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Physical Testing Characteristics and Technical Event Performance of Junior Alpine Ski Racers

David Heikkinen

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PHYSICAL TESTING CHARACTERISTICS AND TECHNICAL EVENT PERFORMANCE OF JUNIOR ALPINE SKI RACERS

By
David Heikkinen
B.S. University of Maine at Farmington, 1998

A THESIS
Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science (in Kinesiology and Physical Education)

The Graduate School
The University of Maine
May, 2003

Advisory Committee:
Robert Lehnhard, Associate Professor of Education, Advisor
Phil Pratt, Cooperative Associate Education
Stephen Butterfield, Professor of Education and Special Education
The purpose of this study was to determine if a battery of physical tests can be used to distinguish between the ability levels of junior alpine ski racers. Many sports, such as football, have established laboratory and field tests to assess their athlete's preparation for competition. It would be of benefit to coaches in the sport of alpine skiing to be able to use a field test to assess the physiological readiness of the alpine ski racers they work with.

At the junior level, alpine skiing in the United States consists of four events today. These events are the downhill, super giant slalom, giant slalom, and slalom events. Each event is different in the amount of distance between the gates, use of terrain features, speed, and demands on the athlete. Junior ski racers compete in more than one event, and many compete in all four. Ski racing in the United States has also become dominated by athletes within
several full time training programs at college preparatory ski academies. These programs strive to develop the athlete in every capacity that contributes to their successful performance. To this end, year round physical conditioning is important, and many of these academy programs have developed physical testing protocols to assess their athletes readiness for competition.

This study examined a battery of field tests, and the field test's correlation with alpine ski race performance. 42 members of a private college preparatory ski academy alpine program performed a battery of tests as part of their usual athletic training. These tests were developed with the intent of examining different physiological demands of alpine ski race performance. The results of these tests were compared with the athlete’s USSA points profiles in both the slalom and giant slalom events. A bivariate correlation was computed utilizing the Pearson r to see if any correlations existed between the field tests of the battery and competitive performance.

The conclusion of this research is that many of the field tests within this battery would be ineffective to utilize as predictors of alpine ski competition success in junior ski racing athletes. In this study, many of the field tests demonstrated weak correlations with competition results for either the slalom or giant slalom events for both genders. The field tests with stronger correlations found by this research could be condensed into a smaller battery of tests that is both more time efficient, and effective.
ACKNOWLEDGMENTS

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INTRODUCTION

In the field of athletics, in addition to the sport specific skills required, there are physiological factors that contribute to the success of an athlete. Factors such as absolute strength, flexibility, anaerobic and aerobic capacity all contribute to facets of athletic performance. The degree to which each of these factors contributes is dependent on the demands of the competition in which the athlete partakes. In some sports, such as swimming or track, which are performed in a controlled environment with few external influences, the demands of competition on physiology can be quantified quite easily. In other sports, such as football or alpine ski racing, there are external influences to which the athlete must often adapt in the middle of a performance. In these 'free play' types of situations, speed and direction of movement change constantly, and this places varied demands on the different physiological systems of the performer. No matter what the physiological contributions may be to the specific sport, coaches know that physical conditioning has an effect on performance. The effect of physical conditioning has long been assessed through various measures of physiological function.

There is a need for coaches in the field of alpine skiing to be able to assess and prepare athletes for ski racing competition in a dry land training setting. Many high level ski racing organizations assess this preparation in a laboratory setting. A field test that would assess an athlete’s level of readiness without expensive equipment or extensive training on the part of the coach administering the test, could be of benefit in implementing and assessing dry
land training programs for alpine coaches at a grass roots level of competition. Such testing could also be applied to higher level athletes who face barriers to laboratory testing due to travel restrictions common in the sport.

However, there has been a limited amount of research done in the sport of alpine skiing correlating race performance to field or laboratory tests of relative physiological function. Many sports use physiological testing to assess the qualities an athlete would require to succeed in his or her sport. A need exists for the development of a quality battery of field tests with the purpose of evaluating the physiological qualities an alpine ski racer requires in competition. The purpose of this study was to determine if tests currently being used have any correlation to actual race performance.
In the search for assessing physical characteristics that may predict athletic performance, many sports have established laboratory and field tests designed to assess these factors. Understanding what physiological characteristics a successful athlete displays can help coaches to focus training programs, or to predict which athletes have the physiological capacity to be successful. For example, in the sport of cycling, researchers have evaluated the qualities of professional road cyclists (Mujiko & Padilla, 2001). Cyclists display enormous cardiovascular capacity, despite some anthropometric differences related to their event and terrain specialties. Other research done with high level cyclists has looked into the physiological characteristics of successful triathletes. (Burke & Jin, 1996; Whyte, et al., 2000) Again, in this study laboratory tests show that elite triathletes exhibit similar physiological traits. Cardiac morphology was measured using echocardiology, and maximal oxygen consumption was measured as well. Tests documented the elevated levels of cardiac output, and increased ability to utilize oxygen in this group of athletes. This is an example of laboratory testing. Understanding laboratory procedures can help create field tests that assess the specific traits that are required for success in a particular sport. Knowing that successful athletes from a particular sport show similar physiological characteristics is key to designing appropriate training regimes.

Many other sports have developed protocols to assess their athlete’s readiness for competition. Football is one of these sports. A battery of tests
done with football players (Sawyer, et al., 2002) found that the vertical jump has a high correlation with football playing ability at all positions on the field. Running speed was found to be important to the success of wide receivers, defensive backs, running backs, tight ends, and line-backers. Strength was found to be important to the success of defensive players. The one repetition maximum scores of these players in the bench press and power clean showed a high correlation to performance on the field. The study suggested that utilizing tests such as the vertical jump could be a way of assessing the football playing ability of a group of non-football athletes. The study also shows that even within the sport of football, testing must be specific to the task the athlete must perform on the field. This is demonstrated by the positional differences within the test scores. A study done by Remedios and Holland found results similar to others conducted with football players (Remedios & Holland, 1992). Their study of community college level football players found that differences in their physical abilities related to their positional duties. Again, running speed was found to be important to the success of running backs, wide receivers, and defensive backs. These athletes were also found to have high vertical jumps. Strength was reported to be important for offensive and defensive linemen. Offensive lineman were found to have the highest 1RM squat, and defensive lineman were found to have the highest 1RM bench press in the survey. It was also stated that athletes at this level of competition were generally not as fast, large, or strong as their higher level Division 1 counterparts. Further studies done with football players indicate that a battery of tests can predict the order in which a college athlete might be selected in the NFL draft. McGee and Burkett found that the draft number of some positions
could be accurately predicted with a battery of physical tests (McGee & Burkett, 2003). The same study showed that other positions could not be predicted as accurately utilizing the same testing protocol. These findings are similar to what was found in previous studies relating a battery of tests to football playing ability. Sawyer, et al. studied the physical testing protocol used at the National Football League’s 2000 combine testing camp. In this study it was found that the vertical jump had the highest correlation to football playing ability for the running back position. It was also found that the 225lb. bench press fatigue test, a test of strength and muscular endurance, had little or no correlation to success at this same position. This suggests that it should be effective to measure the explosive strength of a running back with the vertical jump test to assess potential football playing ability, but that the muscular strength required to complete the 225lb. bench press fatigue test may not have relevance to a running back’s success. Other positions, such as the quarterback were found to have different tests that correlated with their positional football playing ability. A 3 cone drill test, which measured the agility of the athlete correlated highly with this position. This study demonstrates that a battery of tests can be used to assess sport specific ability, but the test must also be specific to the position played on the field. This understanding of specificity would also be relevant to tests used to assess specific qualities by position and event in other sports.

Additional research with football players conducted at the Appalachian State University has established that starters and non-starters at the collegiate level can be differentiated by their strength and jumping ability (Barker, et al., 1993). This study supported the previous findings of others by demonstrating that
physical qualities varied by playing position (McGee & Burkett, 2003; Remedios & Holland, 1992; Sawyer, et al., 2002). Starters, which were assessed by their coaches as having a higher level of football playing ability also demonstrated higher 1RM squats and higher vertical jumps than non-starters who were said to have a lower level of football playing ability. The research conducted with football players shows how a battery of physical tests can be used to differentiate between levels of playing ability. This sort of testing has been done with other sports as well.

A fitness evaluation done with the United States national women's rugby team showed that a battery of physical tests could also demonstrate differences between elite athletes within this sport (Townsend, et al., 1992). The test was performed on the world champion women's rugby team from the United States. The athletes performed a battery of tests that included tests of strength (the seated press and squat one repetition maximum), speed (the 40 yard sprint, 100 meter sprint, and 300 meter run), and aerobic capacity (20 meter 'bleep test'). Power was assessed through a vertical jump test. Differences in the test results could be clearly shown by the position of the player. Forwards were shown to be stronger, and demonstrated more power. This would be in line with the demands of their position on the field, which involves physical contact such as tackling opposing players. Backs had a higher aerobic capacity, and were faster in the running tests. This is also in line with the demands of their positions, which would include evading opposing players and attempting to
move past the opposition to score goals. This study further supports the idea that differences in playing ability can be found through a battery of physical tests.

Another example of coaches using physical testing to assess playing ability is the sport of volleyball. Volleyball has identified physiological factors that are important to sport specific success (Ferris, et al., 1995). In the sport of volleyball, spiking speed is important to the success of a team. The higher the spike velocity, the lower the chance the other team will be able to successfully return the ball. Research has identified that shoulder extension strength at high speed is the dominate physiological factor which predicts the velocity at which an athlete will be able to serve a volleyball at high velocity. This is a correlational relationship that can be used to predict which athletes may have the physiological capacity to serve a volleyball powerfully at high velocity. This information could also be used to design training programs that focus on developing a high level of shoulder extension strength at high velocity for maximizing an athlete’s potential.

Studies done in the sport of cross country skiing have shown that for physical testing to be effective it must be as sport specific as possible. It has been shown in cross-country ski racers that treadmill roller skiing is more effective in predicting ski performance than is treadmill running (Mahood, et al., 2001). This is because athletes develop not only physiological but mechanical systems as well that are specific to their sport. Attempting to measure an athlete’s physical readiness must not be done with random tests, but instead
with tests which including the motor skills that an athlete needs for success in his or her individual sport. It has been shown that physical preparation can be most effective when highly specialized and specific training is implemented (Muller, et al., 2000). Athletes develop certain motor abilities that are specific to their sport. These motor abilities evolve along with physiological abilities to meet the demands of training. Knowing that sport specific training is important is a key factor in developing physiological tests. A study by Muller, et al. shows that a physical test is most effectively used as a predictor of performance when it is as close to simulating actual sport specific skills as possible (Muller, et al., 2000). With this in mind, a battery of tests for assessing alpine skiers must include skill factors that are as closely related to race performance as possible.

Sport specific physical testing can vary by the nature of the sport in regards to what physiological factors need to be identified. The studies discussed above show that a battery of physical tests can be used to assess the competitive abilities of athletes. The studies also demonstrate that testing must be as sport specific as possible, and even specific to the sub-group roles or specialties of the athlete within the sport. The knowledge that testing has been utilized in other sports to assess playing ability is important. The fact that physical testing has been shown to be effective in predicting athletic success suggests that the same could hold true in the case of alpine ski racing. Alpine skiing is a sport that relies on many physiological systems for success. The sport is made up of different events with different physical demands. Understanding the physiological characteristics of a successful alpine ski racer would be the first step in developing a battery of tests to assess these qualities.
Alpine ski racers exhibit certain measurable physical characteristics (Brown & Wilkinson, 1983). They have lower levels of body fat than in untrained members of the general population, and are similar in their body composition to swimmers, and weight lifters. Alpine ski racers also demonstrate high levels of flexibility, core strength, isokinetic leg strength, and anaerobic power. A study done by Haymes and Dickinson also determined high levels of isokinetic leg strength in these athletes (Haymes & Dickinson, 1980). Results such as these suggest that leg strength is an important factor in being a successful alpine ski racer. Brown and Wilkinson also found that alpine skiers had lower levels of aerobic capacity than do their nordic skier counterparts (Brown & Wilkinson, 1983). Alpine skier’s VO2 max values ranged from 61-63ml/min/kg, while nordic skiers values ranged from 73-78ml/min/kg. For comparison, an untrained individual would have a VO2 max of roughly 35 ml/kg/min. These findings suggest that aerobic conditioning is more important to nordic skiers than their alpine counterparts, with both types of skiers demonstrating higher than average aerobic capacity.

The alpine skiers in this study were also found to have highly developed glycotic capacities. Blood lactate accumulations in this group showed that alpine skiing generates high levels of blood lactate which correlates to anaerobic power, endurance, and glycotic capacity. Blood lactate accumulation illustrates the involvement of the short and medium anaerobic systems in alpine skiing. Skiers showed similar blood lactate readings in the high box test as they did while skiing. The high box test is a measure of the anaerobic system utilized by many high level ski racing organizations as a field test of this
system. This test was originally developed in Austria for alpine ski racers. (Kornexl, 1977). This is an example of how laboratory tests such as measuring blood lactate could be used to demonstrate the validity of field tests. Using laboratory tests to understand the characteristics of an alpine skier is important in order to effectively isolate and assess these factors in training and testing situations. Effective training and tests would stress these physical systems in the same sport specific fashion as actually alpine skiing.

Further research has shown that alpine ski racers exhibit high levels of intermediate and long term anaerobic performance (Bacharach & Von Duvillard, 1995). It has been estimated that the anaerobic system supplies up to 65% of the total energy expended during an alpine ski race. This suggests that it is important to make sure the anaerobic system be trained sufficiently to deal with the rigors of the competition. This same study also suggested that since alpine skiing is dependent on a number of different physical qualities, that no single quality could be used as an efficient measure for predicting alpine ski race performance. The researchers concluded that a battery of tests would be required to adequately test all the systems and skills that are relevant to the sport. The fact that this study demonstrated difficulty in assessing an alpine skier from one physical test shows the multi-faceted nature of the sport. Although the short and medium anaerobic systems are stressed in much the same way in the course of the testing done in this study, a high correlation was not made. This suggests that in a sport like alpine skiing many different factors would have to be tested to truly assess an athlete’s physiological readiness. A test of a solitary physical characteristic does not show enough of
the picture to make a strong correlation, although the research may have shown this physical factor in particular to be specific to the sport of skiing. These results provide a strong argument for developing a testing protocol for the sport of alpine skiing which would include different tests of different physiological systems.

In order to test an alpine skier's physical readiness for competition it is helpful to understand what muscles an alpine competitor uses, and in what way. Understanding of muscle recruitment in terms of which muscle groups are used, and which type of contraction occurs is important in developing tests or training that would stimulate the muscles in the same fashion as competition. Research has been done on elite skiers that identifies which muscle groups are used, and their activity levels (Hintermeister, et al., 1995). This research shows that elite alpine skiers have a quasistatic component to their muscle contractions, meaning there is evidence of antagonist muscle groups co-contracting. This research also showed that the musculature of the lower body and torso was activated to a high degree throughout the movements of alpine skiing, with some muscles such as the adductors working at over 100% of their maximal voluntary contraction rate almost continuously throughout a turn. This understanding of what muscles are activated, and to what degree is important in developing sport specific training guidelines. Attempting to develop a training protocol without the knowledge of what is being trained is difficult at best. An understanding of what musculature is being used aids in the development of tests which assess the strength component of the sport of alpine skiing.
There has been previous research suggesting that a battery of physical tests can be used to predict an alpine athlete's competitive performances (Andersen, et al., 1990). This study found that a battery of field tests had some correlation to alpine ski race performance. In this study, skiers from the Canadian national team outperformed the divisional and provincial level skiers in the field tests used. Further research is warranted to see if these findings can be repeated in other skiing populations.

The sport of alpine skiing has seen great amounts of change in the past decade. The introduction of new equipment has progressed the technical aspects of the sport enormously. Skis with more sidecut, and the ability to turn more quickly and carve more cleanly have brought on a massive change in technique. Athletes in the sport of alpine skiing are now becoming larger and stronger than their predecessors, and course sets are evolving as well. Courses today have greater directional changes, yet higher speeds than those of only a few years ago in all of the alpine events. Racers now negotiate courses that are groomed into sheer ice, and must be strong and agile enough to resist the forces acting upon them. Skiing has simply evolved into a sport where equipment and the modern athlete are better built than they ever have been before. Changes in equipment and course layouts are further reason for new research relating field testing to race times.

Some research has been done in the past to find tests that can be used to assess the competitive readiness of alpine ski racers. One such test is the box jump test. The box jump test was originally developed in Austria (Komexl,
1977), and it has been shown to have high correlation with alpine ski racing performance in the past. (Andersen, et al., 1990). This test assesses the athlete's anaerobic strength, and muscular endurance. It incorporates a sport specific movement with it's lateral jumping component, and it takes place over a time period similar to that found in an alpine ski race. Studies have shown that highly developed anaerobic capacity in a duration such as the one tested with the box jump is important to an alpine ski racer (Bacharach & Von Duvillard, 1995) Other studies have shown that the blood lactate accumulated in this test is very similar to the blood lactate levels found during alpine skiing (Brown & Wilkinson, 1983). These similar blood lactate results suggest that the anaerobic system is being stressed to the same capacity in both activities.

Other tests have been developed as well to assess the physical readiness of an alpine ski racer. The hexagonal jump test is a measure of an athlete's agility, coordination, and foot speed. This test has also been shown to have a high correlation to alpine ski racing performance (Andersen, et al., 1990). It has been used by many national level ski racing organizations to test their athletes' physical readiness. The Sargent vertical jump test measures the athlete's explosive leg strength (Sargent, 1921). A moderate correlation has been made between this test and alpine ski racing performance (Andersen, et al., 1990). This test has also been used by many national level alpine skiing organizations. The five hop test is a plyometric type exercise that also measures the athlete's explosive leg strength. This test has been correlated to alpine skiing performance by the Canadian national ski team, and is used by other national level ski racing organizations such as the United States ski team.
Another test that has been developed is the zig zag run test. This test measures the athlete's agility and short anaerobic capacity in a marked course that emphasizes sport specific lateral movement. This lateral movement utilizes many of the same muscles shown to be used in the sport of ski racing (Hinterrmeister, et al., 1995). The 20 meter shuttle run was designed to test the short anaerobic system, and the athlete's agility. This test has been shown to have a moderate correlation to alpine ski racing performance (Andersen, et al., 1990). This test, like the others has been used by many national level ski racing organizations to test their athlete's physical preparedness for alpine competition. In light of the fact that all the above tests have been correlated with alpine ski racing, it may be hypothesized that a combined battery of these tests could identify the differing ability levels of alpine ski racers. Such a battery of tests could also be used to establish physical preparedness for the sport. Knowing the physical characteristics of an alpine ski racer, and that certain tests have shown a correlation to ski race performance, a ski academy in Maine has developed a battery of field tests. The purpose of this study was to determine if this battery of physical tests can be used to distinguish between the ability levels of junior alpine ski racers. In other words, are the results of these field tests correlated to race times?

In this investigation, the slalom and giant slalom will be studied. These are considered the technical events in alpine ski racing. The slalom is known for its quick turns occurring from 10 to 15 meters apart, requiring agility and speed. Average times for the slalom event can range from 35 seconds to one
minute. The giant slalom is generally accepted in the ski racing community as the basis of good ski racing skill and fundamentals. Gates are from 18 to 24 meters apart, and speeds are higher than in the slalom event. The average times for the giant slalom event can range from 45 seconds to over one minute. Both events require a high level of technical proficiency. An effective physical testing program should correlate highly to these two events in which all junior ski racers in the United States, and around the world compete.
METHODS

The purpose of this study was to determine a correlation (if any), between scores on field tests for performance and the actual competitive performance of alpine skiers. The physical testing data used were taken from the results of a battery of tests developed for the purpose of assessing an alpine ski racer's physiological readiness for competition. These test results were then compared with the athlete's USSA points profiles in both the slalom and giant slalom events. A Pearson product moment correlation was used to examine the relationship between the field testing results, and the athlete's ski racing performance. The USSA points profile of the athlete is an interval/ratio scale which is a representation of his or her ski racing ability in relation to that of the best athlete in the world in that particular event.

Subjects: The subjects were 42 members of a New England ski academy alpine ski racing program during the 2002 and 2003 seasons. These subjects ranged in age from 15 to 19 years, and had varied levels of alpine ski racing experience. Some subjects competed only at the state level in the Maine Alpine Racing Association (MARA), while others competed up to the national level in high caliber Nor-am continental cup competition. There were 30 male
subjects, and 12 female subjects that completed the battery of field tests. All the subjects completed the physical testing as part of their team's training.

**Box Jump test:** Performance of this test involved the athlete jumping laterally from left to right over a box. The number of jumps completed in 90 seconds was recorded to score the test. One jump was defined as jumping from the top of the box, to one side, and back to the top of the box. The athlete started from the top of the box. The tester signaled the athlete to begin the test, and the athlete jumped off of, and on to the box as many times as possible in 90 seconds. The tester signals to the athlete verbally when the 90 second time period was over.

**Hexagonal jump test:** The athlete was timed as he or she jumped laterally over a hexagon shaped series of barriers. The barriers range in height from 15cm to 35cm. The athlete began jumping at the lowest obstacle of 15cm, and from the outside border of the hexagon. The athlete jumped laterally over the first 15cm high obstacle to the inside border of the hexagon, and then jumped forward and laterally to the outside border of the next obstacle. The athlete continued with this jumping pattern of laterally to the inside and laterally to the outside of the obstacles proceeding around all six sides of the hexagon. The athlete began at the verbal command of the tester, and the tester stopped the timer when the athlete finished. Both clockwise and counterclockwise directions were timed for three revolutions around the hexagon (in two separate time trials). The times were then added together to obtain the athlete's score.
The athlete must was not allowed to come into contact with any of the barriers while jumping over them. Any contact with the barriers resulted in the athlete restarting that particular time trial.

Sargent jump test: This test measured the athlete's vertical jump. The equipment used in this test was the Vertec device. A two-legged jump utilizing a pre-stretch (crouch), and arm swing was performed. The highest jump recorded in three trials was used as the athlete's score.

Five hop test: The five hop test is a plyometric exercise that measures the athlete's explosive leg strength. The test was performed by completing five forward jumps in succession. The athlete's feet had to leave the floor and land at the same time. The athlete was allowed to use an arm swing for momentum. The distance traveled from the starting line to where the athlete's heels landed after the fifth and final jump was the athlete's score for this test.

Sit ups: The athlete began by lying on his or her back, knees bent at a 90-degree angle with the feet flat on the ground. The arms were crossed over the chest, and held at right angles to the chest while the thumbs touched the clavicles. The feet were held to the ground by the tester, or a partner to help the athlete maintain position throughout the test. The athlete was given a verbal command to start. Proper form required the athlete to raise his or her torso from the floor until the elbows touched the knees, followed by a return of the
shoulders to the ground. The total number of sit ups completed in 60 seconds was recorded as the athlete’s score for this test.

**Push ups:** This test was performed from a starting position of a straight back, elbows flexed at 90 degrees, and the hands placed at a comfortable width to the body. The athlete had to maintain a straight back and legs during the push-up movement, and the chest had to come to the floor for the push-up to be counted. A break in form resulted in the repetition not being counted. The total number of push ups completed in a 60 second time period were recorded as the athlete’s score.

**Pull-ups:** This test was performed from a starting position using an overhand grip on the bar with the hands placed at a comfortable width. The elbows were fully extended to start the test. The athlete pulls his or her body up until the on the chin cleared the bar, then lowered them self back down to the starting position. Only pull ups completed with the full range of motion during the 60 second time period were scored.

**Estimated One Repetition Maximum (1RM):** Each athlete’s 1RM for both the bench press and squat were estimated. A weight was lifted close to the athlete’s maximal lift, and the number of repetitions that were completed were recorded. 1RM was estimated using the following formula:

\[
\frac{\text{Number of repetitions}}{1.0 - (\text{Weight lifted} \times 0.02)}
\]

The athletes adhered to strict form in both lifts to insure safety, and accuracy.
Zig Zag run: The athlete negotiated a marked course in a X shaped pattern. The athlete sprinted around cones in this X shaped pattern beginning at one end, turning around the cone in the center of the X, and then heading in the direction of the next cone at the perimeter of the X. This pattern of perimeter to center was repeated until each cone in the X was circled and the athlete had returned to the starting position. The athlete’s time to complete the pattern was recorded.

20 meter shuttle run: This test of aerobic fitness was performed by the athlete sprinting between two cones spaced 20 meters apart. An audio tape containing a number of auditory ‘beeps’ at intervals of decreasing time was played. The interval between ‘beeps’ decreases, and the athlete is forced to keep pace with these signals. The athlete is expected to make it to the next cone before the next ‘beep’ signals. The athlete stopped running between the cones when he or she could no longer keep pace with the ‘beeps’. The distance covered was recorded as the athlete’s score in this test.

Testing was performed during the last week of April, 2002 for 8 of the subjects, and during the first week of December, 2003 for the other 36 subjects. The tests were not performed in a specific order for all the subjects, but all were completed during the weekly time periods allotted for testing by the coaching staff. The results of the tests from the spring of 2002 group were compared to the USA final points list for the season, which coincided with the time in which
the tests were completed. The results of the tests from the winter session group were compared to the USSA third points list for the 2002/03 season, which coincided with this testing period.

The physical testing results were gathered and then compared with the direct variable, the two USSA points profiles of each athlete in the slalom and giant slalom events. The USSA points profiles are an interval/ratio scale that represents the time the athlete would finish behind the number one ranked athlete in the world in that event. The method for calculating the points profiles is presented in Table 1.

Statistical Procedures: A Pearson product-moment correlation coefficient was computed to establish the relationship between each of the test results and the points profiles for both the slalom and giant slalom events. An excel stats program was used to compute the r values.
Table 1: USSA Points System

How the points are scored:

Race points + penalty = Racer’s result

Calculation of ‘Race points’

Race points are determined by comparing the winner’s time and the individual racer’s time. The formula for points makes this comparison, and produces points in each discipline according to the ratio of the racer’s time to the winner’s time.

In its simplest form, the formula can be stated as follows:

\[ P = (Tr/Tw - 1) \times F \]

Where:

- \( P \) = race points
- \( Tr \) = the racer’s time, in seconds
- \( Tw \) = the winner’s time, in seconds
- \( F \) = is a constant, different for each discipline

\( F \) values for each discipline are:

- Downhill: 1350
- Super-G: 980
- Giant slalom: 860
- Slalom: 570

For example:

If a winning time for the slalom is 100 seconds, a racer with a time of 108 seconds receives 45.60 race points.

\[ 45.60 = (108/100 - 1) \times 570 \]
Table 1 (cont.): **Penalty Points**

Penalty points are calculated to reflect the best point holder in the race to the best point holder in the world (0 points).

Penalty calculation:

<table>
<thead>
<tr>
<th>Best five at the start:</th>
<th>Seed points</th>
<th>Race result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Racer 1</td>
<td>3.69</td>
<td>11</td>
</tr>
<tr>
<td>Racer 2</td>
<td>9.28</td>
<td>2</td>
</tr>
<tr>
<td>Racer 3</td>
<td>9.92</td>
<td>1</td>
</tr>
<tr>
<td>Racer 4</td>
<td>18.50</td>
<td>DNF</td>
</tr>
<tr>
<td>Racer 5</td>
<td>19.37</td>
<td>9</td>
</tr>
</tbody>
</table>

**Seed points (current list)** | **Best 5 Race pts. of these five** |
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>1) Racer 3 9.92</td>
<td>9.92 0</td>
</tr>
<tr>
<td>2) Racer 2 9.28</td>
<td>9.82 1.63</td>
</tr>
<tr>
<td>3) Racer 6 20.90</td>
<td>20.35 3.10</td>
</tr>
<tr>
<td>4) Racer 7 34.92</td>
<td></td>
</tr>
<tr>
<td>5) Racer 8 40.18</td>
<td></td>
</tr>
<tr>
<td>6) Racer 9 29.77</td>
<td>29.77 8.04</td>
</tr>
<tr>
<td>7) Racer 10 35.92</td>
<td></td>
</tr>
<tr>
<td>8) Racer 11 46.03</td>
<td></td>
</tr>
<tr>
<td>9) Racer 5 19.37</td>
<td>19.37 11.07</td>
</tr>
<tr>
<td>10) Racer 12 34.55</td>
<td>88.69=A 23.84=C</td>
</tr>
</tbody>
</table>

-Add the total of A and B, then subtract by C, divide the result by 10, rounding to the 100th of a point.

\[(A+B-C)/10 = \text{Penalty}\]

In this case:

\[(88.69 + 60.76 - 23.84)/10 = 12.56 \text{ (race penalty)}\]

Add race penalty to race points for the athlete’s result.

(United States Ski and Snowboard Association, 2002)
The individual scores on each field test were compared to the athlete's USSA points profiles using a bivariate correlation coefficient (The Pearson r). The athletes were grouped by gender and the field tests were correlated to the slalom and giant slalom events. The $r$ values for each comparison are presented in Table 2. The majority of the correlations are negative due to the fact that faster race times are recorded with lower numbers.
Table 2: Physical Testing Results/Points Profiles Correlation

<table>
<thead>
<tr>
<th></th>
<th>Female</th>
<th>Slalom</th>
<th>Giant Slalom</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=12</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>Test-</td>
<td>-0.30</td>
<td>-0.45</td>
<td></td>
</tr>
<tr>
<td>1RM Bench</td>
<td>-0.10</td>
<td>0.48</td>
<td></td>
</tr>
<tr>
<td>1RM Squat</td>
<td>-0.28</td>
<td>-0.06</td>
<td></td>
</tr>
<tr>
<td>Sit-ups</td>
<td>-0.09</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>Push-ups</td>
<td>na</td>
<td>na</td>
<td></td>
</tr>
<tr>
<td>Pull ups</td>
<td>-0.72*</td>
<td>-0.60</td>
<td></td>
</tr>
<tr>
<td>5 Hop</td>
<td>-0.43</td>
<td>-0.52</td>
<td></td>
</tr>
<tr>
<td>Sargent</td>
<td>-0.22</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>Hex Jump</td>
<td>-0.07</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>Box Jump</td>
<td>0.77*</td>
<td>0.71*</td>
<td></td>
</tr>
<tr>
<td>Zig Zag run</td>
<td>-0.34</td>
<td>0.50</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Slalom</th>
<th>Giant Slalom</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=30</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>Test-</td>
<td>-0.41*</td>
<td>-0.41*</td>
<td></td>
</tr>
<tr>
<td>1RM Bench</td>
<td>-0.63*</td>
<td>-0.66*</td>
<td></td>
</tr>
<tr>
<td>1RM Squat</td>
<td>0.05</td>
<td>-0.05</td>
<td></td>
</tr>
<tr>
<td>Sit-ups</td>
<td>na</td>
<td>na</td>
<td></td>
</tr>
<tr>
<td>Push-ups</td>
<td>-0.39*</td>
<td>-0.47*</td>
<td></td>
</tr>
<tr>
<td>Pull ups</td>
<td>-0.62*</td>
<td>-0.72*</td>
<td></td>
</tr>
<tr>
<td>5 Hop</td>
<td>-0.36</td>
<td>-0.43*</td>
<td></td>
</tr>
<tr>
<td>Sargent</td>
<td>0.58*</td>
<td>0.69*</td>
<td></td>
</tr>
<tr>
<td>Hex Jump</td>
<td>-0.60*</td>
<td>-0.67*</td>
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<tr>
<td>Box Jump</td>
<td>0.63*</td>
<td>0.62*</td>
<td></td>
</tr>
<tr>
<td>Zig Zag run</td>
<td>-0.46*</td>
<td>-0.58*</td>
<td></td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level (2-tailed)
Every test correlation was also graphed on a scatterplot, and examined for outliers and curvilinear relationships. None were found. In addition, the field tests were broken down into groups by the physiological/metabolic qualities that each test was meant to assess. These four groups were measures of muscular strength, measures of muscular power, measures of agility and anaerobic capacity, and aerobic capacity. Each of these groups was examined for its own intercorrelations. The results for the female athletes are presented in Table 3. The male athlete results are presented in Table 4.
Table 3: Intercorrelations Between Groups of Field Tests - Female

<table>
<thead>
<tr>
<th></th>
<th>Max Bench</th>
<th>Max Squat</th>
<th>Sit-ups</th>
<th>Push-ups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Bench</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Max Squat</td>
<td>0.82*</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Sit-ups</td>
<td>-0.34</td>
<td>-0.10</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Push-ups</td>
<td>0.38</td>
<td>0.82*</td>
<td>-0.22</td>
<td>/</td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level (2-tailed)

**Female Measures of Muscular Strength**

<table>
<thead>
<tr>
<th></th>
<th>Sargent</th>
<th>5 Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sargent</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>5 Hop</td>
<td>0.55</td>
<td>/</td>
</tr>
</tbody>
</table>

**Female Measures of Muscular Power**

<table>
<thead>
<tr>
<th></th>
<th>Box Jump</th>
<th>Hex Jump</th>
<th>Zig zag run</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box Jump</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Hex Jump</td>
<td>-0.67*</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Zig zag run</td>
<td>-0.26</td>
<td>0.33</td>
<td>/</td>
</tr>
</tbody>
</table>
Table 4: Intercorrelations Between Groups of Field Tests - Male

---

**Male Measures of Muscular Strength**

<table>
<thead>
<tr>
<th></th>
<th>Max Bench</th>
<th>Max Squat</th>
<th>Sit-ups</th>
<th>Pull-ups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Squat</td>
<td>0.73*</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Sit-ups</td>
<td>0.14</td>
<td>-0.06</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Pull-ups</td>
<td>0.59*</td>
<td>0.68*</td>
<td>0.06</td>
<td>/</td>
</tr>
</tbody>
</table>

*Correlation is significant at the 0.05 level (2-tailed)*

---

**Male Measures of Muscular Power**

<table>
<thead>
<tr>
<th></th>
<th>Sargent</th>
<th>5 Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sargent</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>5 Hop</td>
<td>0.81*</td>
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</tr>
</tbody>
</table>

---

**Male Measures of Agility and Anaerobic Capacity**

<table>
<thead>
<tr>
<th></th>
<th>Box Jump</th>
<th>Hex Jump</th>
<th>Zig zag run</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box Jump</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Hex Jump</td>
<td>-0.83*</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Zig Zag run</td>
<td>-0.80*</td>
<td>0.82*</td>
<td>/</td>
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</tbody>
</table>
DISCUSSION

In this study it was found that a number of the tests examined did, and some did not appear to have a correlation with ski racing performance. For the female athletes, the strongest correlation was found with the Zig zag run test. This correlation appeared for both the slalom \((r=0.77)\), and the giant slalom events \((r=0.71)\). This is a test which requires the athlete to use a sport specific lateral movement to negotiate the course, and utilizes the anaerobic system, which previous research has shown to be highly developed in alpine ski racers (Bacharach & Von Duvillard, 1995; Tesch, 1995; Tesch, et al., 1978). The Zig zag run was also found to be the strongest correlation with slalom race performance with the male subjects \((r=0.63)\), and showed a strong correlation with the male giant slalom race performance \((r=0.62)\). Athletes with higher levels of ski race performance generally demonstrated lower times for the run than did athletes with lower ski race performance.

The hexagonal jump test found strong correlations to ski race performance in the male athletes, but the results did not find statistically significant results in the female athletes. The male athletes demonstrated some of the stronger correlations for the field tests for both the slalom \((r=0.58)\) and giant slalom \((r=0.69)\) events. Andersen, et al. also found a high correlation to the hexagonal jump test and giant slalom skiing performance \((r=0.82)\) (Andersen, et al., 1990). These results would suggest that this test is effective in predicting the performance of alpine ski racers. The female athletes in the study
demonstrated results that were not statistically significant at the 0.05 level. The author hypothesizes that the low statistical significance found in the female athletes may be due to age and strength.

The box jump test demonstrated similar results to the hexagonal jump test. The correlation for the male athletes between the box jump and alpine ski race performance was among the stronger correlations in the test battery, while the correlations were not statistically significant for the female athletes. The male athlete’s r values for the box jump were strong in both the slalom (r=-0.60), and giant slalom (r=-0.67) respectively. The female athletes demonstrated weaker correlations in the slalom (r=-0.07), and the giant slalom (r=0.13) but these findings were not statistically significant at the 0.05 level. The box jump test has been shown by Andersen et al. to have a high correlation with giant slalom ski race performance (r=-0.80) in a comparison of Canadian National team skiers and their regional level competitors, so the findings with the male athletes concur with previous research (Andersen, et al., 1990). The box jump test is meant to assess an alpine ski racer’s anaerobic capacity with a sport specific lateral jumping movement. The box jump test has been shown to create blood lactate levels very similar to those created during a ski race (Brown & Wilkinson, 1983). All these findings suggest that the box jump test can be used as an effective tool in predicting the performance of an alpine athlete. This is the same as previous research done with the hex jump suggesting that this test can be used as an effective predictor of alpine ski race
performance. The results found in this study demonstrated low statistical significance with the female athletes in relation to this test. This could be due to the low n (n=12) for the female athletes.

The Box jump, Hexagonal obstacle, and Zig zag run were grouped together as measures of agility and anaerobic capacity. These three tests were intercorrelated to determine the relationship, if any. For the male athletes, there were strong correlations between these three field tests. The Hex jump demonstrated strong correlations between the Box jump (r=-0.83), and the Zig zag run (r=0.80). There was also a strong correlation between the Zig zag run, and the Box jump (r=-0.80). The female athletes demonstrated weaker intercorrelations of these field tests. The Hex jump had the strongest correlation to the Box jump (r=-0.67) for the females. There were weaker correlations found between the Zig zag run, and the Box jump (r=-.26), or the Hex jump to the Zig zag run (r=0.33). The weaker correlations found between the Zig zag run, and the Box jump, and the Hex jump to the Zig zag run for the female athletes was found to not be statistically significant at the 0.05 level. The other strong intercorrelations between these three tests suggest that there is a relationship between the results of these tests. The strong intercorrelations suggest that the same physiological qualities are tested by all three of these tests. This might suggest that in using a battery of tests to assess the physiological readiness of alpine ski racers, not all of these tests may need to be done in order to measure the agility and anaerobic capacity of an athlete.
The 5 Hop test also demonstrated a strong correlation with ski racing performance. The 5 Hop test proved to have the strongest correlation of all the tests for the male subjects within the giant slalom event ($r=-0.72$). There was also a moderate correlation with this test and the slalom event for the male subjects ($r=-0.62$). The 5 Hop test was also one of the strongest correlations for both events with the female subjects. There were moderate correlations for both the slalom ($r=-0.72$), and the giant slalom ($r=-0.60$) events, although the correlation found to the giant slalom event was found to not be statistically significant. This could be due to greater restriction of range within the giant slalom points profiles of the female subjects in this test. In the past this test has been correlated with alpine ski race performance (Bayli, 1997). This test is a plyometric type test which utilizes the explosive power of an athlete, as well as the coordination of the body movements to maximize the distance traveled.

The Sargent Vertical jump test (Sargent, 1921) demonstrated a weaker correlation to alpine ski racing performance in the group of athletes tested for this study. For the male athletes a weak correlation was found in the slalom ($r=-0.36$) and giant slalom ($r=-0.43$) events. The correlation was higher for the female athletes in the slalom ($r=-0.43$), and giant slalom ($r=-0.52$) events. Only the correlation between this test and the giant slalom event for the male subjects proved to be statistically significant. Weak correlations have been made in the past between alpine ski race performance and this test (Andersen, et al., 1990). It is observed by the author that in the vertical jump, plantar flexion of the ankle is a large part of the overall movement. Plantar flexion is quite limited, and not permitted to the degree found in this test when an alpine
athlete has a rigid ski boot on their foot. This limited range of motion may very well effect the athlete's jumping mechanics, and therefore his or her peak jumping height. This test shows little ability to predict the performance of an alpine ski racer.

Intercorrelations were calculated between the Sargent Vertical jump test, and the 5 Hop test. These tests are meant to assess the athlete's power, and plyometric jumping ability. There was a strong correlation found for the male subjects between these two tests ($r=0.81$). The results found for the female athletes were not statistically significant. This could be due to a low $n$ ($n=12$) for the female athletes. The fact that these two tests show a strong relation to one another, and that the 5 Hop test appears to have a stronger correlation to ski race performance suggests that the 5 Hop may be a better test than the Sargent vertical jump for evaluating alpine skiing athletes.

The tests of absolute strength, such as the 1RM bench press and squat, performed by the subjects demonstrated a wide range of results, from strong to weak correlations. For the male subjects the squat was found to have a strong correlation with the slalom ($r=-0.63$), and giant slalom ($r=-0.66$) performance. The higher level skiers generally were able to demonstrate greater strength in this exercise. The male subjects showed a weaker correlation to the bench press with the slalom ($r=-0.41$) and the giant slalom ($r=-0.41$) events. This would suggest that lower body strength is more important to alpine ski race performance than is upper body strength. Leg strength has been shown to be important to ski racing performance in previous studies (Brown & Wilkinson,
1983; Haymes & Dickinson, 1980), and this research done with the male subjects concurs that strength is an important trait for an alpine ski racer to have. The tests of absolute strength showed different results for the female athletes. The bench press was shown to have a weaker correlation to the slalom \(r=-0.30\) and giant slalom \(r=-0.45\) events. The squat revealed a weak relationship to the giant slalom event \(r=0.48\), and slalom \(r=-0.10\). This was the lowest correlation the female athletes had with ski racing performance for all the tests performed. The results of these two tests for the female athletes was found to not be statistically significant at the 0.05 level. The author hypothesizes that the correlations found for the female athletes are not statistically significant due to a small sample size. The number of female athletes that were able to complete the 1RM squat test was also low \(n=7\) due to various injuries at the time of testing. The female athletes in this study who were unable to take the 1RM squat test were also among the higher level ski racers of the group.

The tests that were performed to assess muscular strength and endurance showed little ability to predict ski racing performance. The number of sit-ups performed in one minute was one of the lowest correlations for the males in the giant slalom \(r=-0.05\), and slalom \(r=-0.05\) events. The same poor correlation in the test of sit-ups was found for the females in the giant slalom \(r=-0.06\) and slalom \(r=-0.28\) events. None of these tests were found to be statistically significant, perhaps due to restriction of range within the results. Previous research has shown that alpine ski racers demonstrate high levels of core strength and endurance (Brown & Wilkinson, 1983). Although the
correlation with alpine ski racing for this test may be weak, the athletes in the study demonstrated above average results in relation to the general population. The weak correlation, and lack of statistical significance may not suggest that abdominal strength is not important to ski racing, but may be more a result of restriction of range. While the characteristic of core strength may be important to alpine skiing as previous research suggests, this test may not be useful in predicting alpine ski performance as all the participants displayed fair levels of core strength in relation to this test.

The number of push-ups completed in a one minute time period, also showed little correlation to ski racing performance. This test was only completed by the female athletes, and resulted in a poor correlation to both the slalom ($r=-0.09$), and giant slalom ($r=-0.18$) events. These tests were not found to be statistically significant, and this may be due to the fact that alpine ski racing is not a sport that relies heavily on upper body muscular endurance for success. The other test of muscular endurance was the number of pull-ups completed, but this test was only completed by the male subjects. The pull-up test also demonstrated weak correlations to the giant slalom ($r=-0.47$), and slalom ($r=-0.39$) events. The pull-up test is known as being a good measure of upper body strength. Of the several tests completed in this battery, the tests of muscular endurance held the weakest correlation to alpine ski racing for both male and female athletes. These findings suggest that these tests are ineffective predictors of alpine ski racing performance in junior athletes.
Intercorrelations were calculated between the tests that were performed to assess the muscular strength of the athlete. There were strong correlations found between the 1RM Squat, and the 1RM Bench press for both the male (r=0.73), and the female subjects (r=0.82). A strong correlation was also found between the 1RM Squat, and Pull-ups for the male subjects (r=0.68). For the female subjects, the 1RM Squat, and push-ups (r=0.82) also demonstrated a strong correlation. Weaker correlations were found between the 1RM Bench press, and Sit-ups for both the male (r=0.14), and female subjects (r=-0.34). A weak relationship was also found between the 1RM Bench press, and Sit-ups for both the male (r=0.14), and female (r=-0.34) subjects. The 1RM Squat also demonstrated a weaker correlation to the results of the Sit-ups for the male (r=-0.06), and female (r=-0.10) subjects. A stronger correlation was found for the male subjects between the 1RM Bench press, and the pull-ups (r=0.59). The 1RM Squat also demonstrated a stronger correlation to the Pull-ups (r=0.68) for the male subjects. The female subjects demonstrated a strong correlation between the 1RM Squat, and the Push-ups (r=0.82), but a weaker correlation between the Push-ups, and the 1RM Bench press (r=0.38). Among the weaker correlations found were between the Sit-ups, and the Push-ups (r=-0.22) for the female athletes. The male athletes also demonstrated a lower correlation between the Sit-ups, and the Pull-ups (r=0.20). All the strong intercorrelations between these tests for both genders were also found to be statistically significant.

The 20m Shuttle run demonstrated some of the weakest correlations of all the tests in the battery for both the male and female athletes. There was an inverse
relationship for the male athletes in both the slalom ($r = -0.46$), and giant slalom ($r = -0.58$). In general, the results demonstrated that the lower level ski racers were able to demonstrate better results for this test. The female athletes demonstrated an inverse relationship between this test and the slalom event ($r = -0.34$), and a low correlation for the giant slalom event ($r = 0.50$). The results of the female athletes proved to not be statistically significant, perhaps due to restriction of range within the results of this field test. Previous research has shown this test to have a moderate correlation with ski race performance (Andersen, et al, 1990), but this study did not show it to be an effective means of predicting alpine ski race performance. This could be due to the fact that alpine ski racing relies heavily on the anaerobic system for energy production, and this is a test of the aerobic system. The author observes that the aerobic system is important to an alpine ski racer during training situations, when an athlete must recover between training runs. In this way, an alpine athlete must have some aerobic capacity. Perhaps a different test would be more effective in determining what an adequate level of aerobic fitness is for a junior alpine ski racer.

In this study, differences were found between the results of the male and female athletes. Many reasons could be pointed out for the differences in these results. There was a smaller sample population for the female athletes ($n = 12$) than for the male athletes ($n = 30$). Ski racing is also a sport that depends on a number of factors for success. Physiological tests alone do not encompass the psychological skills, individual race experience, and other factors that are
critical to the sport. Equipment issues, psychological preparation, and many other factors all play in the results of an alpine ski race. These factors can not be measured by physiological tests alone. It should be noted that any of these factors and more can play in the results of an alpine ski race. Physiological testing may demonstrate the athlete’s ability to physically handle the rigors of alpine ski competition, but physical preparation alone does not ensure success. A high physiological capacity does not ensure that the athlete has the experience and skill to be a successful ski racer. An excellent athlete with little ski racing experience may do very well on this battery of field tests, but may still ski race without a high level of proficiency.

The conclusion of this research is that many of the field tests within this battery would be ineffective to utilize as predictors of alpine ski competition success in junior ski racing athletes. The strongest statistically significant correlations found between these field tests and alpine ski race performance were the Zig zag run, the 5 Hop test, the Hex jump, and the 1RM Squat. Many of the tests of this battery, such as the 20m Shuttle run, Sit-ups, Push-ups, Pull-ups, and Sargent vertical jump demonstrated weak correlations to alpine ski racing performance. Many of these tests also demonstrated a strong relationship to other tests that were designed to assess the same physiological qualities. The fact that many of these tests did not demonstrate an ability to differentiate between ability levels of the junior athletes in the study, and the fact that many of the tests intercorrelated strongly to one another suggests that this battery of tests could be simplified into a smaller battery of tests. The smaller test battery
would take less time to administer by coaches, and would more effectively identify physiological capabilities that are important to alpine ski racing success.

The author suggests that a battery of tests that could be more effective and time efficient based on this research would include the Zig zag run, the 1RM Squat, the 5 Hop test, and the Box jump. The Zig zag run measures the athlete's agility and short anaerobic system, and this test demonstrated the strongest correlations to alpine ski race performance for both genders in this study. The 1RM Squat measures the athlete's absolute lower body strength. Lower body strength has been shown to be a characteristic of alpine ski racers. This test also intercorrelates strongly to many of the other measures of muscular strength tested in this battery, such as the 1RM Bench press. The 5 Hop test was among the strongest correlations in this battery of tests for both genders. The 5 Hop test measures the athlete's muscular power, and this test intercorrelated strongly with the Sargent jump test, the other measure of muscular power which demonstrated a weaker correlation to ski race performance. The Box jump measures the athlete's agility, and the short and medium anaerobic systems. This test has correlated strongly with alpine ski race performance in previous studies, and it was also one of the stronger correlations found by this study. This smaller battery of tests measures the athletes muscular strength, muscular power, agility, and anaerobic capacity. This battery eliminates several of the tests that demonstrated low correlations to alpine ski race performance, and also eliminates the tests that intercorrelated highly with tests that measured the same physiological and
metabolic capacities of this smaller battery. Time is always a factor in the training schedules of junior alpine competition programs here in the United States. A more time efficient battery of tests that measures the important physiological capacities of an alpine ski racer would be of great value. A more time efficient battery of field tests would allow alpine ski race programs to spend more time training effectively, and utilize the test more often to measure the progress of this training.

Previous research had demonstrated higher correlations to some of the field tests analyzed by this study to competitive performance. A possible explanation for the different findings may be the different sample population used by this research in comparison with previous research. The research done by Anderson, et al. utilized a large number of National team level athletes (Andersen, et al., 1990). The research done by Kornexl also utilized National team level athletes for his higher correlations to the box jump with competitive performance (Kornexl, 1977). The higher correlations found with the 5 Hop test by Bayli were also done with the Canadian National team (Brown & Wilkinson, 1983). This study utilized junior level athletes, none of whom were currently at a National team level. This differences in the subjects used could be a reason for the different findings. National team members generally have very similar levels of competitive experience, and are generally older. Older, more mature athletes generally demonstrate higher levels of strength and power than what junior level athletes are able to produce at their level of physical maturity. In the world of junior athletes, competition experience can vary a great deal. An inexperienced competitor can still have great physiological capacity, but poor
skill. This age and experience difference could lead to differences in correlations of physical testing to competition performance in junior athletes than with National team level athletes. Another possible explanation could be the evolution of alpine ski racing. Technique, equipment, and course sets have all evolved drastically over just the past ten years. As the sport progresses, so do the skills required to be successful in the sport. The changing nature of alpine ski racing could also be a reason for differences in findings at this point in time, from the findings of just a few years ago.

Further research may be warranted on the subject of utilizing a battery of field tests to assess competitive readiness in the sport of alpine ski racing. More research with junior level athletes may provide different insights than what has been found with National team level athletes in relation to correlations between field testing and competition. More research on National team level athletes may also be warranted. The evolution of the sport of alpine ski racing may have an effect on correlations found in the past between field testing and competition with National team level athletes today. Further research is needed to determine if the findings of this study differ from those of previous research due to the evolution of the sport, or because of differences in the maturation level of National level competitors and junior competitors. Such insights would be of benefit to coaches who must train these different age groups effectively.
REFERENCES


BIOGRAPHY OF THE AUTHOR

David Heikkinen was raised in Walpole, MA and graduated from Xaverian Brothers High School in 1994. He attended the University of Maine at Farmington, and graduated in 1998 with a Bachelor's Degree in Health. After graduating from the University of Maine, he began a career in coaching alpine ski racing at the Carrabassett Valley Academy in Maine. He received his National level coach, full certification from the United States Ski Association in 2000. He is a member of Pi Lambda Theta, a National Honor Fraternity in the field of Human Development.

David entered the University of Maine at Orono in the fall of 2001. He is a candidate for the Master of Science degree in Kinesiology and Physical Education from The University of Maine in May, 2003.