touch both elbows at the same time.

On back: 9. with thighs at right angles to body, sit up and touch elbows to knees.

10. with legs against the wall at 90° to body, sit up and touch elbows to knees.

11. while legs work in a cycling motion, touch right elbow to left knee and left elbow to right knee, alternately.

12. with legs at 90° to body, lower legs slowly to the left, then back to 90°, and then to the right

13. with legs together and toes pointed, extend and flex legs from left to right. Place hands palms down, under buttocks for support.

14. with legs at 90° to body, have a partner push your feet toward the floor in any direction. Resist the push and bring your legs back to 90°.

Side Ups: 15. lying on side with a partner holding calves, hands clasped behind head, sit up side-ways toward partner.

Back Ups: 16. on a table or suitable apparatus lie face down with hips on edge and trunk over the edge. Secure legs and flex from the hip to 90°, then extend from the hip to a horizontal position, no further.

17. repeat 16. and rotate the trunk to left then right with each repetition.

18. repeat 16. with legs over the edge. Lift and lower legs with trunk secured.

19. lying face down on floor with hands clasped behind the head, raise trunk to a moderate height only. Toes remain in contact with the floor.

20. repeat 19., raise legs to a moderate height. Chest remains in contact with the floor.

To prevent injury of the lower back, all sit ups should be performed by progressively curving the trunk when sitting up and progressively straightening the trunk when lying back down (i.e., do not hold the trunk rigid throughout the manoevre). When performing back ups, the back should not be over arched.

Legs and arms circuit - consisted of 30 exercises. Approximately 10 to 15 exercises were chosen per session and 1 to 3 circuits were given. All exercises were as "ski specific" as possible and were aimed at developing strength of the tricep, bicep, deltoid, pectoralis major, trapezius, and spinalis muscle groups around the arms, shoulders, and neck; iliopsoas, gluteus maximus and minimus, hamstrings, adductor longus, magnus, and brevis, vastus lateralis, medialis and intermedialis, rectus femoris, biceps femoris, peroneus longus, gastrocnemius, and soleus muscle groups around the buttocks and legs.

Leg and arm exercises:

Legs:

1. lying on side with head resting on hand, raise and lower extended leg. *

2. repeat 1. with upper leg supported on table edge, lifting lower leg to upper leg and down again. *

3. on back with arms out to sides for support and legs at 90° to body, open and close legs slowly.

4. repeat 3. in a sitting position.

5. stand with toes on edge of step, push up onto toes then slowly lower body weight down and repeat. *

6. on hands and knees, lift left knee out to side, then repeat for right leg. *

7. on hands and knees, point toes and extend leg backwards, then repeat for other leg. *

8. in a racing tuck position, hop on one leg backwards, and slightly from side to side.

9. step up and down from a bench. *

10. repeat 9. with two footed jumps.

11. box jumps, with two feet together jump from side to side on to, then down from a box 50 cm high.

12. with one foot on the edge of a bench, flex to 90° and extend to standing.

13. jump over a pole 60 cm high, on landing absorb by flexing to 90°, then jump backwards over pole and repeat.

Using elastic cord:

14. hip adduction, attach cord to secure object, then to foot. Cross foot in front and behind other leg.*

15. hip abduction, repeat 12. and push left foot to the left and right foot to the right. *

Arms:

Press ups:

16. hands directly under shoulders. *

17. hands wider apart than 16. *

18. hands together under chin. *

19. for increased resistance, raise legs and/or place weight on shoulders. *

20. repeat 16. and clap hands together between each repetition. *

21. for less resistance press up from knees. *

Using suitable apparatus:

22. arm dips, lower to 90° and raise body weight by flexion and extension of elbows.

23. pull ups, raise and lower body weight by flexion and extension of elbows.

24. static pull up for less resistance, pull chin up to bar and hold.

25. tricep push, partner on back with legs up, stand between partners legs, with partner behind, hold partners feet and push down and back. Partner resists slightly (simulates poling action in skiing). *

26. rope climbing with arms only.

Using free weights:

27. bicep curl, lifting weight up to chin, then lowering to hips. *

28. bench press, on back, push weight up from shoulders and back again. *

29. military press, standing or sitting, push weight up above head and back again. *

30. tricep lift, with a small weight in hand, put behind head and extend elbow up and down. *

* Should be performed with pelvic tilt to protect lower back and enhance the exercise.

Where an instruction is given for only the right or left side, the opposite side should also be exercised.

Different intensities and durations of exercise, and numbers of circuits were administered depending on whether endurance, power, or speed training was required, and depending on individual strengths and weaknesses. Either an abdominals or legs and arms circuit were administered each night but not both.

Endurance:

Endurance training consisted of 30 to 45 minute sessions of interval or fartlek running. Interval running consisted of sets of 400, 600, and 800 m runs with active recovery in between each run and each set.

Speed:

Speed training consisted of sprint starts and 30, 50, 100, and 200m sprints. This was occasionally substituted with speed exercises such as skipping, intense running on the spot, or a speed circuit. Occasionally, an agility circuit substituted speed training.

Warm-down:

Each warm-down session consisted of a game i.e., volleyball, basket ball, etc., 20 minutes of stretching, and a short mental relaxation session following Uneståhl's procedures.

Uneståhl's mental relaxation and imagery:

Subjects lie or sit in a comfortable position. However, if a subject tends to fall asleep, aitting is better. Muscular relaxation begins by following a routine of tensing and relaxing each muscle group from the face to the feet and toes. This enhances body awareness by focusing the mind on independent muscle groups. Controlled breathing is also used to assist relaxation. Once a deep state of physical and mental relaxation is achieved (approximately 10 mins for experienced subjects), mental imagery can be applied. Visualizing skiing performance develops familiarity with strengths and weaknesses. Therefore, the subjects are asked to visualize their personal best performance and to compare this to their present performance (approximately 15 mins). Finally, the subjects are instructed to awaken slowly by counting down from twenty.

Appendix B

Competitions, On-snow & Fitness Training

Subject (#.name)	SL & GS Competitions			On-snow Training			Fitness Training Attend.
	Nat.	Prov.	Loc.	Day.	Nig.	Aft.	
1. TB	10	15	5	20	10	10	34
2. SC	-	5	10	30	15	10	34
3. JC	10	15	5	20	10	10	34
4. GC	5	10	5	25	15	10	34
5. SD	-	5	10	30	15	10	34
6. TD	-	2	10	33	15	10	34
7. RD	-	5	10	30	15	10	34
8. JF	-	2	10	33	15	10	34
9. WF	-	2	10	33	15	10	34
10. WC	-	2	10	33	15	10	34
11. JG	-	2	10	33	15	10	34
12. CH	5	10	5	25	15	10	34
13. SH	10	15	5	20	10	10	34
14. WJ	5	10	5	25	15	10	34
15. JL	-	5	10	30	15	10	34
16. MM	10	15	5	20	10	10	34
17. SM	-	5	10	30	15	10	34
18. RP	5	10	5	25	15	10	34
19. RR	-	2	10	33	15	10	34
20. DR	5	10	5	25	15	10	34
* 21. JY	2	2	5	10	2	2	10

SL and GS Competitions: Nat: National, Prov: Provincial, and Loc: Local . Only subjects aged 15 and 16 qualified for National Championships.

On-snow Training: Day: Days, Nig: Nights, and Aft: Afternoons. Subjects trained on holidays, weekends, Wednesday afternoons, and Friday nights when they were not competing.

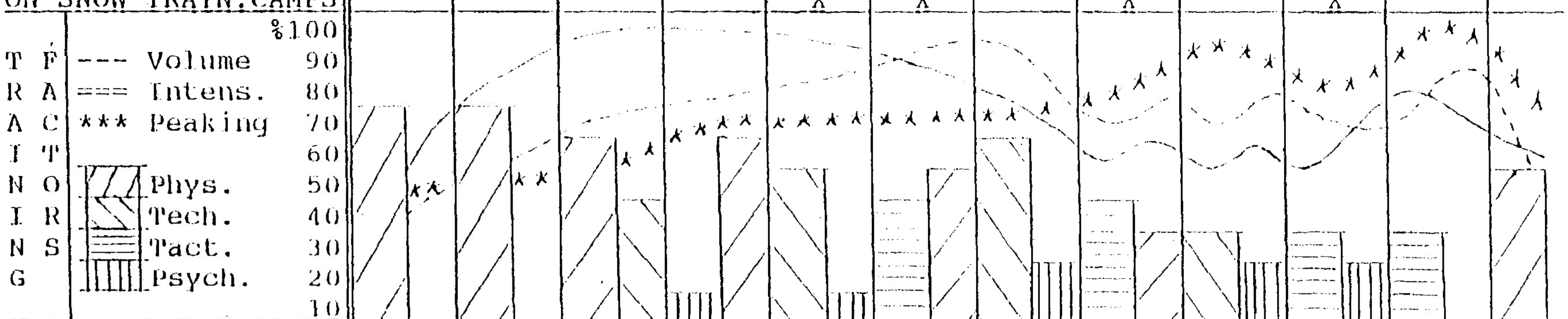
Fitness Training: Attend: Attendance was taken for fitness training every Tuesday and Thursday night.

* Subject 21. JY was injured during the season.

Appendix C

Outlined Annual Training Plan for Elite Subjects in this Study

DATES	MONTHS	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
CALENDAR OF COMPS.	LOCAL								xx	x	x	x	
	PROV.								xxx	xxxxx	xxx	xx	xx
	NATIONAL									x	xx	xxxx	xxx
	LOCATION								TBay, Cwood	TBay, Cwood, Banff	Qubec, TBay, Banff	TBay, Qubec	Cwood, Qubec
COMPETITION GOALS & TARGETS									Qaulify for Nat. Champs		Place Top 40 in FIS race		
PERIODIZATION		Trans	Preparation Phase						Competiton Phase				
TRAINING PHASES		Phase 1				Phase 2			Phase 3		4 / Phase 5		
GENERAL TRAINING		X	X	X		X	X				X		
SPECIAL TRAINING					X	X	X	X	X		X	X	
COMP.SPECIF.TRAIN					X			X	X	X		X	X
MESO-CYCLES		1	2	3	4	5	6	7	8	9	10	11	12
MICRO-CYCLES		1 to 13			13 to 26			26 to 39			39 to 52		
TESTING DATES			X		X			X			X		
MEDIC.CONTROL DATES			X					X					
DRYLAND TRAIN.CAMPS			X		X			X			X		
ON-SNOW TRAIN.CAMPS						X	X		X		X		



Prov. = Provincial; TBay = Thunder Bay; Phys. = Physical; Psych. = Phsychlogical
Trans = Transition Phase; Cwood = Collingwood; Tech. = Technical; Comps = Competitions
Intens. = Intensity; Qubec = Quebec; Tact. = Tactical

Appendix D

Techniques for Measuring Motor Ability

Vertical jump

Subjects performed two separate vertical jump tests. The first followed the protocol developed by Sargent (1921), the second was modified as subjects wore ski boots causing a restriction in ankle flexion specific to skiing.

The apparatus used for the vertical jump test was a chart marked at one centimeter (cm) intervals from 0 to 100cm. The chart was attached to the wall 2 meters (m) from the floor.

Subjects began the test by facing the wall with both arms extended above the head, feet together, and the toes of both feet touching the wall. The highest point reached by the fingers was recorded as an initial value. Subjects were then asked to stand side-ways, 20 to 30cm away from the wall, jump off both feet and reach as high as possible, touching the chart with the hand nearest the wall. The highest value reached by the fingers was recorded and the initial value subtracted from this to determine the score in cm for one trial. Three trials were administered and the best score was recorded.

High box jump

The high box jump test followed the protocol developed by

Kornexl (1977). The test apparatus consisted of a plywood box, 40cm high, 60cm long, and 50cm wide, and a stopwatch.

A subject began by standing on top of the box. At the command "go", the subject jumped off the box to one side and then back up onto the box and off again to the other side. The subject continued to jump with both feet, back and forth for a 90 sec duration, with the objective being to complete as many jumps as possible within that time period. At the end of the time period, the subject was instructed to stop. The number of times the subject touched the top of the box with both feet was recorded as the subject's score. Only one trial was administered to each subject.

<u>Hexagonal jump</u>

The hexagonal jump test followed the protocol developed by Kornexl (1977). The test apparatus consisted of a series of railings placed at various heights on each side of a hexagon whose sides measured 65cm long, and a stop watch. The railings were made from polyvinylcloride plastic pipe and were loosely mounted on plywood plates, so that the railings would fall if the subject hit them.

A subject began by standing in the centre of the hexagon facing the first railing. At the command "go", the subject jumped outside the hexagon over railing one, which was directly in front. The subject then jumped back into the hexagon and as quickly as possible proceeded to jump around each side of the hexagon in a clockwise direction. Three complete revolutions around the hexagon completed one trial. The subject was required to jump with both feet and to face forward, towards railing one, throughout the task. The test was timed from the command "go" until the subject touched the inside of the hexagon after jumping over railing six at the end of the third revolution. If the subject knocked over a railing during a trial, the trial was not recorded and another trial was administered after a sufficient recovery period. One trial per subject was administered and the time recorded to the nearest .01 sec.

Appendix E

Flexibility Tests

The following flexibility tests were administered according to techniques developed by Leighton (1966).

Ankle Flexion - Extension

A subject was asked to sit with the right leg resting on a bench and the foot projecting over the end. The knee was kept straight and the left leg was extended downward. The Leighton flexometer was fastened to the inside of the right foot. The subject then dorsi-flexed the foot to the extreme position and the dial was locked. The foot was then plantar flexed as far as possible; the pointer was locked before the subject was allowed to relax and a reading was taken. The leg remained straight and no rotating of the leg or foot was allowed during measurement.

Knee Flexion - Extension

A subject lay on a bench in a prone position with knees and lower legs projecting over the edge. They were allowed to grasp the bench. The flexometer was fastened to the outside of the right ankle. The subject then flexed the lower leg toward the buttocks and the dial was locked. The lower leg was then forcibly extended while the pointer was locked. The subject could then relax while a reading was taken. The position of the upper leg and body was not changed during movement.

Hip Rotation

A subject began in a sitting position with the right leg resting on a bench and the foot projecting over the edge. The left leg was extended downward. The flexometer was fastened to the bottom of the right foot. The right leg was rotated outward as far as possible and the dial was locked. The leg was then rotated inward as far as possible and the pointer was locked. The subject could then relax while a reading was taken. The knee and ankle joints remained locked and the position of the hips did not change throughout the test.

Trunk Lateral Flexion

A subject began in a standing position with feet together, knees straight, and arms at their sides. The flexometer was fastened to the middle of the back at nipple height. The subject then bent sidewards to the left as far as possible and the dial locked. Then the subject bent sidewards to the right as far as possible while the pointer was locked. The subject could then relax while reading was taken. Both feet remained flat on the floor, knees were kept straight, and no forward movement was allowed throughout the test.

Appendix F

Pre-test Raw Data

Subjects	Slalom (sec)	Giant Slalom (sec)	% Body Fat	Skinfold (mm)	Vertical Jump (cm)		Hexagonal Jump (sec)
					Boots	No Boot	
1.TB	39.63	26.96	20.0	36.3	37	58	18.45
2.SC	42.96	28.86	16.8	28.3	22	40	30.07
3.JC	40.11	27.04	15.7	25.6	33	54	18.45
4.GC	43.63	28.44	16.7	33.0	22	39	19.67
5.SD	48.88	30.68	15.7	25.4	22	42	29.62
6.TD	49.87	32.69	24.5	51.8	25	38	23.03
7.RD	46.61	31.18	14.7	23.7	22	43	23.56
8.JF	55.45	34.00	16.0	26.3	26	35	35.25
9.WF	51.65	31.84	19.7	35.4	26	38	19.51
10.WC	49.86	31.75	22.8	44.3	12	38	24.64
11.JG	48.80	32.11	27.4	64.4	22	33	32.24
12.CH	39.08	27.62	20.6	37.7	39	53	18.68
13.SH	44.63	29.04	16.5	27.4	32	48	20.50
14.WJ	42.75	28.73	18.2	31.7	30	49	22.34
15.JL	46.86	29.50	17.1	28.9	21	41	22.38
16.MM	38.76	26.81	15.8	25.7	43	56	18.23
17.SM	41.20	28.31	14.8	23.8	34	49	18.40
18.RP	40.32	28.46	12.5	20.0	47	65	17.61
19.RR	48.75	31.92	31.5	16.1	33	49	23.21
20.DR	41.26	28.55	17.4	29.8	39	62	19.31
21.JY	39.40	27.11	21.8	10.6	33	50	19.51
Mean	44.78	29.60	18.9	30.8	29.5	46.7	22.60
S.D.	4.84	2.15	4.6	11.9	8.6	9.0	5.09

Appendix F

Pre-test Raw Data Continued

Subjects	High Box Jump (reps)	Grip Strength (kg)		Quadricep "0" Degree (Nm)		Fatigue Index Quadricep (%)	
		Right	Left	Right	Left	Right	Left
1.TB	71	53	53	309	209	38	42
2.SC	58	31	29	152	155	50	43
3.JC	65	63	61	222	233	42	40
4.GC	59	30	27	157	155	61	54
5.SD	42	33	32	133	130	72	56
6.TD	39	25	23	130	152	46	54
7.RD	53	38	37	155	195	57	60
8.JF	46	26	25	125	103	37	47
9.WF	56	38	32	122	125	64	48
10.WC	43	25	23	106	117	71	65
11.JG	34	23	21	106	98	65	65
12.CH	76	53	56	285	315	40	53
13.SH	73	34	40	198	195	59	57
14.WJ	70	48	41	190	190	58	49
15.JL	69	41	32	136	125	62	65
16.MM	72	52	45	250	260	51	47
17.SM	63	45	42	217	182	63	51
18.RP	74	42	38	195	187	27	33
19.RR	62	43	42	160	182	54	48
20.DR	66	43	40	198	193	55	58
21.JY	56	38	32	171	163	60	59
Mean	59.4	39.2	36.7	177.0	174.5	54.3	52.1
S.D.	12.5	10.8	11.0	56.1	52.9	11.5	8.6

Appendix F

Pre-test Raw Data Continued

Subjects	Fatigue Index Hamstring (%)		Sit & Reach (cm)	Ankle F.E. Degree	Knee F.E. Degree	Trunk L.F. Degree
	Right	Left				
1.TB	48	54	18	67	152	113
2.SC	68	52	8	55	144	85
3.JC	68	92	21	54	146	117
4.GC	79	76	13	65	155	105
5.SD	67	63	21	53	156	120
6.TD	33	72	7	80	159	92
7.RD	75	68	22	61	153	103
8.JF	71	57	8	60	160	123
9.WF	83	77	3	66	146	180
10.WC	86	73	15	65	154	112
11.JG	73	61	1	65	150	104
12.CH	71	53	22	74	165	135
13.SH	56	87	16	61	155	117
14.WJ	72	63	23	58	154	103
15.JL	86	82	12	72	151	98
16.MM	61	58	21	67	158	125
17.SM	89	85	23	70	145	117
18.RP	45	42	11	54	147	115
19.RR	64	63	13	74	145	96
20.DR	60	62	16	71	140	95
21.JY	82	69	10	62	162	102
Mean	68.4	67.1	14.5	64.5	152.2	112.2
S.D.	14.4	12.9	6.7	7.4	6.6	19.8

Appendix F

Pre-test Raw Data Continued

Subjects	Hip Rotation Degree	Forced Vital Capacity (L)	$\dot{V}O_2$ (l/min)	$\dot{V}O_2$ max (ml/kg/min)	Anaerobic Threshold (%)	Anaerobic Power (watt/min/kg)	Anaerobic Capacity (joules/min/kg)
1.TB	94	4.45	3.47	52.0	73.4	11.48	557
2.SC	85	2.67	2.42	54.0	80.0	7.35	363
3.JC	84	4.87	3.60	50.9	68.6	10.51	501
4.GC	102	2.43	2.49	55.3	70.0	10.09	505
5.SD	107	3.64	2.60	51.7	73.1	6.51	354
6.TD	106	3.01	2.22	42.4	73.3	5.86	302
7.RD	96	3.67	3.07	57.3	70.0	6.58	369
8.JF	74	1.81	1.96	54.5	71.3	5.90	334
9.WF	95	2.60	2.06	40.5	64.7	11.09	509
10.WC	99	2.50	2.03	51.1	58.9	5.09	276
11.JG	74	2.44	2.39	50.1	62.3	6.43	326
12.CH	89	4.28	4.40	51.6	61.6	10.04	502
13.SH	109	4.18	4.02	64.0	62.7	7.60	329
14.WJ	101	4.12	3.90	60.5	69.4	10.06	522
15.JL	78	2.25	2.62	60.8	68.6	5.32	274
16.MM	80	4.69	3.62	54.7	65.8	10.70	509
17.SM	109	4.51	3.89	59.1	68.0	6.72	354
18.RP	74	3.44	3.18	53.7	78.6	11.67	565
19.RR	105	3.49	3.58	56.4	79.6	5.58	305
20.DR	75	3.29	3.43	51.9	74.3	13.37	553
21.JY	99	3.35	3.42	67.1	62.7	11.09	509
Mean	92.1	3.44	3.07	54.3	69.4	8.53	419.9
S.D.	12.7	0.93	0.74	6.2	6.0	2.58	105.0

Appendix G

Post-test Raw Data

Subjects	Slalom (sec)	Giant Slalom (sec)	% Body Fat	Skinfold (mm)	Vertical Jump (cm)		Hexagonal Jump (sec)
					Boots	No Boot	
1.TB	37.96	27.35	19.2	33.8	39	56	16.80
2.SC	39.57	28.31	16.5	27.6	24	41	23.92
3.JC	37.85	27.58	13.8	22.3	34	56	18.45
4.GC	39.14	28.05	17.9	31.0	22	42	17.94
5.SD	43.67	29.84	17.6	30.2	26	45	25.03
6.TD	44.72	30.63	25.1	53.8	27	43	23.03
7.RD	42.07	29.27	13.8	22.1	31	50	26.39
8.JF	46.61	31.28	17.2	29.2	20	42	34.29
9.WF	46.08	31.16	18.0	31.2	31	40	23.79
10.WC	43.79	29.45	23.1	45.4	19	35	20.51
11.JG	44.94	29.99	31.0	82.5	22	30	26.01
12.CH	37.61	27.69	23.0	44.9	32	49	18.31
13.SH	39.24	28.42	16.5	27.4	39	59	20.02
14.WJ	38.97	28.11	19.1	33.9	35	51	20.31
15.JL	42.95	29.13	18.3	31.9	25	42	23.15
16.MM	37.15	26.96	13.9	22.4	39	56	16.70
17.SM	38.37	27.84	16.9	28.5	33	48	18.04
18.RP	39.21	28.11	12.6	20.2	48	64	18.48
19.RR	45.42	30.83	20.9	38.6	38	48	22.47
20.DR	39.94	28.21	18.5	32.5	46	64	19.27
21.JY	37.64	27.38	14.7	23.7	35	54	17.90
Mean	41.09	28.84	18.5	34.0	31.7	48.3	21.47
S.D.	3.21	1.34	4.3	14.0	8.2	9.0	4.23

Appendix G

Post-test Raw Data Continued

Subjects	High Box Jump (reps)	Grip Strength (kg)		Quadricep "0" Degree (Nm)		Fatigue Index Quadricep (%)	
		Right	Left	Right	Left	Right	Left
1.TB	82	54	57	282	277	41	37
2.SC	58	32	33	133	141	40	46
3.JC	65	63	61	203	239	56	51
4.GC	59	33	29	146	174	53	48
5.SD	50	38	36	125	130	68	52
6.TD	41	25	25	130	146	58	54
7.RD	64	38	40	182	182	36	51
8.JF	50	27	24	130	117	60	53
9.WF	50	28	24	114	127	52	67
10.WC	41	24	20	127	122	53	61
11.JG	40	24	24	122	108	64	54
12.CH	86	56	59	285	296	51	53
13.SH	80	48	44	209	201	51	45
14.WJ	80	54	44	217	168	45	43
15.JL	58	30	34	141	125	70	63
16.MM	85	57	44	279	271	38	48
17.SM	52	48	45	187	198	62	47
18.RP	77	45	38	209	174	58	43
19.RR	66	48	48	168	163	41	46
20.DR	72	49	43	209	190	46	47
21.JY	57	38	37	203	144	71	75
Mean	62.5	40.9	38.5	181.0	175.9	53.1	51.6
S.D.	14.9	12.3	11.9	54.7	55.0	10.6	8.8

Appendix G

Post-test Raw Data Continued

Subjects	Fatigue Index Hamstring (%)		Sit & Reach (cm)	Ankle F.E. Degree	Knee F.E. Degree	Trunk L.F. Degree
	Right	Left				
1.TB	52	41	13	70	158	124
2.SC	55	58	10	55	135	110
3.JC	54	73	21	54	146	117
4.GC	81	42	16	65	159	110
5.SD	64	72	21	58	150	124
6.TD	53	57	7	79	152	110
7.RD	57	50	16	73	165	122
8.JF	53	62	8	75	142	94
9.WF	60	53	1	74	149	94
10.WC	92	64	13	79	142	120
11.JG	74	48	2	58	150	122
12.CH	54	51	27	72	148	135
13.SH	67	82	19	75	152	127
14.WJ	53	48	26	64	156	112
15.JL	71	57	15	75	142	106
16.MM	58	74	26	76	165	120
17.SM	68	73	24	72	151	120
18.RP	96	62	15	64	148	114
19.RR	45	53	15	75	139	74
20.DR	55	67	20	58	147	110
21.JY	65	59	10	72	150	114
Mean	63.2	59.3	15.5	68.7	149.8	113.3
S.D.	13.4	11.2	7.5	8.1	7.8	13.4

Appendix G

Post-test Raw Data Continued

Subjects	Hip Rotation Degree	Forced Vital Capacity (L)	$\dot{V}O_2$ (l/min)	$\dot{V}O_2$ max (ml/kg/min)	Anaerobic Threshold (%)	Anaerobic Power (watt/min/kg)	Anaerobic Capacity (joules/min/kg)
1.TB	104	4.57	3.67	55.3	73.4	11.48	557
2.SC	93	2.77	2.52	54.1	80.0	5.57	314
3.JC	84	4.74	3.52	51.3	80.5	10.01	501
4.GC	125	2.76	2.85	60.9	69.0	10.40	503
5.SD	115	3.21	2.99	55.2	73.1	6.09	331
6.TD	120	2.99	2.39	46.4	74.0	5.86	302
7.RD	110	3.62	3.18	60.8	76.0	6.75	360
8.JF	115	2.25	2.12	56.0	72.2	5.90	334
9.WF	115	2.80	2.37	55.3	66.7	5.37	306
10.WC	113	2.40	2.16	52.9	60.0	5.20	273
11.JG	115	2.52	2.72	55.4	76.9	6.24	317
12.CH	120	5.52	4.40	51.6	63.3	10.04	502
13.SH	112	5.10	4.08	61.1	65.0	7.60	329
14.WJ	119	4.72	3.90	60.5	78.0	9.95	534
15.JL	115	2.66	2.80	61.2	74.0	5.32	274
16.MM	135	5.00	3.62	54.2	80.0	10.60	530
17.SM	155	4.68	4.82	61.3	76.0	6.48	341
18.RP	130	3.88	3.57	59.7	81.0	11.52	577
19.RR	127	3.47	3.57	59.7	81.4	5.77	296
20.DR	106	3.55	3.95	60.5	74.3	13.37	553
21.JY	135	3.62	3.42	64.5	62.7	10.65	524
Mean	117.3	3.66	3.27	57.0	73.2	8.10	407.5
S.D.	15.0	1.01	0.75	4.5	6.5	2.62	112.8

Appendix H

Correlation Matrix Among Selected Variables for Pre-season Results

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Slalom	1.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2. Giant SL	.96[x]	1.00	.		.										
3. Age	-.88[x]	-.87[x]	1.00	.	.	.									
4. Weight	-.73[x]	-.64[+]	.70[x]	1.00	.	.									
5. Height	-.70[x]	-.63[+]	.72[x]	.89[x]	1.00	.									
6. % Body Fat	.32	.40[*]	-.43[*]	-.55	-.22	1.00	.								.
7. Skinfold	.32	.37[*]	-.36	-.19	-.36	.40[*]	1.00	.				.		.	.
8. VJ With Boots	-.68[x]	-.60[+]	.69[x]	.75[x]	.73[x]	-.22	-.40[*]	1.00	.			.	.	.	.
9. VJ Without Boots	-.79[x]	-.72[x]	.74[x]	.78[x]	.78[x]	-.29	-.47[*]	.88[x]	1.00	.		.	.	.	.
10. Hexagonal Jump	.70[x]	.70[x]	-.58[+]	-.62[+]	-.59[+]	.20	.30	-.60[+]	-.70[x]	1.00	.	.	.	.	.
11. High Box Jump	-.72[x]	-.74[x]	.71[x]	.66[+]	.59[+]	-.38[*]	-.49[*]	.71[x]	.76[x]	-.71[x]	1.00	.	.	.	.
12. Grip Strgh Right	-.71[x]	-.73[x]	.67[x]	.80[x]	.67[x]	-.25	-.41[*]	.68[x]	.75[x]	-.67[x]	.77[x]	1.00	.	.	.
13. Grip Strgh Left	-.68[x]	-.68[x]	.69[x]	.88[x]	.74[x]	-.22	-.36	.67[x]	.74[x]	-.62[+]	.75[x]	.95[x]	1.00	.	.
14. Quadracep "0°" Right	-.80[x]	-.78[x]	.79[x]	.85[x]	.74[x]	-.25	-.24	.76[x]	.78[x]	-.64[+]	.77[x]	.81[x]	.87[x]	1.00	.
15. Quadracep "0°" Left	-.76[x]	-.69[x]	.74[x]	.88[x]	.74[x]	-.19	-.26	.70[x]	.71[x]	-.64[+]	.73[x]	.79[x]	.86[x]	.87[x]	1.00

[*] significant at $p<.05$ level.
[+] significant at $p<.01$ level.
[x] significant at $p<.001$ level.

Note: SL = Slalom
VJ = Vertical Jump
Strgh = Strength

Appendix H (Continued)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
16. Fat.Index Quad.Right	.27	.19	-.37*	-.30	-.23	.23	.18	-.61+	-.50*	.16	-.38*	-.35	-.38*	-.46*	-.37*
17. Fat.Index Quad.Left	.33	.31	-.43*	-.34	-.34	.31	.36	-.59+	-.50+	.25	-.44*	-.48*	-.48*	-.46*	-.36
18. Fat.Index Ham.Right	.14	.03	-.25	-.35	-.40*	-.05	-.13	-.45*	-.40*	.11	-.12	-.06	-.16	-.30	-.26
19. Fat.Index Ham.Left	.12	-.00	-.18	-.06	-.08	-.05	-.01	-.35	-.27	-.24	-.06	.04	.04	-.19	-.14
20. Sit & Reach	-.52+	-.53+	.52+	.67x	.68x	-.42*	-.38*	.30	.50*	-.42*	.50*	.65+	.68x	.62+	.67+
21. Ankle Flex & Extens.	.08	.16	-.26	.15	-.06	.54+	.33	.05	-.06	-.25	.01	-.03	-.03	.09	.13
22. Knee Flex & Extens.	.05	.02	.05	-.06	-.02	.05	.09	-.07	-.21	.10	-.12	-.15	-.09	.09	.17
23. Trunk Lat. Flexion	.15	.05	-.06	-.01	-.02	-.17	.02	.15	-.03	-.21	.11	.20	.20	.11	.10
24. Hip Rotation	.08	.05	-.11	.09	.27	.20	-.12	-.24	-.18	-.19	-.10	-.10	-.01	-.03	.01
25. Forced Vit Capacity	-.71x	-.67x	.67x	.92x	.90x	-.20	-.27	.64+	.68x	-.60+	.59+	.81x	.87x	.83x	.85x
26. $\dot{V}O_2$ max (l/min)	-.75x	-.69x	.71x	.92x	.86x	-.12	-.39*	.71x	.73x	-.61+	.76x	.75x	.82x	.80x	.83x
27. $\dot{V}O_2$ max (ml/min/kg)	-.36	-.40*	.34	.14	.26	-.21	-.59+	.13	.21	-.10	.39*	.14	.12	.17	.12
28. Anaerobic Threshold	-.01	.05	.11	.05	.14	-.10	-.33	.21	.25	.12	.11	.06	.04	.02	-.04
29. Anaerobic Power	-.67x	-.67x	.71x	.47*	.42*	-.31	-.22	.68x	.71x	-.63+	.56+	.56+	.50+	.59+	.50*
30. Anaerobic Capacity	.67x	-.67x	.74x	.47*	.43*	-.33	-.24	.67x	.69x	-.60+	.56+	.60+	.53+	.62+	.53+

* significant at $p<.05$ level.
\+ significant at $p<.01$ level.
x significant at $p<.001$ level.

Note: Fat. = Fatigue, Quad. = Quadricep, Ham. = Hamstring
Flex. = Flexion, Extens. = Extension, Lat. = Lateral
Vit. = Vital

Appendix II (Continued)

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
16. Fat.Index Quad.Right	1.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.
17. Fat.Index Quad.Left	.77^{x}	1.00	.	.	.	.	.	.	.	.	.	.	.	.	
18. Fat.Index Ham.Right	.64^{+}	.45*	1.00	.	.	.	.	.	.	.	.	.	.	.	.
19. Fat.Index Ham.Left	.46*	.36	.39*	1.00	.	.	.	.	.	.	.	.	.	.	.
20. Sit & Reach	-.01	-.14	-.02	.10	1.00	.	.	.	.	.	.	.	.	.	.
21. Ankle Flex & Extens.	.10	.35	-.09	.12	-.08	1.00	.	.	.	.	.	.	.	.	.
22. Knee Flex & Extens.	.01	.25	-.04	-.11	.03	.11	1.00	.	.	.	.	.	.	.	.
23. Trunk Lat. Flexion	.06	-.20	.22	.11	.00	-.06	.11	1.00	.	.	.	.	.	.	.
24. Hip Rotation	.45*	.17	.06	.43*	.24	.14	.19	.01	1.00	.	.	.	.	.	.
25. Forced Vit Capacity	-.20	-.35	-.24	.06	.73^{x}	-.03	.07	.13	.25	1.00	.	.	.	.	.
26. $\dot{V}O_2$ max (l/min)	-.17	-.21	-.12	.02	.61^{+}	.07	.04	-.03	.17	.87^{x}	1.00	.	.	.	.
27. $\dot{V}O_2$ max (ml/min/kg)	.12	.19	.30	.13	.20	-.22	.17	-.40*	.15	.18	.49*	1.00	.	.	.
28. Anaerobic Threshold	-.49*	-.56^{+}	-.49*	-.42*	.02	-.13	-.47*	-.42*	-.10	-.08	-.07	-.10	1.00	.	.
29. Anaerobic Power	-.35	-.44*	-.21	-.23	.08	-.15	-.13	.27	-.26	.39*	.41*	-.05	.03	1.00	.
30. Anaerobic Capacity	-.40*	-.52^{+}	-.18	-.31	.16	-.21	-.05	.29	-.24	.43*	.41*	-.05	.07	.97^{x}	1.00

* significant at $p<.05$ level.
$^{+}$ significant at $p<.01$ level.
^{x} significant at $p<.001$ level.

Note: Fat. = Fatigue, Quad. = Quadricep, Ham. = Hamstring
Flex. = Flexion, Extens. = Extension, Lat. = Lateral
Vit. = Vital

Appendix I

Correlation Matrix Among Selected Variables for Post-season Results

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Slalom	1.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2. Giant SL	.98^{x}	1.00	.	.	.	.	.	.	.	.	.	.	.		.
3. Age	-.85^{x}	-.83^{x}	1.00	.	.	.	.	.	.	.	.	.	.		.
4. Weight	-.67^{+}	-.61^{+}	.65^{+}	1.00	.	.	.	.	.	.	.	.	.		.
5. Height	-.64^{+}	-.57^{+}	.71^{x}	.90^{x}	1.00	.	.	.	.	.	.	.	.		
6. % Body Fat	.46*	.42*	-.46*	-.14	-.29	1.00	.	.	.	.	.	.	.	.	
7. Skinfold	.44*	.39*	-.42*	-.15	-.29	.98^{x}	1.00	.	.	.	.	.	.	.	
8. VJ With Boots	-.51^{+}	-.46*	.56^{+}	.72^{x}	.75^{x}	-.44*	-.41*	1.00	.	.	.	.	.		
9. VJ Without Boots	-.64^{+}	-.59^{+}	.70^{x}	.69^{x}	.74^{x}	-.63^{+}	-.62^{+}	.91^{x}	1.00	.	.	.			.
10. Hexagonal Jump	.80^{x}	.80^{x}	-.66^{+}	-.64^{+}	-.62^{+}	.21	.22	-.56^{+}	-.53^{+}	1.00	.	.			.
11. High Box Jump	-.69^{x}	-.65^{+}	.71^{x}	.75^{x}	.68^{x}	-.42*	-.44*	.73^{x}	.77^{x}	-.54^{+}	1.00	.			.
12. Grip Strgh Right	-.73^{x}	-.68^{x}	.71^{x}	.91^{x}	.82^{x}	-.42*	-.42*	.72^{x}	.76^{x}	-.62^{+}	.83^{x}	1.00	.	.	.
13. Grip Strgh Left	-.68^{x}	-.62^{+}	.69^{x}	.89^{x}	.80^{x}	-.32	-.34	.62^{+}	.67^{x}	-.55^{+}	.76^{x}	.94^{x}	1.00	.	.
14. Quadracep "0°" Right	-.78^{x}	-.76^{x}	.72^{x}	.83^{x}	.72^{x}	-.29	-.30	.69^{x}	.73^{x}	-.66^{+}	.89^{x}	.85^{x}	.81^{x}	1.00	.
15. Quadracep "0°" Left	-.74^{x}	-.69^{x}	.68^{x}	.82^{x}	.69^{x}	-.25	-.27	.54^{+}	.60^{+}	-.64^{+}	.79^{x}	.84^{x}	.84^{x}	.91^{x}	1.00

* significant at $p<.05$ level.
\+ significant at $p<.01$ level.
x significant at $p<.001$ level.

Note: SL = Slalom
VJ = Vertical Jump
Strgh = Strength

Appendix I (Continued)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
16. Fat.Index Quad.Right	.21	.17	-.07	-.31	-.18	.16	.20	-.32	-.27	.16	-.53^{+}	-.39*	-.33	-.41*	-.47*
17. Fat.Index Quad.Left	.32	.28	-.34	-.51^{+}	-.47*	.10	.10	-.39*	-.40*	.19	-.53^{+}	-.51^{+}	-.46^{+}	-.41^{+}	-.47^{+}
18. Fat.Index Ham.Right	-.02	-.11	-.05	-.33	-.19	.00	.06	-.14	-.14	-.19	-.24	-.36	-.44*	-.25	-.30
19. Fat.Index Ham.Left	-.16	-.14	.05	.22	.29	-.39*	-.36	.23	.35	-.09	.03	.24	.11	.05	.07
20. Sit & Reach	-.65^{+}	-.63^{+}	.59^{+}	.74^{x}	.70^{x}	-.36	-.41*	.40*	.54^{+}	-.51^{+}	.66^{+}	.78^{x}	.69^{x}	.65^{+}	.65^{+}
21. Ankle Flex & Extens.	.25	.27	-.38*	-.15	-.17	.07	-.01	-.08	-.12	.05	-.04	-.21	-.20	.05	.02
22. Knee Flex & Extens.	-.36	-.36	.43*	.26	.36	-.19	-.13	.24	.28	-.31	.35	.29	.18	.45*	.44*
23. Trunk Lat. Flexion	-.57^{+}	-.60^{+}	.46*	.35	.43*	.03	.07	.04	.17	-.38*	.25	.26	.29	.44*	.46*
24. Hip Rotation	-.08	-.08	.04	.13	.21	-.03	-.03	.15	.03	-.23	-.02	-.00	-.11	.12	-.00
25. Forced Vit Capacity	-.75^{x}	-.68^{x}	.67^{x}	.91^{x}	.86^{x}	-.31	-.31	.65^{+}	.68^{x}	-.64^{+}	.80^{x}	.90^{x}	.86^{x}	.88^{x}	.86^{x}
26. $\dot{V}O_2$ max (l/min)	-.70^{x}	-.65^{+}	.63^{+}	.92^{x}	.86^{x}	-.25	-.26	.70^{x}	.67^{x}	-.63^{+}	.69^{x}	.83^{x}	.80^{x}	.76^{x}	.70^{x}
27. $\dot{V}O_2$ max (ml/min/kg)	-.22	-.23	.24	.05	.13	-.41*	-.39*	.31	.31	-.13	.21	.10	.06	.08	-.15
28. Anaerobic Threshold	-.04	-.04	.17	.21	.22	-.20	-.11	.29	.21	.08	.17	.30	.25	.06	.08
29. Anaerobic Power	-.74^{x}	-.74^{x}	.80^{x}	.60^{+}	.54^{+}	-.33	-.30	.69^{x}	.76^{x}	-.66^{+}	.69^{x}	.66^{+}	.55^{+}	.75^{x}	.63^{+}
30. Anaerobic Capacity	-.75^{x}	-.74^{x}	.81^{x}	.56^{+}	.52^{+}	-.38*	-.34	.63^{+}	.71^{x}	-.62^{+}	.70^{x}	.67^{x}	.55^{+}	.75^{x}	.63^{+}

* significant at $p<.05$ level.
$^{+}$ significant at $p<.01$ level.
^{x} significant at $p<.001$ level.

Note: Fat. = Fatigue, Quad. = Quadricep, Ham. = Hamstring
Flex. = Flexion, Extens. = Extension, Lat. = Lateral
Vit. = Vital

Appendix I (Continued)

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
16. Fat.Index Quad.Right	1.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.
17. Fat.Index Quad.Left	.57^{+}	1.00	.	.	.	.		.	.	.	.	.	.		.
18. Fat.Index Ham.Right	.41*	.17	1.00	.	.	.		.	.	.	.	.	.	.	.
19. Fat.Index Ham.Left	.20	.01	.09	1.00	.	.		.	.	.	.	.		.	
20. Sit & Reach	-.40*	-.41*	-.12	.19	1.00	.	.	.	.	.	.	.		.	.
21. Ankle Flex & Extens.	-.04	.30	.01	-.01	.07	1.00	.	.		.	.	.	.	.	.
22. Knee Flex & Extens.	-.29	-.21	-.02	-.14	.27	.16	1.00	.		.	.	.	.	.	.
23. Trunk Lat. Flexion	.07	-.14	.26	.19	.27	-.17	.44*	1.00	.	.		.	.	.	.
24. Hip Rotation	.26	.12	.26	.07	.19	.47*	.27	-.06	1.00	.		.	.	.	.
25. Forced Vit Capacity	-.31	-.42*	-.28	.27	.76^{x}	.00	.41*	.49*	.15	1.00	.	.	.	.	
26. $\dot{V}O_2$ max (l/min)	-.17	-.43*	-.17	.24	.75^{x}	-.09	.29	.36	.35	.87^{x}	1.00	.		.	
27. $\dot{V}O_2$ max (ml/min/kg)	.10	.03	.21	-.02	.20	-.01	.13	-.15	.38*	.05	.36	1.00	.	.	
28. Anaerobic Threshold	-.29	-.56^{+}	-.27	.02	.15	-.43*	.02	-.27	-.09	.09	.13	-.03	1.00	.	
29. Anaerobic Power	-.21	-.33	-.00	-.04	.52^{+}	-.31	.40*	.31	.02	.54^{+}	.55^{+}	.23	.07	1.00	.
30. Anaerobic Capacity	-.21	-.32	-.01	-.12	.51^{+}	-.32	.44*	.30	.05	.56^{+}	.51^{+}	.18	.13	.97^{x}	1.00

* significant at $p<.05$ level.
$^{+}$ significant at $p<.01$ level.
^{x} significant at $p<.001$ level.

Note: Fat. = Fatigue, Quad. = Quadricep, Ham. = Hamstring
Flex. = Flexion, Extens. = Extension, Lat. = Lateral
Vit. = Vital