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A STUDY OF COMPETITIVE ALPINE SKIERS BETWEEN THE AGES OF 13 AND 18 YEARS

By

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ABSTRACT

A STUDY OF COMPETITIVE ALPINE SKIERS BETWEEN THE AGES OF 13 AND 18 YEARS

By

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Coaches and instructors of ski racing need appropriate methods to measure ski racing ability so that they match potential talent with the requirements of the sport, thereby facilitating the development of successful teams. The study attempted to determine if a predictive relationship existed between the three tests and points as determined by the United States Ski Association.

Eight male and eight female ski racers, ages 13 to 18 years, of the Central division of the United States Ski Association (CUSSA) volunteered as subjects for the study. The subjects were tested using the hexagonal obstacle test, the jump-box test and a 60-sec sit-up test. The subjects were tested during the CUSSA Point Improvement race Sunday, March 2, 1986 at Boyne Highlands Resort in Michigan. A multiple regression equation was used to treat the data.

Data analysis showed that a predictive relationship did not exist between the three tests and USSA points in the male subjects. The analysis also showed that a predictive relationship did not exist between the three tests and USSA points in the female subjects.

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Chapter 1

A significant concern of coaches should be the measurement of athletic ability to determine the strengths and weakness that may influence the success of athletes. Coaches and instructors of ski racing need appropriate methods to measure ski racing ability so that they match potential talent with the requirements of the sport, thereby facilitating the development of successful teams.

Ski racing and skiing in general involve many unique and specific movements that pertain only to skiing. In a similar manner running, baseball, football and other sports require specific qualities. These requirements can include physiological variables of muscular power, strength, endurance, and flexibility. Furthermore, each sport requires that specific equipment be worn during competition. Skiing has its own special equipment requirements. These specific equipment requirements tend to separate skiing from other sport activities. Of all athletic events only skiing requires immobilization of the ankle joint. This is due to the design of the boot, which aids in changing the direction of the skis. The direction changes are crucial for a racer to negotiate a race course.

The design of ski equipment makes the movements of the skier's body unique to sports. As a skier descends a mountain the body encounters many forces. Gravity allows the skier to descend in a straight line without much physical effort; however as soon as the skier starts to turn, either by an abrupt movement or a subtle one, the body experiences centrifugal force which must be controlled by the application of centripetal force if the skier wishes to maintain the arc of the turn. If these forces are not properly balanced the desired arc of the turn will not be maintained.

To overcome many of the constantly changing forces, the skier must be able to quickly exert large amounts of force. Most of the forces encountered are determined by the skier's weight, velocity, turning arc, terrain and snow conditions. Ski racers often encounter extreme forces during competition due to the steep slope of the hill, high velocity, and short turn radius (Wantanabe, 1981). Ski racers need to develop specific techniques to control these forces. The control of these forces is based on the skier's techniques, developed and inherited physical attributes and past experiences.

Skiers should be subjected to periodic physiological testing and evaluation of their technique in order to remain competitive. Technical evaluation is accomplished on the hill under the watchful eye of the coach. Modifications in technique then can be developed.

The development and evaluation of physical characteristics can take many forms. For example, maximum oxygen consumption can be determined on a treadmill. Anaerobic capacity and power can be determined with a treadmill or bicycle ergometer. Strength and power of the musculoskeletal system can be evaluated by isokinetic or isotonic testing. The question remains, can measures of the physiological characteristics be used to predict success in competitive skiing.

Several studies have investigated selected physiological and anthropometric variables in an attempt to describe ski racers. Two studies completed by Haymes and Dickinson (1980) and Brown and Wilkinson (1983) described selected physiological variables of elite alpine ski racers. Their work is important in determining the most effective form of evaluation for subsequent testing and the development of elite ski racers. The currently available studies cannot be be used effectively to predict a skier's ability because of a lack of skiing specificity.

Very few studies have included skiing-specific components in their test batteries. A battery of skill tests to select and train team members was developed by McGinnis (1981) for the U.S. Ski team. Presumably, this battery represents skiing-specific test items that presently are available to racers. However, the predictive nature of McGinnis' test was not determined.

Competitive skiing requires specific physiological characteristics and overall skiing technique to be successful. A skier must be able to respond quickly and precisely in a turn. It is assumed that the hexagonal obstacle test and the jump-box test simulates skiing. Thus, they could be used to evaluate skiers.

The hexagonal obstacle test (McGinnis, 1981), the jump-box test (McGinnis, 1981) and the 60-sec sit-up test (AAHPERD, 1981) were selected for the current study because they presumably measure strength, power, and endurance in a way that simulates skiing movements. The hexagonal obstacle test requires the subject to jump over a series of barriers laterally, diagonally, and forward and backward as fast as possible. This action may simulate the agility and leg power needed in skiing. In an unpublished cinematographical study of Jump training: The hexagonal obstacle and its relationship to ski racing by Bransdorfer (1986), several similarities were observed between the hexagonal obstacle test and skiing. A small vertical displacement of the body's center of gravity is present while a subject performs the hexagonal obstacle test. This is similar to what is seen in skiing because of the extension and flexion of the legs under the body of a skier in a turn. A limited amount of horizontal displacement of the body's center of gravity also is observed during performance of the hexagonal obstacle test in films taken from the frontal plane. The downward

vertical projection of the body's center of gravity tends to remain within the physical confines of the hexagonal obstacle while the legs clear each of the hexagon's barriers. In skiing it has been shown that the body's center of gravity moves to the inside of the arc of a turn. As the velocity and ability level of the skier increase, this repositioning of the center of gravity is more pronounced (Sodeyama, Miura, Kitamura, and Matsui, 1976). This movement towards the center of the arc is important to the skier in order to control centrifugal forces that are experienced in a turn. These observed similarities were used to substantiate the skiing specificity of the hexagonal obstacle test and thus to justify its use in this study.

The jump-box test was selected because of the leg power and muscular endurance required to jump laterally off of and onto the box for 90-sec. The duration of the test is similar to the duration of a ski run. The jump-box test also fits the description of lateral movement of the legs and therefore, was deemed to evaluate leg power and endurance while also being skiing specific.

Abdominal strength/endurance is important to a skier. The abdominal muscles are used to stabilize the trunk in the preparatory phase of turning. Therefore, the 60-sec sit-up test was selected to evaluate abdominal strength.

Need for the study

In order to evaluate a ski racer's ability, selected tests need to be skiing specific. Given such tests, it may be possible to predict a skier's performance level. Furthermore, predictive tests could provide important criteria for training team members. Therefore, there is a clear need to identify discriminative tests of skiing ability.

Purpose of the study

The purpose of this study was to determine whether the three selected test variables could predict performance levels of competitive ski racers between 13 and 18 years of age. The tests were hypothesized to predict ski racing performance.

Specific aims

Competitive male and female alpine ski racers of various abilities, between the ages of 13 and 18 years, were evaluated on three tests. A hexagonal obstacle test was used to evaluate leg power and agility, a jump-box test was used to evaluate leg power and muscular endurance for 90-sec, and a 60-sec sit-up test was used to evaluate abdominal strength/endurance.

Research hypothesis

The following research hypothesis was tested. The selected tests of leg power, leg endurance, agility, and abdominal strength are significantly predictive of ski racing ability.

Research plan

Normative values describing performance on selected variables are prevalent in many sports. Values for competitive alpine ski racers, however, are not available. Only a few studies, such as those by McGinnis (1981), Haymes et al. (1980), and Brown et al. (1983), have measured the physiological capacities of skiers.

This study attempted to predict ski racing ability using three test variables. The three test variables were: the hexagonal obstacle test, the jump-box test and the 60-sec sit-up test. The hexagonal obstacle used was constructed using the dimensions of McGinnis (1981). The subject was required to jump laterally, diagonally, forward and backward over barriers of different heights. One revolution was defined as successfully jumping over all six barriers. The time required for three revolutions was recorded as the subject's score. This test evaluated leg power, muscular endurance and agility.

Leg power and muscular endurance were determined as the subject jumped laterally off of and onto a 40-cm high box. The number of times the subject returned to the starting position in 90-sec was used as the score. The jump-box test was found to be objective, reliable and valid by McGinnis (1981) and Brown and Wilkinson . (1983).

Abdominal and hip flexor endurance was determined by a 60-sec bent-knee sit-up test. A standardized test from the American Alliance for Health, Physical Education,

Recreation and Dance (AAHPERD, 1980) was used. The completed number of sit-ups in a 60-sec time period was recorded as the score.

Measures of central tendency and variability were recorded, and multiple regression procedures were used in an attempt to determine if the three test items were predictive of skiing ability. The independent variables in the analysis were the three tests used. The criterion variable was seed points as determined by the United States Ski Association (USSA). USSA points are determined in the following manner.

> The winner of any seeded race is given zero 'race points', a penalty is calculated for every event and added to each racer's points to produce the racer's results for that event. The magnitude of the penalty depends upon (1) the seed points of the best five racers among the top ten finishers and (2) whether the times of those five racers are clustered near the winner's or relatively widely dispersed (Crane, 1983).

This method of determining point levels allows all racers in any event to be compared with the top seeded racers.

The tests used have been shown to be reliable in previous studies. The hexagonal obstacle test was investigated by McGinnis (1981). The jump-box test was used in the studies of McGinnis and Brown et al. (1983). Good reliability was reported in both of these studies. The 60-sec sit-up test was taken from the AAHPERD Health Related Physical Fitness test manual. Reliability has been determined, and norms have been established for

children between 5 and 18 years of age. The similarities between the test requirements and the motor patterns involved in skiing were taken as justification for use of the three tests selected for inclusion in this study.

Assumptions

The investigator assumed that the efforts of all subjects were representative of their abilities. He also assumed that the volunteer subjects were representative of the population being studied.

Limitations

Participation of the subjects was voluntary, thus recruitment was difficult. The number of subjects could not be controlled due to the voluntary participation of the subjects. The sample size used was deemed to be reasonably appropriate as this was a preliminary investigation of the predictive nature of the three independent variables. Volunteers were obtained from the participants of the Point Improvement Race of the Central USSA held March 2, 1986 at Boyne Highlands Ski Resort in Michigan. The results of this study must be interpreted with caution because the sample size was limited.

Significance

The information obtained from the study can be used by coaches and other ski professionals in further evaluation of the three selected test items.

Chapter 2

Literature Review

Presently, research on ski racing in the United States is limited. The available literature is either descriptive or normative. There is a definite need for further research, especially in the area of alpine skiing.

Skill testing of Alpine skiers

In the past, skill test batteries for Alpine skiers were developed to evaluate unskilled or inexperienced skiers. Collins and Hodges (1978) have described two skill test batteries designed for skiing. The Roger's skiing test, as reported by Collins and Hodges (1978), objectively measures selected skills of beginning skiers. These skills included climbing, turning, and stopping. Scoring is based upon the overall time the subject takes to complete the test. The Street skiing test, as reported by Collins and Hodges (1978), measures the general ability of downhill skiers, but it also incorporates a specific component for more skilled skiers. The Street test is composed of two sections. The first is used regardless of skill and the second is used only for more skilled subjects. Both the Street and Roger's tests require the

subjects to move around a series of obstacles. Use of these tests is limited to teaching skiing. They are not appropriate for evaluating racers because of the lack of difficulty involved.

At the present time, only one skiing specific skill test battery has been developed for evaluating elite or highly skilled racers. A battery of skill tests for the evaluation and selection of United States Ski Team members was developed by McGinnis (1981). This battery evaluates neuromuscular determinants of alpine skiing. The subjects performing the battery of tests ranged from 11 to 29 years of age. The subjects' skill levels varied from that of recreational skiers to U.S. Ski team members. The testing procedures contained nine test variables: three of jumping dexterity, two of strength and local endurance of the leg extensor muscles, one of jumping strength, and three of flexibility. Included in the jumping dexterity tests are the jump-box test and the hexagonal obstacle test. Both items were found to be objective, reliable and valid ($P<0.001$). Group comparisons were made on all of the test variables, and the results showed that older, more experienced racers scored higher on the tests than did younger, less experienced racers. This can be attributed to age, maturity, skiing ability or all three.

Descriptive studies in Alpine skiing

Descriptive studies characterizing ski racers are more prevalent than are skill test batteries for racers.

Brown and Wilkinson (1983) compared Canadian national, divisional and club racers in tests of flexibility, muscular strength, power, endurance, and aerobic and anaerobic capacity. Club skiers were found to score significantly lower in sit-ups, the vertical jump, the jump-box test, and an anaerobic treadmill test than did the other two groups of racers ($P<0.01$). The differences in age and physical maturity level may have contributed to this finding. The club skiers were the youngest of the groups tested. No significant differences were found between national and divisional team members. All of the skiers, even though the club skiers scored lower, had high levels of abdominal muscular endurance as measured by a 60-sec sit-up test. All racers had high levels of leg muscular endurance and anaerobic capacity as measured by the jump-box test. The authors did conclude that non-physiological factors also may be involved in determining elite skiing performance. This may account for the lack of difference between the national and divisional racers.

A study of physiological characteristics, using U.S. Ski team members was conducted by Haymes and Dickinson (1980). They examined aerobic capacities as well as strength and power measures of highly trained ski racers competing in Alpine, Cross-Country, and Nordic combined events. The racers were tested for isometric and isokinetic quadricep strength and leg muscular endurance.

Maximal power, agility, response time, and balance also were tested. The study showed that male alpine racers were the strongest but had only moderate maximal oxygen uptakes. The female alpine racers were stronger than the other female skiers and also scored higher in leg strength than did the men in the cross-country and nordic combined events. Significant correlations between International Ski Federation (FIS) points and isokinetic strength were found (males: r=-0.80, females: r=-0.78). Significant correlations between FIS points and percentage fat, body weight and lean body mass also were found.

Investigations of specific physiological parameters also have been completed on Alpine ski racers. Eriksson, Ekholm, Hulten, Karlsson and Karlsson (1976) studied anthropometric, physiological, and histological factors common to downhill skiers. Much of their work involved observed changes in muscle usage during competition with different angles of inclination of the ski boot. Histological changes were noted with different boot inclinations. Muscle activity was determined by use of EMG. The vastus lateralis was found to be involved to a large extent in competition.

EMG procedures were used by Karlsson (1977) to investigate muscle activity during skiing. The data showed that unskilled skiers utilize a static position more than skilled skiers. The static contractions of

unskilled skiers results in an inefficient use of the musculature during activity.

Karlsson also compared muscle activities during on-snow slalom skiing and off-snow slalom running. The results showed very different EMG patterns. It can be concluded that the use of slalom running is of little neuromuscular value as a training device for alpine skiers because of its lack of skiing specificity.

Energy cost of Alpine skiing

Energy sources of Alpine skiers need to be determined if appropriate training methods are to be developed. That is, training procedures must be specific to the metabolic requirements of the task if the ski racer is going to be competitive.

Studies investigating the energy cost of skiing generally have been done with Cross-Country skiers. These endurance athletes clearly are not similar to alpine skiers because of the different time involved in the two sports. The Alpine racer competes in races ranging from 30-sec to approximately two minutes, whereas the Cross-Country skier engages in events which may last for hours.

The aerobic and anaerobic metabolism of ranked Italian national slalom and giant slalom racers was investigated by Veicstinas, Ferretti, Margonato, Rosa, and Tagliabue (1984). A field test was performed using a backpack with a meteorological balloon attached. This

procedure allowed measurement of the expired air of the skier under actual race conditions. Because of the complexity of the sport and the unique types of movements involved, the investigators concluded that field tests provide the most appropriate methods of evaluating alpine ski racers. By using the backpack with the Douglas bag system, the skiers can be evaluated on the hill making the evaluation skiing-specific.

Evaluation of muscle glycogen depletion and blood lactate concentration during alpine skiing was investigated by Tesch et al. (1978). The study provided depletion patterns for the indirect assessment of muscle fiber recruitment. Also, anaerobic metabolism was investigated in terms of lactate accumulation in skilled and unskilled skiers during competitive and recreational skiing. Swedish national ski team members and Swedish physical education students were compared. The results showed that there was a more pronounced glycogen depletion in the fast-twitch fibers of the unskilled than of the skilled skiers. The skilled skiers had a greater tendency to use slow-twitch as well as fast-twitch fibers. This suggests that skilled skiers recruit different muscle fibers than do unskilled skiers. Lactate accumulation was shown to be related to each subject's overall fiber type and not necessarily to skill level. The subjects with the greatest proportions of fast-twitch fibers accumulated the most lactic acid.

Youth skiing research

Very little research has been done in the area of youth racing. Performance and body physique of competitive alpine skiers was compared by Ross and Day (1978). The study used skiers, ages 14 years and under, who were assigned to teams based on previous racing performance. Somatotype was determined by the Heath-Carter method. Performance was defined as the points earned per race entered by the subjects. Zero-order and first-order partial coefficients, with age held constant, did not reveal significant relationships between body physique measures and performance.

Chapter 3

Methodology

The selected tests were chosen because of their movement similarities with alpine skiing. The hexagonal obstacle test is similar with regards to the extension and flexion of the knee and hip joints during skiing. Because skiing is primarily anaerobic, the short duration of the hexagonal obstacle test also was an important similarity.

The jump-box test and the hexagonal obstacle test include jumping and landing phases. The landing phase can be compared to the control phase of skiing. The control phase occurs when the skier maintains the arc or present direction of a turn. An eccentric contraction is needed to effectively control centrifugal force. The jumping phase of the tests can be compared to the extension phase of the legs during a turn. A concentric contraction is needed to initiate the direction change. If this extension did not occur the skier would be unable to change direction and would fall or come to a stop. Both tests include lateral movement of the legs as the body's center of gravity tends to remain over the center of the test device.

Abdominal strength is important as a stabilizing force in the preparatory phase of a turn. A 60-sec sit-up test was selected to test abdominal strength.

The selected tests were used in previous studies to characterize alpine ski racers (McGinnis, 1980; Brown and Wilkinson, 1983; Haymes and Dickinson, 1980). The determination of a predictive relationship between these independent variables and skiing performance was needed to further evaluate them.

Subjects

Male and female ski racers, between 13 and 18 years of age, who attended the United States Ski Association-CO-Region III (CUSSA) Point Improvement Races at Boyne Highlands Resort in Michigan, on March 2, 1986 were asked to volunteer for the proposed study. Nineteen subject volunteered for the study, eight males and 11 females. An informed consent form signed by a parent or a legal guardian was required for participation.

Methods

Three tests, the hexagonal obstacle test, the jump-box test and the 60-sec sit-up test were used in the study. These independent variables were selected because of similarities between their mechanics and those of alpine ski racing (Abraham, 1983).

Hexagonal Obstacle Test A hexagon (McGinnis, 1981) consisting of polyvinylcholride (PVC) plastic pipe of

different heights was used to investigate the leg power and agility of the subjects.

The obstacle's construction consisted of six PVC pipe barriers loosely mounted by plastic pins on three-quarter inch plywood. In the event of a mistrial the barrier fell over upon contact reducing the risk of tripping or falling. The device was held together by one-eighth inch spring steel slats to keep the obstacle rigid while in use.

Each subject was asked to stand in the center of the obstacle facing the front barrier. On the command of "GO" the subject, while facing the front barrier throughout the entire trial, jumped using both feet, back and forth as well as laterally and diagonally, over each of the six barriers in a circular pattern for three complete revolutions. The time required to complete the three revolutions was recorded using a stop watch. In the event that a subject knocked over a barrier, the trial was stopped and one additional trial was given after a 5-min rest period.

Jump-Box Test A 40-cm high by 60-cm long by 51-cm wide box (McGinnis, 1981) constructed of three-quarter inch plywood with two-inch by four-inch boards used internally for support was used to evaluate leg power and muscular endurance. The subject stood on the box. At the command "GO" the subject proceeded to jump laterally off the box with both feet to one side then back onto the top

and off the other side. The number of times the subject returned to the starting position in 90-sec was recorded as the score. One trial was performed.

Sit-Up Test. A standardized 60-sec sit-up test was used to determine each subject's abdominal and hip flexor endurance and power. The subjects performed as many bent-knee sit-ups in 60-sec as possible. The subjects were instructed to keep their arms crossed and knees bent. One test administrator counted the number of sit-ups and secured the subject's feet, while another timed the trial.

Each of the three stations had two test administrators who were familiar with the procedures of timing and recording. Timing was accomplished by stopwatches at each station. The scores of each of the tests were recorded by a test administrator on the subject's score card. Each subject received a copy of his or her score card. Each subject had an opportunity to become familiar with the test procedures prior to starting the test session.

The administrators either timed or recorded at each of the three stations. One administrator timed the three revolutions of the hexagonal obstacle test. A stopwatch that counted down from 90-sec was used, as the administrator counted the times the subject returned to the top of the jump-box. During the sit-up test an administrator counted the number sit-ups while holding the subject's feet and another administrator timed the test

for 60-sec. The order of testing was the hexagonal obstacle test, the 60-sec sit-up test, followed by the 90-sec jump-box test. Because of the anaerobic nature of the tests, a 10-min rest period was allotted between them.

Because the testing was administered during a racing event, the racers completed the test sequence after their racing for the day. Each athlete tested was given at least a 30-min rest period following their racing prior to starting the test procedures.

Treatment of Data

Measures of central tendency and variability were determined. Multiple regression procedures were used to determine if significant predictive relationships existed between the independent variables and the dependent or criterion variable of USSA point level. USSA point levels was used as the criterion because of its assumed ability to differentiate performance levels. The giant slalom race points were used as it was the only race run that day.

Chapter 4

Results and Discussion

The results of this investigation are presented in two sections: male responses and female responses. A discussion will follow the results.

Male responses

Eight males volunteered for the study. Each subject was tested on the hexagonal obstacle test, the 60-sec sit-up test, and finally the jump-box test. Summary statistics and multiple regression significance levels are presented in Appendix A.

No predictive relationships were found between the three independent variables and ski racing performance as measured by USSA point levels. Sit-ups accounted for the greatest amount of variance in USSA points (P=0.106), followed by the jump-box test (P=0.115), and the hexagonal obstacle test (P=0.249). The overall corrected multiple correlation coefficient was R=0.606. The regression equation used is as follows:

$\hat{Y}=(3.67)x_1+(9.71)x_2+(-.66)x_3+(-168.22)$.

Female responses

Eleven female subjects originally were tested, but three were dropped because of missing values. The results are given in Appendix A.

No predictive relationships were found. Sit-ups accounted for the greatest amount of variance in USSA points (P=0.360), followed by the jump-box test (P=0.515) and the hexagonal obstacle test (P=0.697). The overall corrected multiple correlation coefficient was R=0.276. The regression equation used was as follows:

$\hat{Y}=(-28.99)x_1+(116.80)x_2+(6.48)x_3+(-1059.45)$.

Discussion

Several possible reasons can be cited for the apparent lack of ability to predict the subjects' point levels. Because the subjects were 13 to 18 years of age, their levels of physical maturity may have been an uncontrolled factor. At this age the development of strength and power probably lag behind the development of skiing technique, and some of the subjects may have been relatively underdeveloped in muscular strength and power in comparison to older racers.

Comparisons with other studies are difficult. In the study by McGinnis (1981) no data were presented for racers under the age of 18. This makes comparisons non-specific to the population of the present study. The same observation is applicable to the study of Brown and Wilkinson (1983).

Another factor may have been the duration of the selected tests. Michigan races are approximately 30-sec in duration. Therefore, the selected tests may not be specific to actual racing conditions for this population.

The limited sample size may also have been a factor. The study by McGinnis (1981) used a much larger sample and more independent variables. It is not known, however, if a larger sample size would yield different results.

Because of the absence of a ski boot while completing the hexagonal obstacle test and the jump-box test it is not known if the two tests are skiing specific. Inversion of the ankles was observed as the subjects landed. This inversion does not occur in actual skiing. It is not known if the muscle recruitment is comparable between the test and actual skiing. Furthermore, it is not known if modifications of the tests, making them more skiing specific, would change the results.

Although all relationships were non-significant, it is clear that the independent variables selected were much more highly related to racing performance in the males than the females. Tests of the male subjects accounted for approximately 60 percent of the variance while the female subjects only accounted for approximately 27 percent of the variance. The female subjects point standard deviation was 290.6 with an extreme outlying value of 990 points. The male subjects standard deviation was only 37.4. Such a large difference in the point range

may account for the difference in the correlation coefficients. However, it is not known if a different range of points or a larger sample would change the results.

The known differences in male and female physiological variables of muscular strength and power could have been a reason for the differences. However, at this time it is not known if this is the case. Furthermore, it is not known if adjusting for these physiological variables would change the results.

Chapter 5

Summary, Conclusions, and Recommendations

Eight male and eight female members of the Central division of the United States Ski Association, 13 to 18 years of age were subjects in this study. Participation was voluntary. Data were obtained from the hexagonal obstacle test, the jump-box test and a 60-sec sit-up test. Multiple regression procedures were used to determine if significant predictive relationships exist between the selected variables and skiing performance. No such relationships were found.

Conclusions

Within the limitations of this investigation, the following conclusions are warranted:

1) The selected tests are not predictive of skiing performance for males or females age 13 to 18 years.

2) The skiing specificity of each of the selected tests is not known.

Recommendations for further study

In light of the questions posed by this investigation, the following are recommendations for further research.

1) A larger sample should be utilized in any further investigation.

2) Different combinations of presumably skiing specific devices should be investigated.

3) A stable criterion should be used. For example, times of a particular race could be used.

4) Pooling the subjects by the number of races completed to ensure experience of the racers does not influence the results.

5) Differences of slalom, giant slalom, and downhill racers should be completed, because of the differences involved in each of the events.

6) Use of different sampling techniques should be used. For example, using a stratified random sample could be used.

7) Electromyographic (EMG) analysis should be completed during the hexagonal obstacle test and the jump-box test to determine the muscles used.

8) A comparison from EMG analysis of actual ski racing and the two jump-training devices should be completed.

9) The duration of the tests should be adjusted to be more specific to the geographic location which influences the length of the race courses.

10) A interdisciplinary study of ski racers should be completed. Many factors in addition to physiological variables probably contribute to skiing performance.

APPENDIX A

Tables

Male responses to selected test variables

	Mean	S.D.	P
Sit-ups	53.5	5.9	P=0.106
Jump-box	73.9	7.4	P=0.115
Hexagonal obstacle	18.3	1.6	P=0.249
USSA Pts.	157.25	37.42	

Female responses to selected test variables

	Mean	S.D.	P
Sit-ups	50.5	7.0	P=0.360
Jump-box	58.5	18.7	P=0.515
Hexagonal obstacle	19.7	1.9	P=0.697
USSA Pts.	311.58	290.60	

REFERENCES

References

Abraham, H. (1983). Skiing Right. Johnson Books: Boulder, Colorado.

Alpine Training Manual: United States Ski Team. (1977). U.S. Ski Team: Park City, Utah.

Bransdorfer, A.H. (1986). Jump training: The hexagonal obstacle and its relationship to ski racing. Paper presented at the meeting of the Biomechanical Interest Group of Michigan State University, E. Lansing, MI.

Brown, S.L., and Wilkinson, J. (1983). Characteristics of elite male and female ski racers. Medicine and Science in Sports and Exercise. 12(3):153-158.

Collins, D.R. and Hodges, P. (1978). A Comprehensive Guide to Sports Skills Tests and Measurement. Bannerstone House: Springfield, Illinois. pp. 305-316.

Crane, B.A. (1983). FIS points and the seeding list. Alpine Skiing Competition Guide 1984 (p.98). Colorado Springs, United States Ski Association.

Eriksson, A., Ekholm, J., Hulten, B., Karlsson, E. and Karlsson, J. (1976). Anatomical, histological and physiological factors in experienced downhill skiers. Orthopedic Clinics of North America 7(1):159-165.

Haymes, E.M., and Dickinson, A. (1980). Characteristics of elite male and female ski racers. Medicine and Science in Sports and Exercise 12(3):153-158.

Health Related Physical Fitness: Test Manual (1980). p.17. American Alliance for Health, Physical Education, Recreation and Dance. Reston, Virginia.

Karlsson, J. (1977). The Physiology of Alpine Skiing United States Ski Coaches Association, Park City, Utah.

Mackova, E.V. (1982) Enzyme activity patterns of energy metabolism in skiers of different performance levels(m. quadriceps femoris) European Journal of Applied Physiology 48:315-322.

McGinnis, P.M. (1981) Skills Test for the Discrimination of Alpine Skiing Ability Unpublished masters thesis, University of Illinois at Urbana-Champaign.

Ross, W.D. and Day, J.A.P. (1972). Physique and performance of young skiers. Journal of Sports Medicine and Physical Fitness, 12,30-37.

Tesch, P. and Larsson, L. (1978). Muscle glycogen depletion and lactate concentration during downhill skiing. Medicine and Science in Sport and Exercise 10:85-90.

Veicsteinas, A., Ferretti, G.,Magonato, V., Rosa, G., and Tagliabue, D. (1984). Energy cost of and energy sources for alpine skiing in top athletes. Journal of Applied Physiology 56(5):1187-1190.