5-3-2012

Performance Changes During a Weeklong High Altitude Training Camp in Lowlander Youth Athletes

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B.S. University of New Hampshire, 2008

A Thesis

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master's of Science

at the

University of Connecticut

2012

APPROVAL PAGE

Master's of Science Thesis

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University of Connecticut

2012

Table of Contents

Chapter 1
Review of Strength and Conditioning for Alpine Ski Racing

The purpose of this article is to provide the necessary background for a strength coach to implement as much evidence based coaching as possible for alpine ski racing.

Summary

The sport of alpine ski racing requires relatively slow eccentric and concentric movements that produce forces of up to 3G, with course durations from 40 seconds to over two minutes. As finally controlling the ski snow contact and ability to limit the dissipation of speed requires dynamic balance through a wide range of lower limb and hip mobility. Strength and conditioning should focus on hypertrophy, maximal strength development, balance, dynamic mobility, and anaerobic metabolic support.

Introduction to the Sport of Alpine Skiing

Alpine ski racing has been an Olympic sport since 1988 with five events: Slalom (SL), Giant Slalom (GS), Super-Giant Slalom (SG), Down Hill (DH), with Combined (C, 1 run of SL and 1 run of DH) and Super Combined (SC, 1 run of SL and 1 run of SG) since been added.

What are referred to as the technical (Tech) events are SL and GS, these consist of two time runs, with a 45 minute course inspection before each run, and the athlete with the fastest combined time wins. SL consists of gates 4-13 meters apart; however recent rule changes may restrict SL to a short as 9 meters in some age groups. Course times are typically 60-90 seconds with average speeds of 75 $km \bullet hr^{-1}$ (1, 2) and courses are required to have a vertical drop of 140 to 220 m (under 100 m for SL and under 200 m for GS in children's racing) (1).

The other tech event, GS, consists of gates about every 18-25 meters apart, with speeds ranging 40 to 80 $km \bullet hr^{-1}$ (20 to 50 $mi \bullet hr^{-1}$). Course times are also 60-90 seconds in duration, with a vertical drop of 250 to 450 m (1). For this

reason few courses have vertical drops of this length without at least one substantial flat section.

The speed events consist of SG and DH and the winner is the fastest of one run. The SG events occurs on a single day with a 45 minute inspection of the race course prior the competition (1). Gates are 25 to 40 m apart with a course vertical drop of 350 to 650 m (250 to 400 m for children's racing) (1). Speeds can reach as high as 113 km•hr^{-1} (70 mi•hr^{-1}) but are typically between 88-105 km•hr^{-1} (55-65 mi•hr^{-1}).

Down hill requires at least one and up to three training runs on days leading up to the competition, with a 45 minute course inspection allowed each day. In DH there can be "speed controlling" turns placed in the course at the officials discretion to maintain reasonably safe speeds, however there are usually as few turns as possible (1). Speeds have been recorded up to 160 km•hr^{-1} (100 mi•hr^{-1}) (13), but are typically between 95 to 120 km•hr^{-1} (60 to 75 mi•hr^{-1}), with run times from 1 minute to as long as 2.5 minutes, and vertical drops range 450 to 1,100 m (1).

Because a strength and conditioning professional's role has gone from preparing for a specific sport task and competition to training for the physical demands of sport practice it is important to understand the schedule and physiological demands of a typical sport training session.

On Snow Training Schedule. The schedule of a training day include 1-4 warm up runs, 1 inspection run of a training course, with 3-8 training runs on the course with 0-4 additional runs to help maintain the snow conditions on the course. Thus training sessions last 2-4 hours with a total of 4-14 runs. A ski run can last from 1 minute to 10 minutes in duration with a rest break of riding a chair lift lasting 5-15 minutes (42). Some training centers are accessed by high-speed detachable quads, which can double the volume of vertical distance during a training session. Also some alpine training centers have installed ground lifts (T-Bars and Pama Lifts), which increase the number of runs per session, as well. Although the runs tend to be shorter, than lift access training centers, these typically will be

more aggressive skiing, per meter of vertical drop. It is also not unusual for athletes to do two-a-days especially for youth athletes on weekends or during training camps.

Physical Demands of Alpine Skiing

The Carved Turn. The most important aspect to all alpine ski racing events is carving a turn and resisting the forces generated during a turn while maintaining edge control and balance. Centripetal force is equal to the mass of the object multiplied by velocity squared all divided by the radius of the turn. In addition, the steeper the slope of the hill the more the force of gravity is added to the centripetal force of the turn, which is especially apparent from the apex of the turn through completion. Therefore, as either the radius of the turn becomes shorter (quicker turn) or the velocity increases, the forces that must be resisted in order to maintain balance and technique can increase dramatically. Thus the ability for the lower body to maintain adequate forces to resist snow reaction forces and maintain the dexterity needed for edge control is critical for alpine skiing success. The last third of a course where **courses** have been known to have the steepest, fastest and shortest turn sections is critical to being able to maintain speed or even develop speed, avoid crashing and subsequent injury.

Phases of the Carve Turn. The turn is typically broken down into four phases: the initiation phase, turning phase, completion phase, and the transition phase (see figure 1). In the initiation phase the up hill and outside leg supports the body weight and the skis role on edge as the shoulders move towards the gate. In the turning phase the shoulders become level with the snow surface, outside leg remains long, and the inside leg bends as needed to allow the hips to move close to the snow creating a high edge angle. In the completion phase the skis continue to carve through to the end of the turn as the hips rise up and the outside leg starts to bend, decreasing the edge angle of the skis. And in the transition phase the legs continue to bend allowing the feet move under the hips, as the hips move down the hill, and the body weight transfers from the down hill

ski to the new up hill ski. At all times the athlete should have "cuff pressure," with the front of the boot, which is accomplished by keeping the feet balanced under the body, with the knees over or forward of the toes. And the upper body should remain balanced and stable, without excess arm movement.

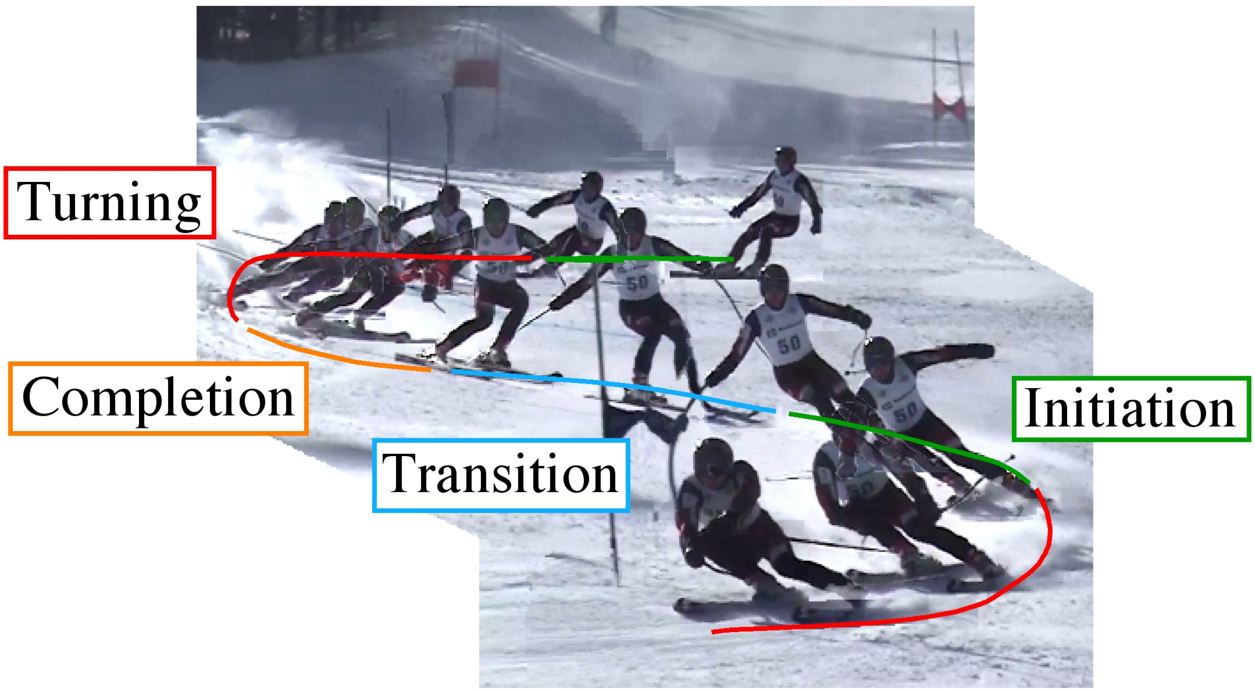


Figure 1. Phases of a carved GS ski turn. Blue is the transition phase, green is the initiation phase, red is the turning phase and the orange is the completion phase.

Biomechanics. Biomechanical analysis of alpine skiing has identified key muscles and movement patterns needed to maintain balance and edge control through the carved turn. A seminal study for the sport by Hintermeister et al. 1995, who monitored EMG activity of lower leg, thigh and trunk muscles during both SL and GS of US and British National Team members, concluded that quadriceps muscle groups' primary role was to maintain balance and ski carving

and turning through the turn and projects the hips forward during the completion to maintain balance as the skis come under the body and release energy from being bent in the apex of the turn (20). Additionally, the activations of the tibialus anterior was shown to be critical, as dorsiflexion pulls the body at a forward angle towards the tip of the skis, maintaining symmetrical fore-aft balance as the skis move forward and laterally under the skiers body (25, 45). Sustaining this symmetrical fore-aft balance over the skis has been shown to correlate with SL ski performance (25, 45). This group also showed that EMG activity of muscles around the knee and hip was highest in the turning phase where centripetal forces are greatest. In addition, the rectus abdominus muscle had the greatest EMG activation from the middle of the turning phase (apex) through the completions of the turn, where ski-snow reaction forces are greatest, which parallel the novel core pulse theory described by McGill et al. 2010 (33, 34).

Forces and Joint Angle Velocity of Alpine Ski Racing. The forces generated in alpine ski racing turns are generally between 1-2.5G with peak forces within a course or landing from a jump to exceed this range in world cup level athletes. In two studies utilizing several camera angles, calculated peak forces in SL turns to be 2-3G (44, 46). Using a Pedar Mobile system on a FIS SL course with a 17º slope forces where measured to be 1.5G with the force predominately going through the forefoot, suggesting that this takes advantage of the steering nature of the front of the ski (29).

Investigations comparing maximal strength at various angular velocities have found alpine skiers to be the strongest at slow velocities (47). One turn typically requires one set of knee flexion through the first half of a turn and knee extension from just after the apex of the turn through completion.

What is important to the strength and conditioning coach is the angular knee velocity for each event: SL, 69±11; GS, 34±2; SG, ~17 deg $\cdot s^{-1}$. These are much less than recorded in a typical running gate, 300 deg $\cdot s^{-1}$, or during sprinting efforts, 600-700 deg $\cdot s^{-1}$ (47). This is combined with relatively long movement cycling times (time to complete a left and right turn; SL, 1.6±0.2; GS,

3.5±0.6; SG, ~4.1s) and relatively high percentages of maximum voluntary contractions (SL, 74±33; GS 73±21%) creates a situation where muscle blood diffusion is reduced, with relatively slow muscle movements as compared with other anaerobic dominated sports (47). Knee extensions as low as 20-45% of maximal voluntary contraction of the quadriceps muscle group can restrict blood perfusion (9). Turnball et al. (47) suggested that there is a unique cardiovascular adaptation to allow for greater blood flow during the transition period between turns, this combined with the vibration exposure, makes the time for on snow skiing an important stimulus for developing metabolic energy supply adaptations specific to alpine ski racing.

Vibration in Alpine Ski Racing. In addition to the extremely high-force demands, alpine skiing has additional hypoxic stress that can compound, which include the relative altitude, the length and force of the muscle contractions, and the vibration stress caused by the ski snow contact. Recent investigations have quantified the effects of vibration on ski performance from a metabolic and mechanical perspective. Vibrations in alpine skiing depend on the snow conditions, equipment (skis and boots), velocity, the point in a turn, turn shape and event (12). Vibration forces during free skiing have been measured on the ski boots to be as high as 30G with frequencies of 5-30 Hz, in experienced skiers (12). EMG of major lower body muscle, show significant positive correlations with vibration acceleration data (31). The ability to dampen vibration forces has been shown to be inversely related to the frequencies of the vibrations, with 30% occurring at the hip and 20% at the neck for 10 Hz, but less than 12% occurring at the hip for vibrations above 60 Hz (12). Thus as the vibration frequency increases the bodies has a reduced ability to dampen it. Dampening occurs from an improved muscle tendon tension (muscle tone) for a flexed ankle, knee, hip and spinal column seen in alpine skiing technique and passively form soft tissue and cartilage (12). The dampening of these forces are not only needed to maintain smooth gliding of the skis to conserve speed, and tactical positioning on

courses, but to also maintain visual field search (41) and reduce additional perturbations to muscle blood supply.

It has been hypothesized that during vibration stress in micro blood vessels red blood cells are jostled laterally in the capillaries causing damage to vessel walls and decreased velocity of blood flow (35). This increases total peripheral resistance which as been measured between 10-20% (35). Mester et al. (36) showed that PCr depletion of 20% occurred from a 100 second contraction of the gastrocnemius muscle increased to 50% and 95% when a vibration loads of 8 Hz was added for contraction lengths of 60 seconds to 80 seconds respectively. Alone vibration and occlusion have not shown decreases of intramuscular pH, but the combination have (35). Thus the duration of the increased muscle tension needed to dampen vibration and the long eccentric and concentric muscle action in a carved ski turn reduces blood supply to active muscle tissue. A desirable training adaptation from extensive endurance training is increase capillary density, which would be the best mechanism for increasing muscle blood supply during high levels of vibration stress. Thus for alpine skiing, vibration stress should be viewed, not only from the traditional strength perspective, but from a bioenergetics perspective.

Investigations into the efficacy of vibration training in the strength and conditioning room induce adaptations in neuromuscular firing that increase the dampening capabilities of the muscular skeletal system have shown some promise. Spitzenpfeil et al. (43) in a pilot study compared elite level hurdlers, hockey players and alpine ski racers and showed that as the vibrations demands of the sport increased so did the dampening abilities of the athletes. Additionally, this groups showed that with 8 session of vibrations training, with 4 sets of 12 reps of squats with 60% 1RM load on a vibration plate set at 24 Hz at ± 2.5 mm of amplitude increased the dampening ability of all the athletes (43). However, it has yet to be shown if improvements in vibration dampening ability from the supplemental vibration training carry over to sports specific vibration dampening and improves sport performance. Therefore, it is currently recommended that the adaptations of vibration be left to those induced by training for the sport. With one

caveat, that athletes with limited on snow training time might have a benefit from supplemental vibration plate training.

Energy Supply for Alpine Skiing. Alpine ski racing is an ATP-PCr sport with glycolitic support. When differentiating the total yield of energy supply to compete a GS run 28.3% came from the ATP-PCr energy system, 25.3% was buffered through the lactate energy system, and 46.4% came from the oxidative system (2). Blood lactate accumulations have been reported as high as 15.7 mmol•L^{-1} for athletes on the Swedish national team after a 93 second GS race, however when tested during similar course conditions in training, values where lower (course length and blood lactate values not reported) (2). And 12-15 mmol•L^{-1} where observed in Austrian National Team athletes after a competitive world cup run (event and course length were not reported) (2, 11, 38, 42).

The oxygen uptake for each event is slightly different with the technical events (SL and GS) observed to be 160-200% of VO_{2max}, and in speed events (DH) to be reported ~80-90% VO_{2max} (13). The heart rate during GS training of elite skiers reach about 87% heart rate max (HRmax) as compared to collegiate skiers (SL and GS only in NCAA) who reach 97% HRmax and older recreation skiers who free ski (no course) reach about 80% HRmax (42). Elite skiers were also able to reach higher HRmax's than their recreational counter parts (95% v. 65-75% HRmax, respectively) (2). Combining these energy demands with 60-90 second durations for the technical events and 1-2.5 minutes with the speed events leads to a great deal of oxygen deficit and subsequent acid build up as indicated by blood lactate levels described above in elite level alpine skiers. However, von Durvillard et al. observed that during a GS course of forty gates which took about sixty seconds to complete in nine (16.1±1.4 yrs) high school skiers attending a eastern USA ski academy during training used only about 50% VO2max while skiing the course (49). The range of data for aerobic fitness in alpine ski racers has been a matter of debate (38, 39). However, it seems logical from data available that alpine skiers should work toward developing a lactate threshold that is above the intensity level needed for a portion of the race course,

to allow for the delay in lactate accumulation or recovery of lactate accumulation that occurs during challenging sections. This will allow for the maintenance of strength and therefore sport technique for the last section of the course, where separation of performances between competitors can occur.

VO_{2max}. Cycling ergometer VO_{2max} performances for elite alpine skiers in 1997-2000 who had frequent world cup podium finishes were 56.1±4.1 and 58.6±3.63 $ml•kg^{-1}•min^{-1}$ for women and men respectively and put them on the bubble of high and very high on normative charts (21, 38). These where similar to men on the Europe-Cup circuit with aVO_{2max} of 55.2±5.2 ($ml•kg^{-1}•min^{-1}$) at the season end, which was significantly higher than preseason levels (52.7±3.6 $ml•kg^{-1}•min^{-1}$) (16). Normative values for VO_{2max} of elite alpine skiers from youth through professional can be seen in table 2. These VO_{2max} levels are about the level observed for recreationally trained athletes, and in most high level athletes can be achieved with interval training, which should be already incorporated into a program to improve the capacity of the anaerobic metabolism (17). To further support this hypothesis in a study of the Austrian National ski team over three years and three groups, only the speed group had a significant correlation between aerobic power and sport ranking, for one of the three years (38).

Relative Power at Lactate Threshold. More interesting are the training adaptations of the watt thresholds for lactate accumulations of 2 and 4 $mmol•L^{-1}$ and max because all increased more than 10% over the three seasons, if not in one season, in a group of athletes on the Austrian National Ski Team (W_{2mmol}, women, 1.8±0.3; men, 2.4±0.3; W_{4mmol}, women, 2.8±0.4; men, 3.4±0.3;) (38).

Wingate Tests. In 1995 Bacharach et al. (3) measured 30 second and 90 second Wingate tests (load of 0.075 $kg•kg^{-1}$ BW) and found over two years, peak mean and minimum power outputs to be have several time points that significantly ($p \leq 0.05$) correlated with SL and GS USSA point ranking system for the 90 second test but not the 30 second test (correlations values not reported). And recommended that a more sport specific test duration be used.

Physical Characteristics of Elite Alpine Skiers

Anthropometric data of elite level alpine skiers as reported can be seen in table 1. Age and competition level are as reported by the studies, and data organized by male, and female from highest level of competition to lowest level then by age from oldest to youngest. Values are mean ± standard deviation. The majority of elite male alpine skiers tend be 175-185 cm tall and weigh 73-87 kg, where women tend to be 160-170 cm all and weigh 58-68 kg.

It has been shown that elite national level skiers tend to consists predominately of mesoectomorphs, which allow for greater lower limb strength and power (10). Prior to 1988 body fat percentage for men were 8-11% and women were 20-22% (2), with SL specialists the leanest and DH athletes being the heaviest (2). Recent anthropometric data can be found in table 1.

Leg circumferences, as an indicator of thigh muscle cross sectional area, in elite Austrian Top World Cup Skiers in 1997-2000 was 59±2.5 cm for women and 64.5±1.5 cm for (38). However, it should be mentioned studies looking at high and low performers within elite and youth athletes have not observed correlations of sport performance measures with leg circumference, but no study has looked at differences between these groups (26, 38).

Table 1. Anthropometric Measurements of Competitive Alpine Skiers in Descending Ages and Level.

Source	Age (years)	Level (As Reported)	Men N	Men Body Fat (%)	Men Height (cm)	Men Weight (kg)	Women N	Women Body Fat (%)	Women Height (cm)	Women Weight (kg)
Professional and Semi-Professional Athletes										
Andersen et al. 1988(2)		International	Review	8-11%			Review	20-22%		
Impellizzer et al. 2009 (23)	27.4±2.8	International (Top 15 on Italian the National Team)	8	8.4±2.4	178.8±3.9	82.6 ±9.5				
Neumayr et al. 2003 (38)	M 25.2±3.9 F 27.6±3.5	Austrian National Team	20	15.8±3.7	181±6	87.0±7.1	28	24.5±3.6	166±5	65.1±6.5
Berg 1995 (6)	23±4	Swedish National Team	8		180±6	81±8				
Ried et al. 1997(40)	M 22.7±0.6 F 21.4±0.5	USA National A and B Team	17		179±1.3	80±1.6	23		167±1.1	65±1.2
Maffiuletti et al. 2009 (32)	22 ± 3	Swiss National Team	98	8.1±2.4	180.9±5.5	83.5±5.2				
Impellizzer et al. 2009 (23)	24.7±3.4	International (Bellow the 15 on the Italian National Team)	24	10.0±2.4	180±0.0	83.6±6.5				
Bosco et al. 1994(7)	23.4±4.3	International	12		177±1.4	79.0±8.5				
Gross et al. 2009(16)	20.0±2.9	Europe-Cup	16	7.9±2.6	179.5±7.4	81±8.7				
Hartmann et al. 2005 (19)	19.8±1.1	National B-Team Germany	8		180.6±7.5	80.4±6.7				

Table 1 Continued.

Junior Athletes										
Ried et al. 1997(40)	M 18.4±0.5 F 17.0±0.2	USA National	38		176±1.1	74±1.8	23		169±1.2	62±1.4
von Duvillard et al. 1997(50)	M 17.6±0.9 F 16.6±0.6	Junior National	12	7±1.6	178.1±7.8	76.9±7.9	14	18.2±2.7	165.3±4.7	60.9±4.3
Gross et al. 2010 (15)	17.6±1.4	Swiss Ski Academy	15	12.4±4.6	177±52	73.9±7.5				
von Duvillard 2005 (48)	M 16.8±1.6 F 15.8 ±1.5	USA Ski Academy	9	6.4±4.8	177.2±6.1	72.4±9.0	6	19.9±2.4	164.3±4.9	62.0±2.9
von Duvillard et al. 2009 (49)	16.8±1.4	USA Ski Academy	13	8.2±2.5	176.3±6.8	73.5±9.7				
Ried et al. 1997(40)	M 15.3±0.2 F 15.0±0.2	USA Divisional	46		170±1.4	61±1.3	32		164±1.0	57±0.9
Emeterio et al. 2011(11)	M 14.6±1.1 F 14.9±1.0	Spanish Junior Development	15	10.2±3.5	167±10	59.2±7.9	15	19.2±3.4	159±10	53.0±6.4

Profile of Performance Tests. A selected set of performance measures of elite alpine ski racers can be found in table 2. Data was chosen from studies that reported international, semi-professional and top ranking junior level athletes. Because only a few studies reported the specialty of athletes, technical, speed or all around skiers, data could not be separated out by specialty. The data is reported with the same order as table 1. Testing equipment and methods and details important to testing protocols are listed in the far right hand column. Countermovement jump, average of five countermovement jumps, 1RM squat, VO_{2max} and cycling ergometer Wattage at 4 mmol of lactate (lactate threshold) are all tests and methodology standard to human performance laboratory or field testing.

Unique to alpine ski racing are the HEX testing, the 90 second lateral box jump test and the 90 second Wingate test with a load of 0.075 $kg \bullet kg^{-1}$. Because these protocols are uncommon in the literature, below is a brief but usable description.

The HEX test consists of six hurdles 61 cm wide with the following heights in clockwise order: 20, 35, 20, 25, 20, 32 cm. Facing the same direction throughout the test the athlete does three revolutions of the hexagonal obstacles with two footed jumps as quickly as possible, with the start and finish position in the center of the circle. The time to complete without touching a hurdle is recorded. (40)

The 90-second lateral box test consists of a box that is 40 cm high, 60 cm long and 51 cm wide. The athlete starts on top of the box, jumps down to the right side, then back to the top of the box, briefly touching it and jumps down to the lefts side in a lateral fashion and jumps back up on top of the box, briefly touching it and then back to the right side, and so on. Each time the athlete touches the top of the box it counts as one jump, the score is how many jumps the athlete can do in 90 seconds. With junior athletes (< 16 years old) some coach's have used a 60 second test. (40)

Table 2. Review of Key Human Performance Values That Have Been Reported in Elite Alpine Ski Racers

Reference	N	Age (yrs)	Level	Males	Females	Combined	Method
Countermovement Vertical Jump (cm)							
Impellizzeri et al. 2009 (23)	8	27.4±2.8	International (Top 15 on Italian the National Team)	48.9±5.8			Force Plate (QuattroJump, Kistler, Winterthur, Switzerland)
Bosco et al. 1994 (7)	12	23.4±4.3	International	43.4±4.0			Force Plate (Psion CM, Ergojump)
Gross 2009(16)	16	20.0±2.9	Europe-Cup	52.7±4.6			Quattro Jump force plate (Kistler Instruments, Winterthur, Switzerland)
von Duvillard et al. 1997 (50)	M 12 F 14	M 17.6±0.9 F 16.6±0.6	Junior National	45.7±2.3	35.8±5.0	40.3±6.5	Timing Pad (Fastex, Cybex, Ronkonkama, NY)
Breil et al. 2010 (8)	M 15 F 6	17.4±1.1	Junior National			45.4±6.1	Quattro Jump force plate (Kistler Instruments, Winterthur, Switzerland)
Klika et al. 1997 (26)	M 9 F 8	M 17.5±0.5 F 17.5±0.8	Successful Junior USSA	56.7±11.2	43.1±6.3		Not Reported
Klika et al. 1997 (26)	M 12 F 9	M 15.4±0.6 F 15.4±0.5	Successful Junior USSA	53.5±7.5	40.6±4.8		Not Reported
Emeterior et al. 2011 (11)	M 18 F 15	M 14.6±1.1 F 14.9±1.0	Spanish Junior Development	34.4±7.7	29.8±2.6		Timing Pad (Musclelab, Ergotest Technology, Langesund, Norway)
Average of 5 continuous countermovement jumps (cm)							
von Duvillard et al. 1997 (50)	M 12 F 14	M 17.6±0.9 F 16.6±0.6	Junior National	42.7±2.4	32.2±4.3	36.9±6.4	Timing Pad (Fastex, Cybex, Ronkonkama, NY)
1RM Squat (kg)							
Emeterio et al. 2011 (11)	M 18 F 15	M 14.6±1.1 F 14.9±1.0	Spanish Junior Development	69±13	49±10		Free Weight Barbell

Table 2 Continued.

			HEX Test (Seconds)				
Ried et al. 1997(40)	M 17 F 23	M 22.7±0.6 F 21.4±0.5	USA National A and B Team	29.05±1.65	29.68±1.44		
Ried et al. 1997(40)	M 38 F 23	M 18.4±0.5 F 17.0±0.2	USA National	31.12±2.22	32.53±2.01		
Ried et al. 1997(40)	M 46 F 32	M 15.3±0.2 F 15.0±0.2	USA Divisional	34.35±3.12	34.72±2.65		
			90 sec 40 cm Lateral Box Jump Test (jumps)				
Ried et al. 1997(40)	M 17 F 23	M 22.7±0.6 F 21.4±0.5	USA National A and B Team	97.82±7.34	79±7.38		Box 40 cm high x 51 cm wide.
Ried et al. 1997(40)	M 38 F 23	M 18.4±0.5 F 17.0±0.2	USA National	89.37±9.12	68.17±14.34		Box 40 cm high x 51 cm wide.
von Duvillard et al. 1997 (50)	M 12 F 14	M 17.6±0.9 F 16.6±0.6	Junior National	89.0±14.7	77.3±8.5		Box 40 cm high x 51 cm wide.
Klika et al. 1997 (26)	M 9 F 8	M 17.5±0.5 F 17.5±0.8	Successful Junior USSA	84.6±13.3	73.3±5.4		Box 40 cm high x 51 cm wide.
Breil et al. 2010 (8)	M 15 F 6	17.4±1.1	Junior National			87.2±11.2	Box 44 cm high, width not reported
Klika et al. 1997 (26)	M 12 F 9	M 15.4±0.6 F 15.4±0.5	Successful Junior USSA	69.6±13.3	63.0±6.6		Box 40 cm high x 51 cm wide.
Ried et al. 1997(40)	M 46 F 32	M 15.3±0.2 F 15.0±0.2	USA Divisional	70.43±11.87	53.08±9.33		Box 40 cm high x 51 cm wide.
			90 Second Wingate (0.075 kg•kg^{-1} load) Mean Power (W•kg^{-1})				
Bacharach et al. 1995 (3)	M 10 F 8	< 19	Junior National	7.46±0.49	6.8±1.23		Monark 814E, Stockholm, Sweden
			90 Second Wingate (0.075 kg•kg^{-1} load) Fatigue Index (%)				
Bacharach et al. 1995 (3)	M 10 F 8	< 19	Junior National	50.4±5.5	54.8±52.9		Monark 814E, Stockholm, Sweden

Table 2 Continued.

VO2max (ml•kg^{-1}•min^{-1})							
Neumayr et al. 2003 (38)	M 20 F 28	M 25.2±3.9 F 27.6±3.5	Austrian National Team	56.9±3.9	59.5±4.7		50+ W/ 3 min Cycle ergometer (ER 800, Ergoline , Bitz, Germany)
Impellizzer et al. 2009 (23)	8	27.4±2.8	International (Top 15 on Italian the National Team)	56.5±4.2			25+ W/min Electrically Braked Ergometer (SRM Ergometer, Welldorf, Germany)
Gross et al. 2009(16)	16	20.0±2.9	Europe-Cup	55.2±5.2			5-8+ W/ 10s Ergometrics 800S cycle ergometer (ergo- line GmbH, Bitz, Germany)
Breil et al. 2010 (8)	M 15 F 6	17.4±1.1	Junior National			53.0±5.3	5-7+ W/ 10s Ergometrics 800S cycle ergometer (Ergoline GmbH, Bitz, Germany
Lactate Threshold at 4 mmol Lactate (W•kg^{-1})							
Neumayr et al. 2003 (38)	M 20 F 28	M 25.2±3.9 F 27.6±3.5	Austrian National Team	3.4±0.3	2.9±0.3		50+ W/ 3 min Cycle ergometer (ER 800, Ergoline , Bitz, Germany)

The 90 second Wingate test is similar to other cycling Wingate tests, where the athlete spins up to 110-120 rpm, however the coach loads the resistance at 0.075 kg per kg of body weight, and then the athlete pedals as fast as possible for 90 seconds, the average wattage, peak power and minimum power for five second averages are reported. (3)

Common Injuries and Mechanisms

Anterior Cruciate ligament Injury (ACL). ACL injuries make up 10-20% of all skiing injuries and have a unique mechanism in elite alpine ski racers when compared to recreational skiers (5). ALC injuries occur during both knee extension or full dynamic flexion with the addition of one or a combination of: anterior draw of the tibia internal or external rotation (18). A small portion of knee injuries comes from crashing tumbling into nets or other obstructions. Non-contact or non-crashing mechanisms include: slip-catch, dynamic snowplow, back-weighted landing (5). The first and the most common, slip-catch, occurs during a turn where the outside ski leaves the ground, then with an extended leg initiates a carved turn across the body causing internal rotation as it comes back into contact with the snow (5). The dynamic snowplow consists of a deep knee and hip flexed position, where the ski catches an edge and turns quickly under the skier causing a rapid internal rotation (5). And the back-weighted landing is characterized from a landing where tail of the ski hits the ground and causes anterior draw of the tibia and teibiofemoral compression with additional internal or external rotation if the body is twisted (5). This can also lead to a deep knee and hip flexion (seated position) with feet accelerating forward relative to the upper body when an athlete is entering a turn in an unbalanced position or landing after leveling the ground (24, 37). Elite athletes will try to pull themselves out of this position with a massive contraction of the quadriceps muscle, which many athletes are successful in doing. However, it has been hypothesized that a combination of the quadriceps contraction, lack of co-contraction of the hamstrings, the upper body falling backward, and valgus torque provided by the ski snow contact, will result in the necessary anterior displacement force to

rupture the ACL (24). Fortunately the invention of the spring loaded release binding has reduced the total injuries (all lower body injuries) from 5-8 to 2-3 per 1000 skier days, by providing a valgus release mechanism (37). However, only a few companies have a toe lift release mechanism, to limit the maximum anterior displacement force of the tibia relative to the femur.

For the strength coach, interpreting this injury mechanism, which is season ending and can be career ending, has become the underlying rational for the dynamic hip mobility training and integration of strength in balance training described below. The purpose of this type of training is to increase the neurological motor patterning, dynamic knee stabilization reflex, and functional range of motion in the deep knee and/or hip flexed positions. Athletes develop the proper co-contraction of the hamstring and quadriceps, in a deep squat position, as well as an upper body balance, to reduce the ability for the upper body to fall backward, which, if occurs, will diminish the co-contraction forces that the hamstrings can provide to counter the anterior displacement forces on the tibialis. Evidence supporting this hypothesis is that athletes who went three years without an ACL injury had a peak hamstring torque at a significantly deeper flexion angle (25.4 v. 22.2, SD not reported) than those that did sustain an ACL rupture when monitoring 41 USA freestyle international level athletes (24). This investigation also observed no predictive value for measures of hamstring to quadriceps ratio (24). The implementation of hip mobility training that increases the functional athletic ability of alpine ski racers in the deep squat position has been utilized and may be effective in reducing ACL ruptures.

Shoulder Injuries. In alpine skiing, shoulder injuries make up 4-11% of all injuries and 22-41% of upper extremity injuries, with the four most prominent being: 1) rotator cuff contusion, 2) anterior glenohumeral dislocation/subluxation, 3) acromio-clavicular separation, 4) clavicle fractures (27). Falls provide the mechanism for most injuries, which include a direct “blow to the shoulder, an axial load from an out-stretched arm, or an eccentric muscle contraction associated with resisted abduction by the slope during a fall” (27). A secondary common mechanism for injury in alpine ski racers in GS, SG and DH occurs

when a skier hooks his or her arm between the two gaits and below the panel connecting them, which can cause the arm to be pulled violently into horizontal abduction and internal rotation. However, because both the gate has a spring-loaded hinge at the snow level and the panels are designed to slip off the gate, an athlete with sufficient isometric strength and shoulder stabilization, can pull the panel off and continue down the course without injury or penalty. In cases of shoulder injuries in alpine ski racers, the strength coach should work closely with the sports medicine staff to ensure the implementation of a shoulder rehab program, and respect the need for both upper body maximal strength and strength endurance to reduce the risk injury.

Strength and Conditioning Program

The purpose of a strength and conditioning program for alpine skiers is to maximize lower body strength, focusing on low velocity force production, and developing the anaerobic metabolism, specifically developing the lactate threshold and lactate tolerance. The macrocycle for alpine ski racing can be broken down into five mesocycles: 1) active recovery, 2) off-season hypertrophy, 3) pre-season strength, 4) pre-season strength endurance, 5) in-season maintenance and peaking. Although the exact periodization and program for an athlete is individual, example two-week programs for each mesocycle can be seen in table 3, with workouts described in tables 4 through 9. The active recovery is similar to other sports and should allow the athlete to enjoy physical activity, while providing enough metabolic work to maintain the oxidative metabolism. This typically occurs during mid April through May. In June, the off season phase should start and focus on hypertrophy and developing a technical base for Olympic and power lifting exercises that can be used in the next mesocycle. The pre-season phase should span September and October and focus on developing strength and power, while preparing the athlete for early season on snow training in November. The in-season phase should start in late November and early December, focusing on maintaining strength and power while developing the glycolytic energy system for peaking in mid January through

February. For elite athlete pre qualified for championships, peaking should occur later in the season, as the championship races tend to be in early March.

The next section will provide a brief justification for each type of training presented in the example mesocycles and provide examples for each one.

Table 3. Prototypical Weekly Programs of Mesocycles Commonly Employed for Alpine Ski Racing

				Active Recovery			
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	Recovery with 6 strength exercises	Recreational Game (basket ball, soccer, Mt. biking, surfing…)	Off	Recovery with 6 strength exercises	Off	2 Hour Hike	Off
				Off Season - Hypertrophy Focus			
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Wk 1 AM	Lactate Threshold & Strength moderate	Strength (Heavy Lower)	Jump and Speed	Lactate Threshold & Strength Heavy Upper	Strength (Light)	Off	Off
PM	Jump and Speed	Strength (Light Upper) & Mobility	Rec. Game	ECC Overload Lower	Jump & Mobility	Off	Off
Wk 2 AM	Lactate Threshold & Jump and Speed	Power	ECC Overload	Late start & Recovery	Lactate Threshold & Mobility	ECC Overload	Off
PM	Strength Heavy	Strength – Light Upper Mobility	Strength Heavy Upper	Jump and Speed Rec. Game	Strength (Moderate)	Off	Off
				Pre Season 1 (Predatory for On Snow Sport Training) – Strength Focus			
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Wk 1 AM	Jump and Speed & Strength (Light)	Power	Strength (Light)	Lactate Tolerance & Strength Moderate	Lactate Threshold &	Off	Off
PM	Mobility	ECC Overload (Short)	Rec. Game	Mobility	Strength (Heavy)	Off	Off
Wk 2 AM	Jump and Speed & Mobility	Strength (Upper light)	Strength Moderate	Lactate Threshold & Mobility	Jump and Speed & Lactate Tolerance	Recovery	Off
PM	Strength - Heavy	ECC Overload	Rec. Game	Strength Moderate	ECC Overload	Off	Off

Table 3. Examples for recreational games (Rec. Games) include, volley ball, hockey, soccer, ultimate Frisbee, handball. Eccentric Overload training (ECC Overload) includes loading of 105-115% of one repetition maximum (eccentric-concentric) for the exercise.

Table 3 continued.

Pre Season – 2 (Predatory for Competition) – Strength Endurance Focus							
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Wk 1 AM	Jump and Speed	Lactate Tolerance &	Off	Jump and Speed &	Off	Off	Off
PM	Lactate Threshold & Strength – Moderate	Strength (Light)	Power & Rec. Game	Anaerobic Hill & Mobility	ECC Overload	Off	Off
Wk 2 AM	Ski Training	Add or Incorporate 4 ski runs of non stop 100% SL conditioning	Ski Training	Add or Incorporate 4 ski runs of non stop 100% SL conditioning	Ski Training	Free Ski or Rec. Game	Off
PM	Jump & Power & Mobility	Strength Heavy	Rec. Game	Recovery & Mobility	Anaerobic Hill	Off	Off
In season (Predatory for Major Competitions)							
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Wk 1 AM	Off	Add or Incorporate 4 ski runs of non stop 100% SL conditioning	Ski Training	Add or Incorporate 4 ski runs of non stop 100% SL conditioning	Ski / travel	Race	Race
PM	Strength – Moderate	Short Strength – Heavy & Short Anaerobic Exercise	Recovery	Lactate Threshold & Strength (Power)	Short Jump and Speed	Recovery	
Wk 2 AM	Off	Add or Incorporate 4 ski runs of non stop 100% SL conditioning	Ski Training	Short Ski Training	Ski or off	Race	Race
PM	Short Strength – Heavy & Short Anaerobic Exercise	Power	Moderate Length-Anaerobic Hill	Recovery or Off	Recovery or Off	Recovery with 4 strength exercise - light	

Strength and Power. Axial loading exercises, such as the squat, debt lift, cleans, and snatches, should be the foundation for developing full body structural support in high G-force alpine skiing turns. However, the use of leg exercises that do not provide axial loading are beneficial for three reasons: 1) extensive axial loading is not seen in alpine skiing, as the center of mass of the body is around the navel region when G-force increases, 2) the increased prevalence of kyphosis in the upper back region from the rounding of the upper back in a ski stance and 3) heavy axial loading without proper progressions can exacerbate back injuries. Such exercises as sled leg press or belt squats can be used for athletes with lower back pain that do not tolerate heavy squat or dead-lift exercises. Thus supplementing in closed and open chain exercises for the lower body, will help increase lower body maximal strength, while not limiting training to the fatigue level of the spinal column loading exercises. Example strength and power workouts can be seen in table 4.

Table 4. Prototypical Strength Workouts

Strength Light (2-4 sets x 12-15 reps) Moderate (2-6 sets x 8-10 reps) Heavy (4-6 sets x 1-4 reps)	**Power** (2-4 sets x 4-10 reps)	**Strength and Balance** (2-4 sets x 8-12 reps)
Back Squat or 1 Leg Squat Barbell Squat	Box Jumps 3x10 (body weight)	Front Squat on Dina-Disks
Dead Lift	Hurdle Jumps 3x10 (body weight)	Physioball Dumbbell Press
Bench Press	Power Cleans 4 x (4-8)	One Leg Squat on Dina-disks
Leg Press	Squat Jumps 4x10 (load less than 75% body mass)	Physioball Dumbbell Rows
Cable Rows	Dumbbell Snatch 3x8 each side	Lateral Lunges onto a Bosu ball
Back Extensions 3x20	Numatic or Band Quick Pull Downs (3x8-10)	Single Leg Roman Dead Lift with Curl to Press.
Physioball lateral crunches 3x20	Lateral box Lung Jumps with Dumbbells (3x8 each side)	Progression: Increase reps, then Increase sets and decrease reps. Increase load as technique improves.
	Med. Ball Situp Throws (3x15-20)	
	Med. Ball Rotational Throws (3x15-20)	

Unilateral Strength Training. In addition unilateral lower and upper body training has efficacy. During alpine skiing turns, especially in GS, SG and DH, the inside ski (closest to the turning gate) can be off the ground and with knee and hip in deep flexion. Thus exercises such as single leg squat, leg press, lunges and step ups are beneficial to promote unilateral balance and mobility during high force situations (4).

Strength in Balance Training. Alpine skiing is characterized by instability with ski snow contact especially in soft snow and rutty course conditions. The purpose of strength in balance workouts is to improve motor patterning for unstable conditions through neurological adaptations. Adding an instability component to strength training or plyometric training workouts, with the use of such equipment as Dina-Discs, Bosu Balls, or physioballs, has been shown to improve neuromuscular motor patterning. This leads to improved coordination and confidence in performing a skill and a decrease of co-contraction during the instability (4). However because of the increase in co-contraction, the force output during strength in balance exercise is diminished (4). Thus it should be used as a supplement to more stable strength workouts that have higher force production and subsequent improvements in maximal strength and power at given velocities (4). These types of workouts are ideal for days in which high force production (power and heavy strength workouts) do not make sense when implementing a functional non-linear periodization (28). See table 4 for an example workout.

Dynamic Mobility Training. A recent trend in strength and conditioning for alpine skiing has been the implementation of dynamic mobility exercises. Although little has yet to be written about this type of training, the basic principles are founded in theories of exercise science. The purpose of mobility training is to increase the functional range of motion for synergistic muscles, specifically biarticular muscles and muscle groups of the hip girdle that have small ranges of motion during normal gate, usually less than 20% of physiological range of

motion (30). For instance the hamstrings during normal gate and hoping actually have an eccentric and concentric action during the acceleration phase based on the joint angle velocities of the hip and knee as its function is to transmit force from the quads during knee extension to the hips for simultaneous hip extension (30). Also as the quadriceps extend the knee, the gastrocnemius transmits force to put the ankle into plantar flexion. In addition, during normal gate other muscles simply have a smaller used range of motion compared what are common in the sport of alpine skiing. Such muscles include the gluteus maximus and medius, which work to help maintain postural alignment during the swing phase of walking gait (one foot in contact with the ground). Dynamic mobility exercises typically are designed to target one or two muscles or muscle groups at a time, with body weight or light external loads. Due to the long moment arms of some of these exercises the force loads on muscles can be as high as a 10 repetition maximum, but are typically much less.

The purpose of dynamic mobility training for alpine ski racers, as mentioned above in the ACL injury section, is to increase the athletic ability in a deep squat position and proprioception in a knee extension position. More specifically the purpose is to provide enough hamstring flexibility so as not to allow the upper body to fall backward in a deep squat position, or the legs to not abduct or adduct, while also providing enough ankle flexion so that the center of mass can remain forward between the feet or toes. Because of the instability of the sport, it is not uncommon for these exercises to include a balance component, but do not typically contain a power or maximal strength component due to the stretching stress of the exercise. Because these exercises are not typically found in the exercise description literature, example exercises, photos, and a description with progressions can be found in table 5.

Table 5. Prototypical Mobility Workout and Descriptions

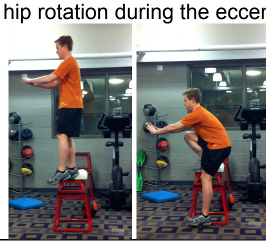
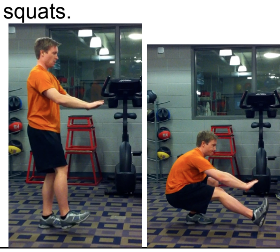
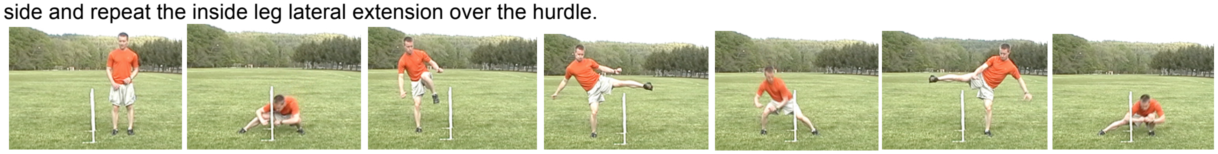
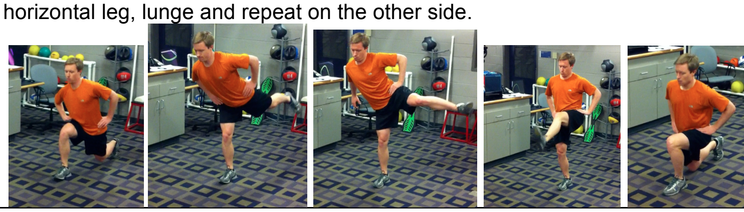
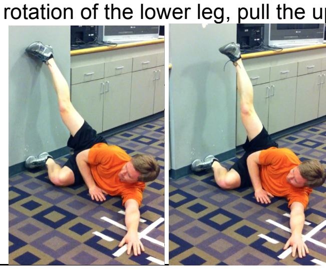
Mobility (2-4 x 10)	
Deep bodyweight squats.	Start standing in an athletic position with hands in front of the body. Lower the hips down to a deep squat position without extensive external rotation of the femur, and maintain heal contact. Some individual will not have the dynamic mobility to do this without the trunk falling backward, and should thus start by holding an object in front of them to maintain balance and proper position while dynamically stretching. Progress from using a heal lift, to no heal lift and then to an unstable surface such as a foam pad, Dyna-Disk or Bosu Ball. Arm progressions start by holding onto an improvable object in front of the body, holding a med ball in front of the body, free hands in front of the body, hands over head, holding dowel over head, and to holding a med ball over the head. 
1 Leg squats on bench	Stand on a box that is longer than the leg length, lower the hips down to a deep squat position or to the limits of the range of motion, while avoiding internal hip rotation during the eccentric phase and the heal lifting off the ground. Progressions are the same as for deep squats. 
1 Leg Ground Squats	Standing on the ground, lower the hips down to a deep squat position or to the limits of the range of motion, with one leg and hold the other leg in front of the body in an extended position. Avoid internal hip rotation during the eccentric phase and the heal lifting off the ground. Progressions are the same as for deep squats. 

Table 5 Continued.

Lateral hurdle ducks with Hip Abduction Dynamic Mobility	Set a hurdle about even with the greater trochanter of the femur. Start standing next to the hurdle and laterally lunge under the hurdle with as little rotation of the upper body as possible. Stand up on the other side, raise the inside leg, closest to the hurdle, and lateral extend it over the hurdle in a slow controlled movement, without allowing the femur to externally rotate. Come back to a one leg standing position and then laterally lunge under the hurdle to the other side and repeat the inside leg lateral extension over the hurdle. 
Lunges with Hip Mobility	Start in a lunge position, single leg squat into a single leg roman dead lift position. Rotate the back leg around to the front while maintaining a straight horizontal leg, lunge and repeat on the other side. 
Lung with spine rotation and lateral rotation	Start with a right foot forward lunge, then add hip flexor stretch with right arm flexion over the head, then twist the core and extend the left arm to the ground, such that there is a straight line from the left hand, through the shoulders and to the right hand. Then reset with hands on hips with a neutral spine and continue with a walking forward lunge to the left foot and repeat on the other side. 
Hip Abduction On side with leg on wall, internal rotation of bottom leg	Start with lying on the left side of the body with a neutral hip and spine. Raise the top leg without rotation in an extended position as high up on the wall as possible, and scoot the body as close to the wall as possible, bending the bottom leg, but keeping the foot on the wall inline with the spine. With internal rotation of the lower leg, pull the upper leg off the wall for a 4-6 second count. The key is to not let the top leg externally rotate, or spine to flex forward. 

Sport Specific Training. Ski coaching literature talks specifically about maintaining level shoulders through the turn and resisting the forces that pull down on the inside shoulder (shoulder closest to the center of the turn or gait) thus elevating the outside shoulder. To maintain a strong stable upper body through the turn and the centripetal forces generated, a synergistic tension in the shoulder, hip girdles and core muscles is needed. To maintain level shoulders, lateral spine flexion in the lumbar region is also required and produced primarily by the quadratus lumborum. Although it is not always necessary to increase strength in these muscles and related muscle groups, it is, however, important to increase strength endurance over all. Given that turns per course range from 30 to 70, building up to repetitions volumes of 15-45 per side with light to heavy external loads in a core workout routine is warranted.

Plyometric / Jump Training. Enhancing vertical power has been a corner stone of strength and conditioning programs for alpine skiing. This has been justified in several correlational studies where explosive power as measured by counter movement jump height and the average of five continuous counter movement jump heights in 26 (12 men, 14 women, age 17.1±0.9 yrs) elite alpine skiers at an eastern United States ski academy has shown predictive ability for alpine skiing performance (50). The correlation coefficients of the highest vertical jump height with USSA national point ranking system was -0.46, -0.60, -0.43, -0.53 for SL, GS, SG and DH respectively (50). And for the average of five vertical jumps was -0.44, -0.63, -0.58, for SL, GS, and DH respectively; the correlation with SG was not significant ($p \geq 0.05$), all others were (50). Mean and SD for these tests can be seen in table 2. A similar field test reported in 1988 by Andersen et al (2) which used five continuous double leg long jumps, had a very strong correlation ($r = 0.89$) with GS skiing performance (measure of performance not reported). This study reported that the Canadian men's national team members reached 14.1 m, regional skiers reaching 13.1 m, club skiers reaching 10.8 m. These moderate to very strong correlations indicate that the physical ability to produce

rapid force production and to maintain it over five jumps, corresponds to sport performance and should be a focus of a strength and conditioning program. See table 6 for an example workout.

Table 6. Prototypical Plyometric Workouts

Jump Training (2-4 x 10)	Speed Training
Forward Jumps	Accelerations 4x15 yrds
Backwards Jumps	Side to Side Lateral Shuffle with direction change 5 yrds or 2-3 shuffles per direction (6x4)
Lateral Jumps	5x5 yrd Box Agility Course
Bounding	T-Agility Course
Lateral 45º Skaters	30 yard cone slalom course (off set should be 10-40% of longitudinal distance)
1 leg Forward Jumps	Progression: As technique improves add resistances and assistance to drills.

Eccentric Training. The supplementation of eccentric training, such as eccentric overload training or eccentric cycle ergometer has proven effective to increase vertical jump height and maintain muscle fiber type distribution. Eccentric overloading is a method of training where there is additional load for the eccentric portion of the lift of 110-120% eccentric-concentric one repetition maximum load. This has shown to be beneficial in causing hypertrophy of the type IIA and type IIX muscle fibers, and subsequent improvements in vertical jump performance as compared to a training program using the same concentric/eccentric load, in a six week long training study, with twenty four trained male athletes, using an eight repetition maximum load, on a specialized knee extension device (14). However this type of training can be performed by using stable weight machines, which allow for one limb (both legs or both arms) to perform the concentric portion of the lift, then one limb can hover just off of the machine during the eccentric portion of the lift. Thus doubling the eccentric load for the limb lowering the weight down. This can be performed on such machines as, leg extension, leg press, chest press, and seated row. For an example workout see table 7.

Table 7. Prototypical Eccentric Focused Workouts

Eccentric Overload (Without Specialized Equipment) (2-4 x 6 Each side)	**Eccentric Cycle Ergometer**
2 Leg CON, 1 Leg ECC Leg Press	15-20 minutes
2 Leg CON, 1 Leg ECC Machine Chest press	60 RPM
2 Leg CON, 1 Leg ECC Leg extension	25-50 watt progression increments.
2 Arm Con, 1 Arm ECC Pull ups (vary hand grip)	150-800 watt progression range.
1 Leg Barbell Roman Dead Lift	Gains seen in as little as 5 sessions.
Glut Ham Raise (3x10-15)	
Progression: Start with 2 sets and increase by a set every 2-3 weeks. Not recommended to do more than 4 sets.	
*Concentric phase (CON) Eccentric phase (ECC)	

A second type of eccentric training involves the use of an eccentric ergometer. Hoopeler et al. (22) found beneficial performance gains in fifteen alpine ski racing athletes starting at 400 watts for 20 minutes and progressing to loads as high as 800 watts with in five training sessions on a eccentric cycle ergometer. Volumes in one study where 20 minutes, three days a week, with an additional 40 minutes of traditional strength training. This study showed an 8% (4.1 cm) increase in vertical jump height, where a control group had no change in height despite equal amount of traditional based strength training (22).

Eccentric Dexterity. In this same study Hoopeler et al. had an interesting finding, which indicated that the ability to more finely modulate eccentric force had a very strong correlation (r = 0.93) with %SD for target eccentric cycling force during a 20 minute effort to whole season SL FIS points, in a group of fifteen elite junior alpine skiers (22). In other words, athletes who could more accurately adjust the level of eccentric force to a dynamic target wattage reading out put on the eccentric ergometer computer, were also subsequently ranked as better SL athletes using a FIS point list – an international skiing sport ranking system. Interestingly it has been shown in GS skiing that approximately 1.0±0.2s is spend in eccentric muscle action of the quad, with only 0.5±0.1s spend in concentric muscle action (6). Providing evidence that the ability to finely adjust ground force reactions against the snow during eccentric movement is a highly important skill for ski racing success.

Table 8. Example Recovery Workout

Recovery
20-40 minute easy aerobic exercise (cycle, jog)
5 mobility exercises (2-3 x 6-8)
10 Core endurance exercises. (Sit-ups, oblique crunches, back extensions, planks…)
*If there was no strength training in the last 3 days add 2 lower, 2 upper body strength exercises and 3 auxiliary strength exercise (2x10)

Table 9. Example Anaerobic Energy System Workout

Anaerobic Endurance (Lactate Threshold)	**Anaerobic – Hill (Lactate Tolerance)**	**Anaerobic Exercise (Lactate Tolerance)**
Mode: Run, Cycle, Swim, Rowing Length 40-120 minutes total	(1-3 x 30-60 sec efforts with 3-6 minutes rest)	(1-4 sets x 10-60 sec efforts with 30-60 sec exercise break, and 8 minute circuit rest)
Interval Length: 1-6 minutes	Forward Jumps	Skiers Edge
Reps: 6-8	Lateral Jumps	1 Leg Hops over a line or bungee
Intensity: ~ 4 mmol•L^{-1} HR or ventilatory threshold	45 Degree Bounds	V-Ups
Rest: 1:1 plus time to resting 2 mmol•L^{-1} HR	Sprint/run	2 step lateral shuffle
		Box jumps
		Lateral Box Push ups
		Russian Twists
		Tuck Jumps
Progression: Increase repetitions, then decrease repetitions while increasing length by 30-60 seconds.	Progression: Add hill and/or resistance (tire drag). Increase time duration followed by sets. When increasing sets and also decrease duration by 10 seconds. Progress every 2-3 weeks	Progression: Increase time duration by 10 seconds followed by sets. When increasing sets and also decrease duration by 10 seconds. Progress about every 2-3 workouts.

Summary

The purpose of a strength and conditioning program for alpine skiers should be to maximize strength, low joint velocity force production of the lower body, and strength endurance - capacity to maintain force and dexterity of force from 45 to 150 seconds. In addition, because an athlete may ski as much as 4-7 days a week, season long durability is critical. As injuries typically occur from falling and crashing, the goal of a portion of the strength and conditioning program should be to develop the skills, strength and functional mobility to avoid a crash. Thus physical performance variables that should be evaluated and coached include: to able to withstand the high forces of turns, perform proper landing techniques, display visual field search abilities, and have quality proprioceptive balance, especially for-aft balance. Bacharch et al. (3) state it is possible to change the physical characteristics of athletes, without effecting their sport skills as a skier and improve their national rankings. Thus a program that focuses on maximal lower body strength development, glycolitic buffering capacity and improving the lactate threshold should improve both sport performance and injury risk reduction.

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Chapter 2.
Introduction to Lowlander Youth Athletes High Altitude Training Camps

Currently, thousands of adolescents travel to altitude to participate in recreational activities throughout the year (7, 30). A large sub group of this population are youth athletes involved in a specific sport camp designed to improve performance and skill. Stays of just 6-12 hours at altitude are known to induce altitude illness, including: acute mountain sickness (AMS), which can progress to high altitude cerebral edema (HACE) and high altitude pulmonary edema (HAPE) (2). The severity and incidence of AMS is related to the altitude attained, length of stay, and speed of ascent (2). Lowlander youth athletes exhibit a 20% rate of AMS in Summit County Colorado, which has been shown to be similar to adults (7). The underlying mechanism that causes AMS is hypoxic stress that induces fluid shifts from blood plasma to the intercellular compartment. The hypoxic stress of the central nervous system has shown to perturb perceptual-motor performances and the fluid shifts are thought to cause: headache, gastrointestinal, fatigue/weakness, dizziness/lightheadedness, sleep, reduction in overall effects on activities, changes in mental status, ataxia, and peripheral edema (6, 7, 10, 23, 44, 58). High altitude youth sport camps can be expensive, thus providing an incentive for the coaches and families to maximize time. However, the effect of AMS while participating in sport training has not been studied in youth athletes. Additionally, scientific evidence is needed to make recommendations on maximizing the effectiveness and safety of these high altitude youth sport camps.

A typical American 10 to 25 year old elite alpine ski racer will participate in one 2-4 week summer ski camp on glaciers at high altitude in the northern hemisphere or travel to ski areas in the southern hemisphere, some of which are at high altitude. As well as a possible second week long camp typically around the late November and December time period, also typically at high altitude. Many of these athletes are considered lowlanders and spend the majority of the year below 450 m (1,500 ft) of elevation.

High altitude imposes a hypoxic stress on the body, including Perkinje cells in the cerebellar cortex, which are known to reduce physical performance variables related to sport performance (6, 10, 58). Of these, balance and motor reaction time are critical to strategic aspects (such as line choice) and technique of alpine ski racing, which are highly related to competition outcome (34, 54). Any decrement in these measures may hinder sport performance, quality of training, and is associated with increased risk of injury.

Field measurements of both of these variables have been shown to be valid and reliable. The use of Y-balance tests has been shown to be sensitive to predict lower extremity injury risk for combined boy and girl high school basketball players (46), and the Quickboard™ React Drill is sensitive to discover changes in reaction time after four weeks of speed agility and quickness training (22).

In addition, it is not clear how physical training through the acclimatization period effects a battery of performance tests that are commonly used validated assessments of youth physical performance: vertical jump, T-Agility test, sit-and-reach, sit ups, push ups in one minute, and estimates of VO_{2max} using the multi stage fitness test (8, 27, 51).

AMS is common among travelers from sea level to high altitude; with a low incidence below 2,400 m (7,874 ft), high incidence above 3000 m (9,842 ft) and approaching 100% incidence above 4,300 m (14,108 ft) (2). AMS is not a medical condition that requires medical attention. Typical treatment is descent (300 meters or about 1000 ft) or to a base camp that is located below 3000 m (9,800 ft) (2). By contrast HACE and HAPE are medical conditions and require immediate decent in altitude and medical evaluation. The Lake Louise Acute Mountain Sickness Questionnaire is a short set of simple questions that are sensitive in quantifying levels of altitude illness and it can be used to monitor low-landers during altitude acclimatization (7, 23, 44).

Evidence to explain the mechanism of AMS currently supports the hypothesis that it is do to an increase in fluid volume in the intercellular compartment (58). At altitude, low barometric pressure creates hypoxic stress by

decreasing the partial pressure of oxygen despite a constant fraction of inspired oxygen of 20.95%. Prolonged hypoxic stress induces free radical damage to the capillary beds including the central nervous system and lungs, leading to fluid shifts from blood plasma to the intercellular space causing the development of AMS, HACE, and HAPE (5, 58). Therefore, the mechanism that causes the sign and symptoms of AMS are changes in oxygen availability and/or osmotic pressure. As an individual acclimates to high altitude, the cardiovascular hypoxic stress diminishes, and plasma volume decreases 14-17% (2). This allows for the blood to carry more oxygen per unit volume (2). In this context, capillary walls can recover, reversing the fluid shifts and mechanisms for altitude illness. (58). However, if the individual does not acclimatize, the perturbations of the capillary walls continue which explains progression form AMS to HACE and HAPE (58). Therefore, it can be speculated that there can be three contributing factors for decrements in performance related to motor coordination in altitude sickness: 1) hypoxic stress, 2) fluid shifts from the blood plasma to the extracellular fluid, or 3) selective sensitivity of Purkinje cell of the cerebellar cortex to hypoxia.

The altitude exposure of athletes competing in alpine skiing is unique from hikers because of rapid ascent and decent, via vehicular transportation to the base of the ski resort, chair lifts, and well-maintained trails. Altitude research has traditionally focused on hikers, specifically un-acclimatized military personal that need to perform at high altitude, who do not have means of rapid descent, the primary treatment of altitude illnesses. Skiers do, thus making altitude illness less likely in this unique population. However, because both groups, hikers and skiers, typically do recover from altitude illness at lower altitudes than that obtain for on snow training, such as altitudes for overnight lodging (typically just bellow 3000 m) is still at high altitude, skiers are still at risk of developing altitude illness. Albeit the risk increases for altitudes obtain during on snow ski training.

Dehydration can compound the decrements of performance induced by hypoxia. Several studies have shown that due to the drier air and hyperventilation at high altitude, dehydration over several days of mountaineering can become significant (2). In a study looking at the effect of *ad libitum* fluid

ingestion during a day of alpine skiing in seven healthy experienced adult skiers (control group, no fluid intake) at the altitude of 2438-3200 m, lost 1.6% (1.1±0.2 kg) and 1.2% (0.8±0.3 kg) in bodyweight (DBW), in a morning and afternoon recreational ski sessions lasting 2.75 hrs with a 1.5 hour rest break, during which *ad libitum* fluids was allowed (50). When looking at hydration across days, a study of men, body weight loss over 12 days climbing to 4325 m was 3.5-4.0 kg (7.7-8.8 lbs), with about 50% accounted for by fluid loss. Not all this fluid loss may be detrimental, as a decrease of plasma volume increases the per unit volume carrying capacity of the blood, diminishing the hypoxic stress and subsequent altitude illness. This change in hematocrit concentrations is expected during the first three to seven days of altitude exposure (2). Levels have been reported to be 14% in the first 3-4 days at 3822 m and 17% after 12 days at 3520 m (2). Given that blood volume contributes to about 87 ml per kg of bodyweight (16), and about 55% of blood volume is plasma (52), 6.6 to 8.1 ml of plasma fluid per kg of body weight is lost during acute altitude acclimatization. If this fluid was all excreted by the body it would result in less than a 1% DBW.

Dehydration and fluid balance can have impacts on multiple aspects of performance, strength, power, and high-intensity endurance with performance effects at 2% and significant effects between 3-4% DBW (33). Decrements in mood and concentration with increase in headache symptoms, have been described in female lowlander college age students with just 1.36% DBW dehydration (3). Children have a greater risk for mild dehydration induced by voluntary dehydration, children’s sensation is inhibited before adequate fluid is consumed to replace fluid losses during exercise, resulting in impaired performance involving visual-motor tracking, psychomotor skills, perceptual discrimination, and short-term memory (13). Therefore this study provided daily hydration monitoring to each subject as a control by using body weight changes, urine color, and urine specific gravity, which have been shown to be valid non invasive markers of hydration (1).

Because biological age and chronological age do not correspond in adolescent athletes and this may have an effect of physical performance and

adaptation to training (18). A growing number of youth studies have used the Pubertal Maturation Observational Scale (PMOS), which has been found to be validated and reliable (25).

To further elucidate performance decrements at altitude, the purpose of this study was to observe and evaluate the effects of acute high altitude exposure on performance variables related to alpine skiing during a week-long training camp at some of the highest altitudes that alpine ski racers regularly encounter (Summit County, Colorado). A second aim was to assess the effect of altitude on performance and learning curves during a week-long preseason athletic training camp, with a moderate hydration control intervention. Since hypoxic environment exposure and subsequent body fluid shifts may exacerbate both acute and chronic perturbation of sport related motor tasks, we hypothesized that performance quality and balance will suffer with acute altitude exposure, but after several days of altitude acclimatization these variables will improve.

Chapter 3. Methods

Experimental Approach To The Problem

A junior alpine ski racing team from Hanover, NH, (160 m) was selected for tracking of performance and hydration variables prior to and during their annual fall ski racing camp in Summit County, Colorado (2828.5 m). This group represents a typical group of athletes that travel to altitude to improve both sport skills and sport specific fitness when snow is not available for training at their home training center. Independent descriptive variables included training volume, altitude of home town and training site, temperature, and humidity of training site, counter movement vertical jump without arms, Lake Louise Acute Mountain Sickness Questionnaire (AMSQ), and hydration status, which was monitored with urine color, urine specific gravity (USG) and change in bodyweight. This was monitored twice a day to provide feedback to each subject about his or her hydration status. Dependent variables chosen were split into daily tests: 1) Y-Balance test and Quickboard^{TM} React Drill (QRD); and 2) a battery of performance tests: countermovement jump with arms, T-agility test, 1 minute sit up and pushups test, and the multistage fitness test. Baseline data was collected at sea level one week before travel to the camp. The daily tests were performed twice a day for six consecutive days while at altitude to assess the effect of altitude and to provide a stimulus for a learning and performance improvements. The battery of performance tests were performed a second time after ski training on the last day (day six) of the camp.

Subjects

All procedures where approved by the Internal Review Board at the University of Connecticut for human subjects in research (appendix). All subjects and parents or guardians were informed about the risks and benefits before giving written consent prior to participating in the study. All subjects filled out a medical clearance form based on the exercise screening recommended for maximal exercise by the ACSM’s Guidelines for Exercise Testing and

Prescription 8th Edition (appendix) (56), which was reviewed by the medical monitor to screen for possible medical complications.

Table 1. Subject Characteristics

	Boys	Girls	Combined
N	4	7	11
Age (yrs)	14.0±0.5	13.5±0.5	13.7±0.5
Maturation (1-8)	5.75±1.3	6.28±1.3	6.09±1.3
Weight (kg)	54.6±2.4	51.2±8.3	52.4±6.8
Height (cm)	153.5±21.1	159.4±5.3	157.2±12.6
% Average Parent Height	89.5±11.8 % (n=10)	93.0±1.8 % (n=10)	91.6±1.8 % (n=10)
Sport Experience			
Skiing (yrs)	8.0±2.2	7.7±2.2	7.8±2.2
Soccer (yrs)	6.3±2.1	5.7±2.1	5.91±2.5
# of Sports	4.0±1.8	4.43±1.8	4.3±1.8

Table 1. provides the subject characteristics for boys and girls. Age is observed at date of baseline test. Maturation is based on the PMOS questionnaire. Adult height was the average of the biological parents. Sport experience is reported based on years of participation and the number of total sports in which the athlete had received organized training.

Eleven subjects participated, 4 boys and 7 girls. There were no differences in the characteristics presented in table 1. The subjects where late in their pubertal maturation, 6.09±1.3, on a scale of 1-8, and were 91.6±1.8% (n, 10) of the average height of their biological parents. Alpine skiing was the sport with most years of experience, followed by soccer, and subjects were actively participating, or participated, in 4.3±1.8 competitive sports for one season or more.

Procedures

All subjects participated in school sports and were members of a club ski team. Subjects filled out a baseline questionnaire and the Pubertal Maturation Observational Scale (PMOS, see appendix) (25) to determine their relative

biological age. The questionnaire consists of eight questions that are answered yes or no. The more questions answered “yes” the later the subjects was in maturation, which was treated as interval like data. A second questionnaire asked for the biological mother and fathers height and for a list of sports that the subject had previously participated in, with approximate start and end dates.

Height was measured with a wall-mounted tape measure. Leg length (from iliac crest to medial malleolus) on the dominant leg was recorded with a standard fiberglass tailor tape measure. And body mass was recorded with a digital floor scale with t-shirt, shorts and socks on (Health-o-meter, Sunbeam Products, Inc. Baco Raton, FL, USA).

Table 2. Tests and Timing

Test	Base Line (New Hampshire)	Daily Tests at the Camp (a.m. and p.m., Colorado)	Last Day of Camp 3:00 p.m. (Colorado)
Descriptive Testing			
Baseline Questionnaire	✔		
Pubertal Maturation Observational Scale	✔		
Height	✔		
Balance and Reaction Tests & Hydration Control			
Body Weight	✔ (3 Days)	✔	✔
Urine Sample for hydration analysis	✔ (3 Days)	✔	✔
AMS Questionnaire (appendix)	✔	✔	✔
Y-Balance Test	✔	✔	✔
QRD	✔	✔	✔
CMJNH	✔	✔	✔
Battery of Performance Tests			
CMJ	✔		✔
T-Agility Test	✔		✔
Sit & Reach Test	✔		✔
Pushup Test	✔		✔
Sit Up Test	✔		✔
Multi Stage Fitness Test (Estimate VO_{2max}(9))	✔		✔
Coaching Evaluations		✔	

Table 2 provides a list of variables and time points for testing.

The testing was broken up into two sections: 1) the daily tests and 2) the battery of performance tests. The order, timing and altitude of the tests can be seen in table 2. Baseline tests were performed at 12:00 a.m. on the Saturday the week before departure to the altitude camp, where the subjects were taught how to perform each of the tests and how to fill out the questionnaires. The daily tests

at the camp were performed at 7:00 a.m. and 4:30 p.m. after at least a 30 minute rest period from arriving back at the lodging. An additional AMS questionnaire, was also administered for after skiing in the base lodge of the ski resort (about 2:30 p.m.). An exception occurred on the last day when the afternoon tests were done at 3:00 p.m. followed by the second battery of performance tests.

Daily Tests. The Lake Louise Scoring System for AMS was used to measure signs and symptoms of acute mountain sickness (AMS) (7, 23, 44). The Lake Louise Scoring System for Acute Mountain Sickness is a series of six questions that each subject answered on a small paper, on a scale from zero to three. These questions were used to measure signs and symptoms of AMS by asking the subject to rate his/her headache, gastrointestinal, fatigue/weakness, dizziness/lightheadedness, sleep, and overall effects on activities. In addition, the investigator evaluated each subject on three additional questions that are part of the Lake Louise Scoring System: 1) changes in mental status, 2) ataxia, walk heal-toe, and 3) an evaluation for peripheral edema.

Then subjects body mass was recorded and Urine was analyzed for urine color (2) and urine specific gravity (USG) with a handheld refractometer (Model A300CL, Spartan Refractometer, Tokyo, Japan) (1). On a second visit before ascending to altitude subjects, provided a urine sample and body weight for the calculations of a standard baseline hydration.

The Y-balance test (46), Quickboard™ React Drill (The Quick Board, LLC Memphis, TN) (22) and a counter movement vertical jump with hands on hips (CMJNH), a Just Jump System™ (Probotics INC. Huntsville, AL, USA) were performed with the best of three trials used in the analysis of performances of each test.

Dynamic balance ability was assessed with the Y Balance Tests, also known as the Star Excursion Balance Test, using the dominant leg, defined as the side preferred for one-ski skiing. The Y-Balance test involves reaching for maximal distance with one leg in three defined directions while balancing their dominant leg, while wearing athletic sneakers. The subjects started with one foot

in the center of the “Y” and their hands on their hips. The balancing foot had to remain fully on the ground and in the same position with heel and toes on the ground at all times. For each trial the investigator recorded the furthest distance reached by the free leg – the heel for the anterior reach, and the big toe for the posterolateral and posteromedial reaches. The best of three trials of each reach direction was chosen, then the three directions where summed and divided by leg length. (46)

The React Drill on the Quickboard™ were assessed using eye and foot coordination and reaction time. This included a set of five LED lights on a small plate placed in front of the subject that correspond with five yellow touch pads on board that the subject stands on. The LED lights and touch sensors are in the formation similar to that seen on the side of a dice with five dots on it. The Quickboard™ randomly illuminates one LED on the display and the subject uses their foot to touch the corresponding touch sensors on the Quickboard™ floor pad. The reaction times for each sensor and total successful and incorrect touches for a 10 second period were recorded. The best average mean reaction time of three trials was used for reporting and statistical analysis. (22)

The counter movement jump was performed on a timing pad (Just Jump System™, Probotics INC. Huntsville, AL, USA). Internal reliability for the Just Jump system was determined to be acceptable ($r = 0.91$), for jump and reach height measured with the Vertec (Vertec, Sports Imports, Hilliard, OH), with ten subjects performing three jumps each. It was also found to be acceptable when compaired to a force plate (AccuPower; Athletic Republic, Fargo, ND, USA) with a sampling rate of 200 Hz for the variables peak watts relative to body mass ($r = 0.97$) and jump height ($r = 0.95$). This agrees with other findings (36). The subject was instructed to stand on the pad and to perform a countermovement jump as high as possible with the subject’s hands on their hips (CMJNH). The highest of three trials was used. For the CMJ trials arm swinging was permitted. (36)

The Battery of Performance Tests. The battery of performances after a standardized warm-up consisted of 5 minutes of light cardiovascular activities,

which included: jogging, skipping, side jacks, lateral cross-over walks, high knees, butt kicks, and 10 repetitions of dynamic stretches. The dynamic stretches were: arm circles, spine twists, lateral spine flexion, hip circles, leg swings, knee hugs, foot-to-butt, cradles and lunges. The first test performed was the CMJ as described above. All running and agility tests where done on asphalt with athletic sneakers.

For the T-Agility test, a course on a level surface in a paved parking lot was set up with five cones in the shape of a "T" (see figure 1). While facing in one direction subjects sprinted out ten yards out and touch the middle cone of the "T", lateral shuffled, 5 yards, without crossing their feet to one side and touch a second cone. Then lateral shuffled 10 yards in the opposite direction to a third cone, followed by laterally shuffling back to the middle cone, 5 yards, and finally back pedaled 10 yards to the start/finish line. The fastest of three trials was used for analysis. Times were measured with an electric eye to start and stop (Track & Speed, Brower Timing System, Draper, Utah). (51)

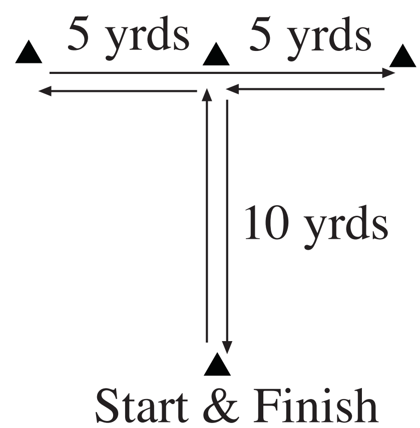

Figure 1. The T-Agility Course.

Sit-and-reach was measured using the best of three trials on a sit and reach box with legs fully extended, feet 15-20 cm apart and hands overlapped. Subjects kept their knees down and reached as far as possible while breathing out slowly. (38)

All subjects performed as many standard push up in one minutes as possible: toes and hands on the ground, with a straight line from the heels to the shoulders. The bottom of the push ups was defined as when subject's chin touched the investigator's/partner's fist, placed on the ground in a neutral position. And the top of the push up was defined as full extension of the subject's elbow.

Subjects performed as many sit ups in one minute as possible while the investigator/partner held the subject's feet. The subject kept a 90º at the knee joint. On the way up the subject held their shirt collar with both hands and arms crossed. Once the elbows touch the thighs and or knees, the subject lowered their torso to the ground such that their shoulder could touch the ground.

The Multi Stage Fitness Test (MSFT) was made up of a 20-meter (22 yard) course designated by cones. The test consisted of a digital audio recording with 23 stages of approximately one minute each. Each stage is comprised of a series of 20m shuttles, where the starting speed is 8.5 km/hr and increases by 0.5 km/hr each stage. The standardized recording played a single beep to indicate the start of a shuttle and 3 beeps indicates the start of the next stage. The subject placed one foot on or beyond the 20 m markers at the end of each shuttle and could not start the next shuttle until the beep. The test ended when the subject failed to reach the end of the shuttle before the beep. The subject was allowed two further shuttles to attempt to regain the required pace before being withdrawn. The subject's score is the last level successfully completed (reach the line before the beep occurs), which can be converted to a relative VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) score (appendix) (48). (8, 37)

Sport Coaches' Perceptions of Athletes. During the preseason camp at altitude training the sport coaches assessed each athlete's participation in training (appendix). Using a 1-5 Likert scale the coaches rated from strongly agree to strongly disagree on each of the following questions: "Was the athlete's mood at training happy and positive?" and "Did the athlete have a high quality day of training?" (39). A third question asked the coach to record number of chairlifts rides each athlete took during training that day for each chairlift at the resort, which was used to measure the vertical drop in meters skied by each subject. A comments section for the coach, was provided to record information about a subject that the coach felt was important to the athlete's participation. An additional section on the investigators recording sheet was provided to record

locally reported weather conditions, temperature, humidity, wind, cloud cover, and precipitation.

Statistical Analysis

The sample size calculation is based on the primary variable, Y-balance test, using the method presented by WG Hopkins (28). Using the "Change in mean in a crossover" formula with a smallest harmful change of 6.96 and typical error of 3.86, a sample size of 4 was calculated. The values used were from Plisky et al. (46) who reported a pre-to-post season variability of the Y-Balance test to be 3.83%, which was the average of the three internal variables in the test. And a decrease of 6% from a mean of 100.9±8.4 to be predictive of lower extremity injury risk for combined boy and girl high school basket ball players (46). The anticipated enrollment of approximately 11 subjects, both boys and girls, exceeds this sample size.

The primary data was also analyzed with a one way ANOVA (day) and two-way ANOVA (time x day) with repeated measures and a Fishers LSD post hoc test to determine mean pairwise differences. If the assumption of sphericity was not met the a Greenhouse–Geisser correction was used. To check for the influence of gender, maturation and AMS a one-way or two-way (time x day) ANCOVA was used. Scores are reported as mean ± SD and significance was set at $p \leq 0.05$. The AMS questionnaires did not allow for two groups to be created that had sufficient sample size for statistical analysis.

Chapter 4. Results

Environmental conditions for baseline testing, altitude testing, and training sessions can be found in table 3. along with training volumes, the number of runs and vertical meters skied each day. There was a main effect for days of skiing (f [2.164, 25] = 4.812, p = 0.030), and an effect for maturation, (f [1, 5] = 2.759, p = 0.041) where athletes with a higher mature score skied more vertical meters. All days had significantly different volumes except between the following days: 1 and 2; 2 and 6; 3 and 6. Skiable altitude is provided along with mountain resorts for each day of training along with baseline and lodging altitudes where testing occurred. Testing was performed in environments with similar temperatures.

Table 3. Environment of the Camp and Testing

	Baseline	**1**	**2**	**3**	**4**	**5**	**6**
Temperature (C°)	5.7	-5.4	-3.3	-4.2	-3.3	-3.3	2.8
Humidity (%)	73	84	70	58	76	37	37
Mean Wind Speed (kph)	4	8	18	6	14	5	6
Training Volume (Mean ± SD)							
Mountain Resort		Love Land	Love Land	A. Basin	A. Basin	Love Land	A. Basin
# of Runs		11.9 ±1.5	12.4 ±1.8	16.9 ±1.2	22.8 ±2.4	11.4 ±0.5	16.6 ±0.9
Vertical Drop (m)		3263 ±336 Y	3534 ±477 Y	3922 ±288 Y	5246 ±566 ¥	2989 ±97 ¥	3811 ±266 †
Skiing Altitude (m, ft)		3328 – 3673 m, 10,919 – 12,050 ft		3328 – 3802 m, 10,919 – 12,472 ft			
Testing and Lodging Altitude (m, ft)	160 m, 524 ft	2828.5 m, 9280 ft					

Table 3. Provides environmental conditions for testing and ski training as well as altitudes for baseline, daily testing and ski training. Temperatures and humidity are a single time point reported for midday. Average daily wind speeds that were reported with temperature and humidity, standard deviations were not available. ¥ Indicates significant difference between all other days ($p < 0.05$). Y Indicates significant difference between all days except: 1& 2, 2 & 6, and 3 & 6. † Indicates effect of maturation was significant ($p < 0.05$).

AMS Scores are reported as sum of scores for the Lake Louise Questionnaire for each subject and a scatter plot can be seen in Figure 2. At baseline one subject reported a score of 4, and on day one three subjects reported having AMS immediately after skiing with score of 5, 6, and 7, which decreased to 2, 4, and 6, respectively at 4:30 pm. On the morning of the second day those three subjects reported scores of 2, 0, 5, which increased to 2, 4, 5 after skiing and all reduced to bellow the cut off for AMS at 4:30 pm. After 4:30 pm on day three no subject reported a score above 2, and after skiing on day five no subjects report a score above 0. Analysis for the effect of AMS scores on dependent variables did not exist at any time point.

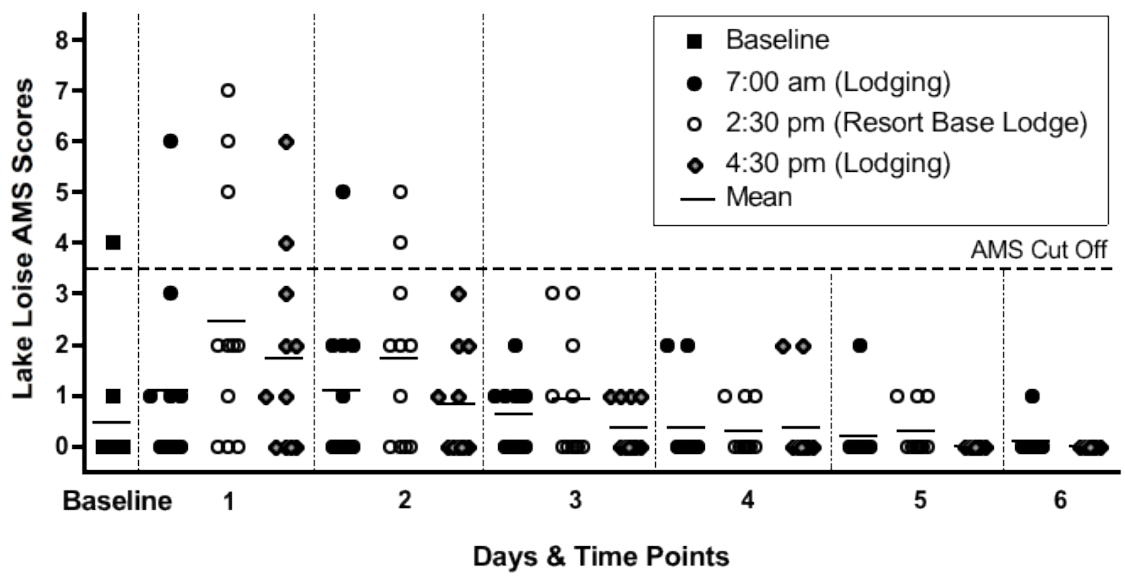

Figure 2. Frequency of subjects experiencing AMS as defined by scoring ≥4 on the Lake Louise AMS Questionnaire.

Results from hydration monitoring, percent change in body mass, and standard measures of USG and urine color are displayed in figures 3, 4, & 5, respectively. There was a main effect for the loss of body mass (f [6, 60] = 10.159, p < 0.000), from day one through day six and the 95% confidence interval was -1.27 to -.57 kg (-2.97, -1.26 lbs). Body weight on days three and four were significantly lower than baseline and days five and six were significantly lower than all previous days. But days five and six were not significantly different from each other (p=0.055 and p=0.051, for first am and pm

time points). There was no effect found of a.m. versus p.m. across days for changes in bodyweight. Between a.m. time point comparisons, first morning body weight after voiding the bladder trended to be greater on days three and four, but five and six were similar.

An order four main effect for both USG and urine color across days was observed (f [1, 10] = 25.569, p < 0.000; f [1,10] = 10.925, p < 0.008). USG on day three was significantly greater than day's one and six. The same pattern occurred in urine color with day 3 being significantly darker than days one and four and five (figure 5). There was no effect detect for a.m. versus p.m. time points for USG or urine color.

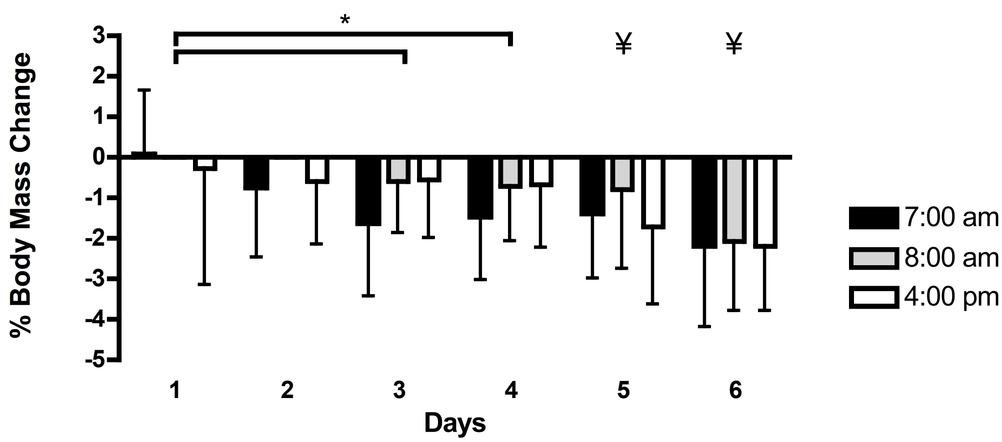

Figure 3. Percent body weight change at after first morning void, second morning void and after skiing. * Indicates significant difference between days ($p < 0.05$). ¥ Indicates significant difference between all other days ($p < 0.05$). Y Indicates significant difference between all days.

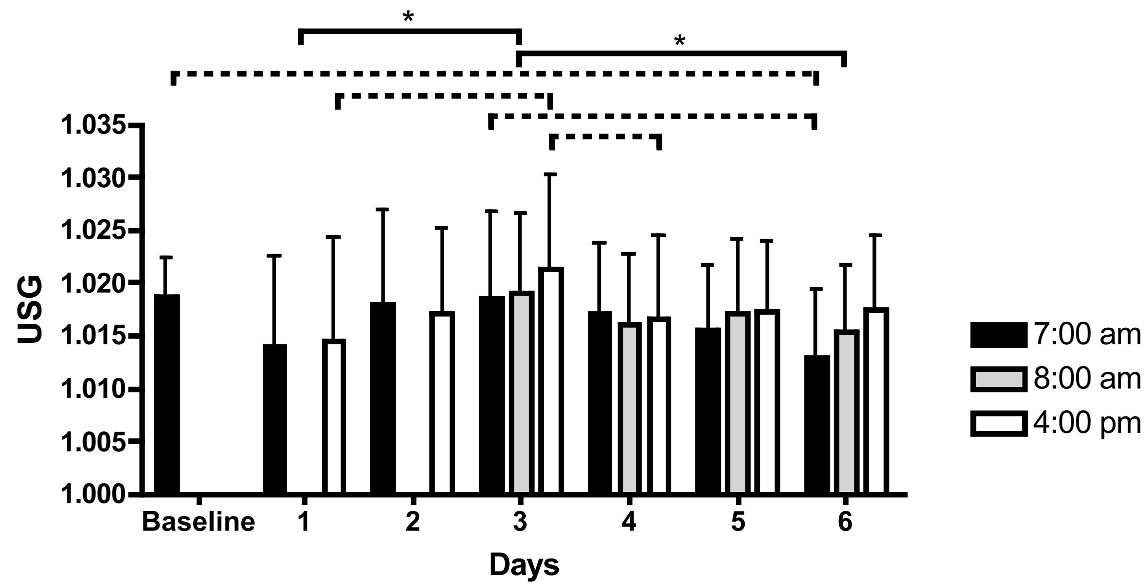

Figure 4. Urine specific gravity across days. * Indicates significant difference between days ($p < 0.05$). Solid bars indicates significant difference between day, and doted lines indicates significant differences ($p < 0.05$) between time points.

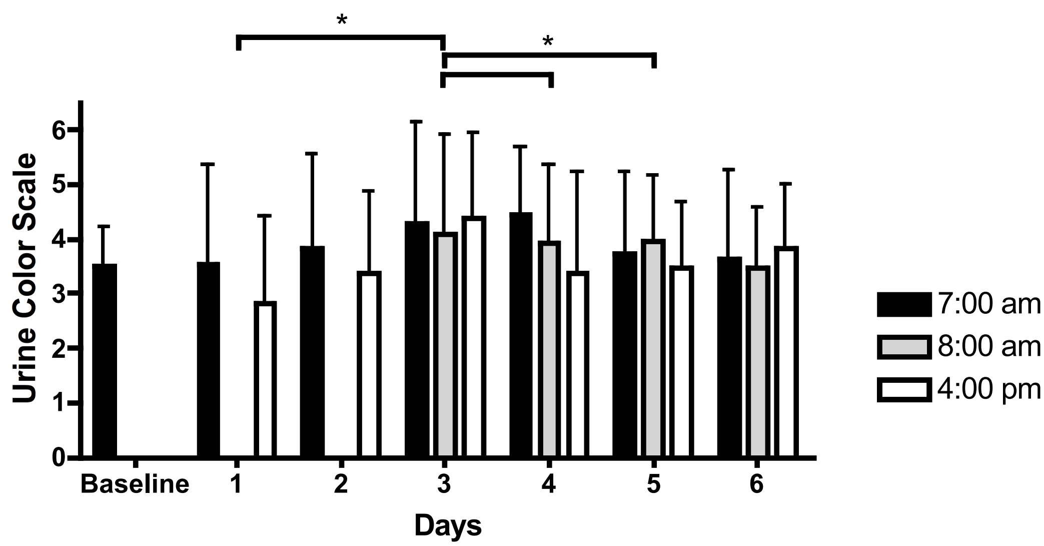

Figure 5. Urine color across days. * Indicates significant difference between days ($p < 0.05$).

The Y balance test improved on days three through six (figure 6) with a main effect between days (f [6, 60] = 34.798, p < 0.000) and from a.m. to p.m. time points (f [1, 10] = 10.980, p = 0.008).

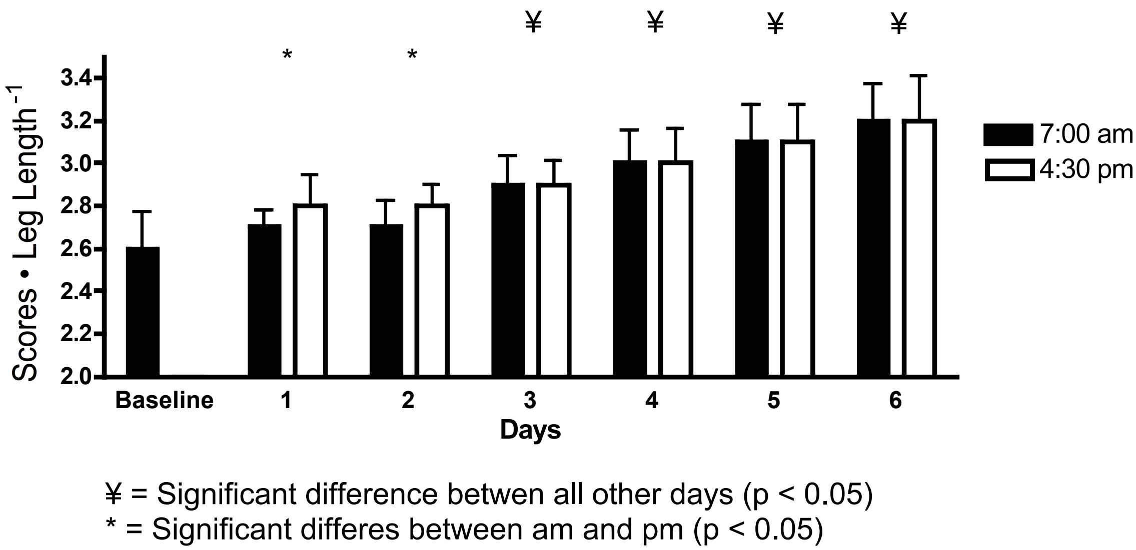

Figure 6. Y-balance scores as reported by sum for the best score in the three reach directions divided by leg length. * Indicates significant difference between days (p < 0.05). ¥ Indicates significant difference between all other days (p < 0.05).

Performance on the Quickboard™ React Drill, was mixed (figure 7). A main effect for days was detected (f [5, 20] = 5.679, p = 0.005) for mean reaction time (QRD). There was an effect for maturation for reaction time (f [5, 20] = 4.572, p = 0.002). Post hoc tests showing that subjects with lower maturation had faster reactions times for the following time points: am and pm on day 1 and pm on day six (p < 0.05). No main effect was found for percent correct touches (f [5, 50] = 2.105, p = 0.080) or a.m. versus p.m. time points for both variables – reaction time and percent correct touches.

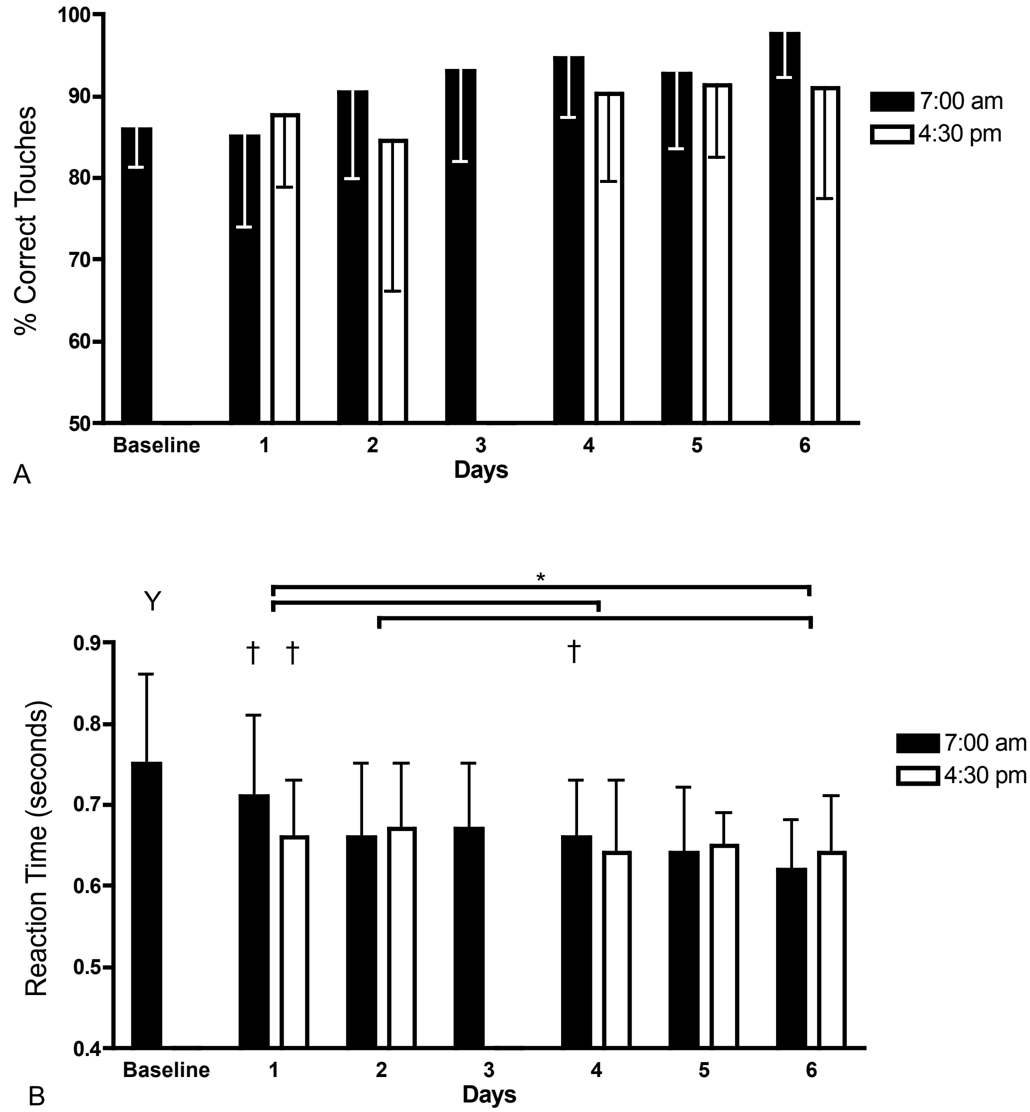

Figure 7A. Percent correct touches and 7B mean reaction times for the Quickboard™ React Drill across days. * Indicates significant difference between days ($p < 0.05$). ¥ Indicates significant difference between all other days ($p < 0.05$). † Indicates an effect of maturation was significant ($p < 0.05$).

A main effect for between days and a.m. versus p.m. was found for CMJNH (f [6, 60] = 5.876, f [1, 10] = 31.699, p < 0.000). Scores increased significantly from baseline on day one of the training camp and remained unchanged (see figure 8) with no effect for gender or maturation. On days two, five and six jumps height increased from am to pm.

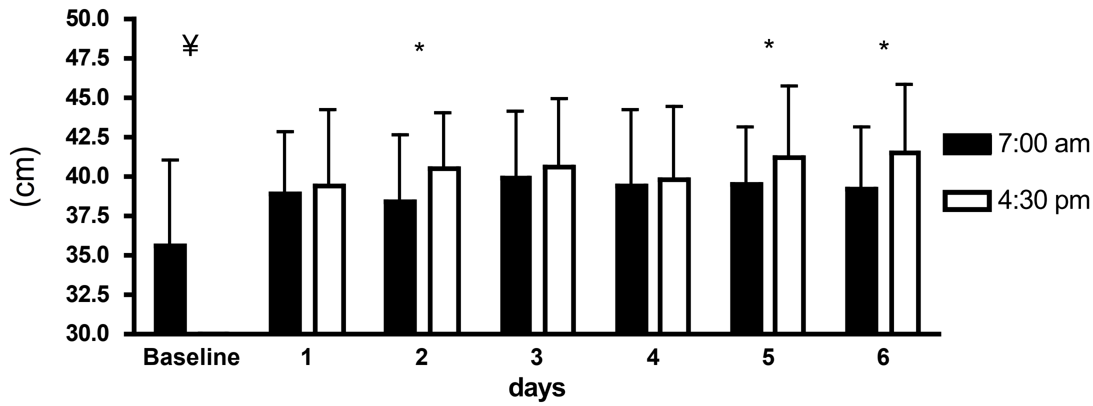

Figure 8. Counter movement jumps with hands on hips pre and post training across days. * Indicates significant difference (p <0.05) between a.m. and p.m. time points for that day. ¥ Indicates significant difference between all other days (p < 0.05).

The coach's perceptions of athletes mood while training decreased from day one through day three during the camp and improved on days four through six (figure 9). The coaches perception remained similar with three athletes scored above one on days two and three but improved to all athletes perceived to have the highest quality of training on days five and six (figure 9).

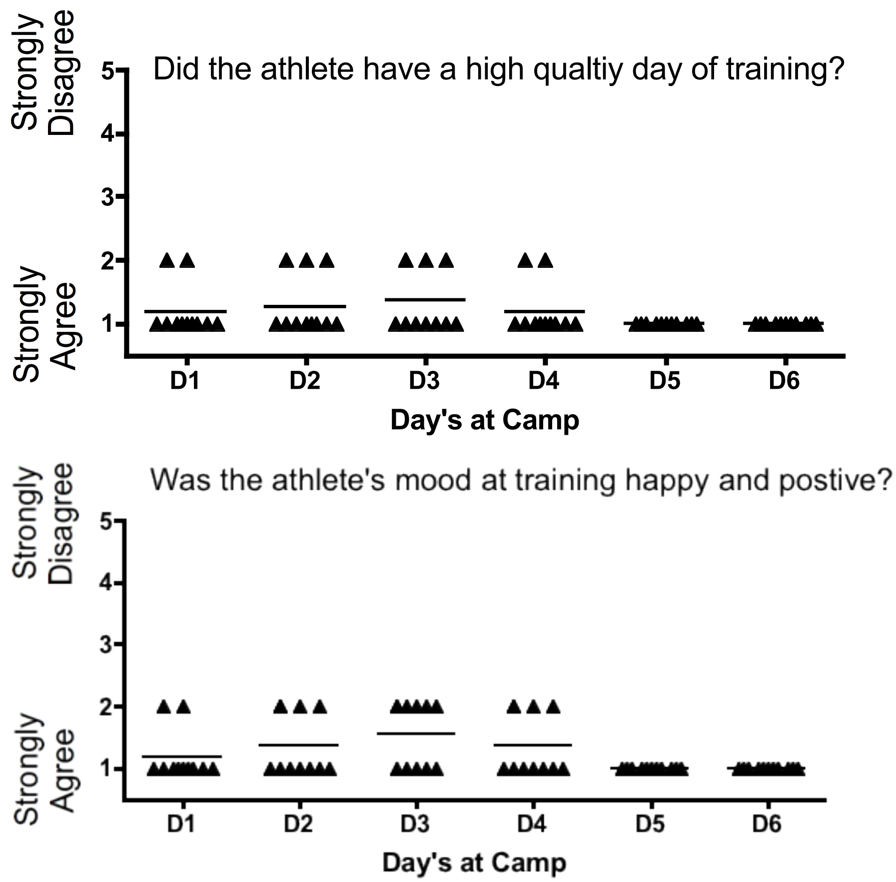

Figure 9. Coaches perception of the quality of mood and quality of training for each subject across days.

Baseline and day six testing for performance variables can be seen in table 4. CMJ increased significantly, with a significant gender effect at the end of the camp, the boys jumped 55.0±5.6 cm as compared to the girls who jumped 47.0±4.6 cm. T-agility test, sit-and-reach, 1 minute sit up and pushup test all increased significantly with the exceptions of the sit up test which had a p = 0.055. All subjects experienced a significant decrease of their MSFT performance with a within subject mean estimated VO_{2max} decrease of -8.9±4.0 ml•kg^{-1}•min^{-1}.

Table 4. Baseline and end of camp performance tests.

	Baseline	**Day 6**	**Sig.**
Counter Movement Jump (cm)	45.1 ± 5.4	49.9 ± 5.6 ‡	p = 0.002
T-Agility Test (seconds)	12.04 ± 0.83 †	11.54 ± 0.55	p = 0.014
Sit-and-Reach (cm, plain of box at 22 cm)	27.3 ± 7.9	29.5 ± 5.8 †	p = 0.037
Sit ups in 1 minute	38.8 ± 3.7	39.8 ± 6.0	p = 0.055
Pushups in 1 minute	20.2 ± 8.9	25.64 ± 7.4 † ‡	p = 0.037
VO_{2max} (ml•kg^{-1}•min^{-1})	42.3 ± 5.5 (boys, n=3 girls, n=6)	33.4 ± 4.9 (boys, n=3 girls, n=6)	p = 0.000

Table 4. Gives exhaustive performance tests for baseline and day six. Significant levels of pre and post differences are in column four. † Indicates an effect of maturation was significant ($p < 0.05$) and ‡ indicates than an effect of gender was significant ($p < 0.05$).

Chapter 5. Discussion

The primary findings of this study were that the Y-Balance and QRD did not have a decrement in performance during acute high altitude exposure, and both tests improve after three days of acclimatization. Therefore this data rejects the hypothesis that acute altitude exposure initially impaired performance at high altitude, but supports the hypothesis that performance data improves over the course of the week at altitude. This data set supports the ability for youth athletes to adapt to physical and perceptual-motor training while acclimatizing to an overnight lodging of 2828.5 m and training between 3328-3802 m.

The altitude of the testing and overnight lodging was just below levels known to cause perturbation in balance, reaction time, and vision, (3048 m, 10,000ft) but all skiing activity was above this threshold altitude (19). Because alpine ski racing is a sport that commonly travels to moderate to high altitude for both training and competition, usually not above 3650 m (12,000 ft), future research is warranted to explore effects of performance for on snow training altitudes.

Three of eleven subjects (27%) experienced AMS, which is consistent with other observations of about 20% in children skiing in Summit County, CO (7, 30, 45). However, rates of AMS in youth at slightly higher altitudes, similar to those reached during on snow training in this study, have been reported to be higher during an overnight stay at 3500 m (641.5 m, higher than this study) reported an incidence rate of 50% of adolescents (n = 10, 15.4±1.5 yrs) (45). A rate of 91.7% was reported in twelve (7 boys, 5 girls, 15-18 yrs) hikers over a 21 day trip to Machu Picchu and the peak of Ausengate (2500 m to 5500m) (30). Despite the incidence of AMS observed, there was no effect found between AMS scores on dependent performance variables measured in this study at any time point. These findings suggest that youth athletes experiencing moderate levels of altitude illness, with short exposures above 3000 m can acclimatize while participating in training, and have benefits from participating in training.

Dehydration. As AMS scores improved throughout the week markers of hydration had a delayed response. Dehydration as measured by change in body mass from baseline slowly increased throughout the week. However, since, USG was higher on day three than days one and six ($p < 0.05$), and urine color was higher on day three than days one and five ($p < 0.05$), indicates that hydration decreased significantly on day three then returned to normal levels on day five and day six. Also second morning body weight did not increase on day six, indicating that bodyweight losses six days into acclimatization and training may not be due to fluid deficit and might be body mass loss from lean or adipose tissue. Son et al. (53) observed similar changes in body during acclimatization to moderate altitude and interpreted this as lean body mass loss in youth alpine skiers using the bio-impedance method.

The order four effect in USG and urine color paralleled improvements in AMS scores, coach's perception's quality of training, and QRD observed in this study. Arginine vasopressin (AVP), which controls whole-body fluid balance by regulating plasma osmolality, by retaining water in the renal collecting ducts of the kidney, responds to high plasma osmolality (dehydration). The AVP threshold for plasma osmolality increased significantly with two days and twenty day's of high altitude (4,300 m) acclimatization in seven men (22±1 yrs) (41). After about 3-4 days of acclimatization the regulation of fluid balance of the body most likely was altered, resulting in better oxygen delivery and reducing the hypoxic stress allowing for improvements in neuromotor performance and the quality of training. Therefore an adaptation of AVP maybe one of the underlying responses that explains the changes in performance seen in this study.

Interestingly, the afternoon time point was equal or slightly more hydrated than morning time points for the three hydration markers, indicating that *ad libitum* fluid consumption during and after training was sufficient to maintain or improve hydration. This was similar to a study looking at the effect of a back mounted bladder hydration system for *ad libitum* fluid intake during alpine skiing for 2.75 hr (3,853 ± 430 m of vertical drop) versus no fluid intake in adult (23-35 years) experienced skiers at 2,438 m to 3,200 m. The subjects who consumed

no fluids during skiing replaced 71% of fluid loss, where a group that used the back mounted water bladder ingested 100% of their fluid loss during skiing and after skiing (50).

Table 5. Markers of Hydration during Training Camp

Subject	Motivation to drink	%ΔBW	USG	Urine Color
2	Avoid the on-set of an headache	-0.77±1.71	1.013±0.006	3.0±1.2
4		0.21±0.53	1.017±0.007	3.7±1.4
All other subjects	In response to an oncoming head ache	-1.3±0.95	1.017 ±0.006	3.8±1.2

Table 5. Gives mean and standard deviation for markers of hydration for all time points during the week at altitude. %ΔBW is the percent change in bodyweight, USG is urine specific gravity. Two subjects (2, 4) motivation to drink fluids was to avoid the on set of a headache and while the rest of the group motivation to drink fluids was in response to an oncoming head ache.

When subjects were ask if the hydration monitoring and feedback from it drove them to drink more, boys consistently reported that it did not but find the notification helpful. The girls did find it useful, and four subjects reported that they drank more fluid volume than otherwise to improve urine indices of hydration. When asked what was the primary motivator to drink fluids all but two subjects reported it was to diminish feeling of an oncoming headache. The other two subjects reported drinking 1-2 extra liters of water per day then they would normally perceive to have done, in order to prevent the onset of a headache. Interestingly, these subjects consistently had markers of urine indices of hydration at or better than the mean of the rest of the group (see Table 5). These subjects also reported that they would add flavor to the fluid or cut fruit juices with water to make drinking the extra fluid more palatable.

Balance. The data from this study indicates that the altitude exposure experienced over a six-day training period at some of the highest ski resorts in the world, did not prevent improvements of performance on dynamic balance scores. The altitude tested in this study (2828 m) was below the threshold of

3,000 m for increased observations of general performance decrements for testing (4), but altitudes for sport activity in this study were above this threshold (3328 – 3802 m). Tests done over acclimatization to altitude showed similar improvements in performance to this study. Wobble board tests improved in one study from baseline during the first two tests at 1345 m and 1660 m, respectively, then remained unchanged at altitudes of 3300 m, 4650 m, and 5005 m in twenty adults (25-46 yrs, 16 men, 4 women) with each ascent to a higher altitude 2-3 days apart (31). This study concluded that the wobble board test maybe a useful adjunct in quantifying ataxia (31). This research group in a larger study showed, during staged acclimatization (eight days per stage) at high altitude that decrements of the Sharpened Romberg Test (ability to stand still for 60 seconds with arms crossed against the chest and eyes closed) to have a sensitivity of 71% at 3610 m to predict AMS and 60% at 5260 m and the specificity to increased from 69% at 3610 m to 89% at 5260 m (32).

However, studies looking into the mechanism of perturbation of balance at altitude have shown it to be sensitive to hypoxia and not to correlate with AMS scores. Fraser et al. (20) showed postural control mechanisms, as measured by three minutes of eye closed postural sway on a force plate, are very sensitive to even acute mild hypobaric hypoxia - 30 minutes at 1524 m. And several studies have shown that decrements in balance performances do not correlate with AMS (5, 6, 12). Cymerman et al. (12) when investigating postural stability showed that decreases in balance did not correlated with AMS after 24 hours of simulated altitude exposure at 4300 m. And Baumgartner et al. (6) in 22 healthy subjects (17 men, 5 women, 42±10 yrs) during a 3 day sojourn to 4559 m showed postural sway decrements not to correlate with AMS scores. But, in a separate paper, after a 24 hour ascent to 4559 m and then 10 minutes of oxygen supplementation (3 L•min^{-1}) had no effect of returning postural sway to baseline levels (6). This also suggested that a hypoxia triggered mechanism separate from AMS, such as selective sensitivity of Purkinje cell of the cereblar cortex to hypoxia, may be related to decrements in balance (6). Thus decrements in

balance performance are most likely due to hypoxic stress on the neurons and are not due to the fluid shifts that are thought to cause AMS.

QuickBoard[TM] React Drill. Choice reaction time as tested with the Quickboard[TM] React Drill (QRD) improved over the course of the week, indicating that the lodging altitude was not high enough to induce reaction time performance decrements. The altitude threshold (ascent rate of 1000 m per day) for decrements in performance of reaction time as tested by pressing a single button, with a finger, after an LED light randomly lights up, was found to be between four and five thousand meters, about 1500 m higher than this study (40). However, in a choice reaction time test designed to determine the threshold for impairments of perceptual-motor performance with six acute (within minutes) altitudes exposures, where altitude was measured by blood oxygen saturation (SaO_2) and ranged from 76% to 86% in increments of 2%, found the threshold to be SaO_2 of 82% equivalent to 3048 m in six adult subjects (3 men, 3 women) (19). In this study, there was a linear relationship between altitude from 3048 to 3475 m with decrements in reaction time, supporting this hypothesis that sensory motor tasks decrements are related to hypoxic stress (19). Other work showed that visual sensitivity decreased by 17% as low as 2500m and 33% at 3500 m (57). Thus conclusions from this study and those mentioned above should be limited to the altitude tested (2828.5 m) and the impact of visual choice reaction time for on snow training altitudes (~3500 m) still needs to be investigated.

Investigations into the mechanism for decrements of choice reaction time (CRT) from altitude exposure show that these are most likely caused by the hypoxia rather than fluid shifts. Experiments using event related potential recording during surface cranial electroencephalography have examined the effects of acute hypoxia on P300 latency (57), which is considered "an index of cognitive activity involved in stimulus evaluation, discrimination, and categorization" (24). Hayashi et al (24) showed that after just two hour of exposure to 4500 m (hypobaric hypoxic chamber) that an increase of P300 latency occurred, which could explain increased choice reaction time (24). This

has been replicated in several other experiments (57). It is not clear what is the exact cause of P300 latency, but a decrease in the cognitive processing speed, or in the sensitivity of the auditory input or cortex brain stem-neurons has been suggested (24).

Explosive Power. The use of changes in CMJNH can be used in assessing strength and power performance of individuals, specifically the relative fatigue of connective tissue and contractile muscle tissue. CMJNH remained constant throughout the training camp. Improvements in explosive power were expected between morning and afternoon time points because circadian rhythms of peak rectal temperature and circulating hormones levels such as melatonin, have direct effects (49). On day's one, three and four where training volume were elevated as compared to other days and prior training, afternoon vertical jump performances did not differ from morning performances. Indicating that significant lower body fatigue was induced on those training days, but the subjects where able to recover day-to-day during the camp.

Quality of Training. The perceptual data collected from the coaches questionnaire on the mood state and quality of training for each subject, matched trends found in AMS, Y-Balance test, CMJNH and QRT: scores improved on or after day three of the camp. Interestingly, coaches did not score any subject above 2 (agree), suggesting that all subjects had quality days of on snow training during the camp. This finding and the observed improvements in CMJNH, Y-Balance test, and QRT over the week, indicates that a reasonable volume of quality training can occur upon immediate ascent to high altitudes.

Battery of Performance Test. Performance tests at the end of the camp indicate that these subjects, despite the stress of altitude and travel, where able to sufficiently improve physical performance of flexibility, vertical jump, quickness, speed and local muscular endurance.

Flexibility improved from baseline levels to a degree similar to youth athletes' involved in several weeks of participation in soccer training (11). In addition, the vibration stress from alpine skiing may cause an increase in the compliance of tendons and ligaments, which would contribute to the flexibility, however the timeline for these adaptations has not yet been investigated (15).

Improvements seen in CMJ increased throughout the week may have been due to other factors than a decreases tendon compliance as previously reported (47). However, due to the eccentric load stress from alpine skiing (21, 29), and a decrease in bodyweight from baseline could contribute to the explanation of the improvements seen in vertical jump performance during the camp (17).

The increased flexibility and decreased bodyweight could also provide preliminary explanation for the improvement in the time required to complete the T-Agility course. In addition, to these changes, lateral agility and strength is a fundamental to the movement pattern of making carved ski turns (55). Thus sport skill improvements and physiological adaptations of muscle and tendons, as well as the decrease in bodyweight could have been transferred to the performance of the T-Agility test.

The changes in the number of sit ups that can be performed in a minute increased with a p value of 0.055. Given that the baseline scores where at 38.8±3.7, indicates that there is little room for improvement (27). Being able to measures change in this performance variable, with only a small range for improvements and low N size of 11, makes conclusions from this data set difficult to interpret. It is clear that core stability and upper body bracing are important in maintaining stability throughout a carved turn (26, 42, 43), which was seen in the number of push-ups performed in one minute. The above results do make it clear that the high altitude training camp did not decrease sit up ability.

Push-ups increased, despite no upper body off snow conditioning between the baseline and the end of camp time points (two weeks). Unlike sit-up, the starting push-up scores where 20.2±8.9, indicating that there was a large range for possible improvement (10-30 more pushups) (27). Douris et al. (14) showed

the greatest balance deficit to be after a fatiguing aerobic upper body trial as compared to a lower body aerobic or anaerobic fatiguing trial. Considering the high force levels generated by a carved ski turn (1-2.5G) (35), the importance of upper body strength endurance to maintain balance and improvements seen in this study from one week of preseason on-snow training, provides preliminary evidence for the importance of upper body fitness among elite youth alpine ski racers.

Changes in MSFT (table 4) were similar to those reported in a review for elite winter sport athletes, which found a 7.7% decrease for every 1000 m of altitude, based on data from eleven studies on unacclimatized men with a mean VO_{2max} of greater than 60 $ml \cdot kg^{-1} \cdot min^{-1}$ (10). Although this regression is based on fit men, using this linear relationship the calculated decrement in aerobic capacity at the altitude encountered during our study is 21.75%, which was nearly identical to the observed 20.34% decrease in performance seen in this study with mix gender youth athletes. Similarly, Son et al. (53) investigated the effects of moderate altitude exposure (lodging at 2100 m and 2700 m for on snow training) in adolescent youth alpine skiers found an immediate increase of RBC concentration of 6% and a 13% increase after five weeks, but no change in anaerobic cycling power in pre-post Wingate tests. Thus during a high altitude youth athlete sport camp, aerobic capabilities will substantially diminish, but anaerobic supported activities should not be affected in youth.

In conclusion, youth athletes traveling to high altitude for athletic camps should expect improvements in balance, reaction time, quickness, strength endurance, and flexibility three to six days into acclimatization and training, despite having signs and symptoms of mild acute mountain sickness.

Practical Applications: Attendance to youth high altitude sport camps is a relatively safe and effective method of improving skills related to sport performance. Coaches and athletes should expect at least 20% of youth lowlander athletes to have signs and symptoms of AMS during the first three days of altitude exposure for alpine lift access sports at altitudes < 3800 m.

Training volumes should increase gradually during the first three days and overnight lodging should be below 3000 m, to help reduce the prevalence of acute mountain sickness in youth athletes, and all athletes should be monitored daily for altitude illness.

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Appendix

HUMAN PERFORMANCE LABORATORY MEDICAL HISTORY QUESTIONNAIRE

Study ***Balance and performance changes caused by altitude in youth lowlanders during an athletic camp.***

Parent / Legal Gardian's Name ______________________

Child's Name ______________________ Sex ______ Age ______ DOB ______

Street ______________________

City ______________________ State ______ Zip ______ Phone ______

Email ______________________

PLEASE ANSWER ALL OF THE FOLLOWING QUESTIONS AND PROVIDE DETAILS FOR ALL "YES" ANSWERS IN THE SPACES AT THE BOTTOM OF THE FORM.

YES	NO	
☐	☐	1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
☐	☐	2. Has your doctor ever denied or restricted your participation in sports or exercise for any reason?
☐	☐	3. Do you ever feel discomfort, pressure, or pain in your chest when you do physical activity?
☐	☐	4. In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	5. Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	6. Does your heart race or skip beats during exercise?
☐	☐	7. Has a doctor ever ordered a test for you heart? (i.e. EKG, echocardiogram)
☐	☐	8. Has anyone in your family died for no apparent reason or died from heart problems or sudden death before the age of 50?
☐	☐	9. Have you ever had to spend the night in a hospital?
☐	☐	10. Have you ever had surgery?

11. Please check the box next to any of the following illnesses with which you have ever been diagnosed or for which you have been treated.

☐ High blood pressure	☐ Elevated cholesterol	☐ Diabetes
☐ Asthma	☐ Epilepsy (seizures)	☐ Kidney problems
☐ Bladder Problems	☐ Anemia	☐ Heart problems
☐ Coronary artery disease	☐ Lung problems	☐ Chronic headaches

YES	NO	
☐	☐	12. Have you ever gotten sick because of exercising in the heat? (i.e. cramps, heat exhaustion, heat stroke)
☐	☐	13. Have you had any other significant illnesses not listed above?
☐	☐	14. Do you currently have any illness?
☐	☐	15. Do you know of any other reason why you should not do physical activity?

16. Please list all medications you are currently taking. Make sure to include over-the-counter medications and birth control pills.

Drugs/Supplements/Vitamins	Dose	Frequency (i.e. daily, 2x/day, etc.)

DETAILS:

____

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17. Please list all allergies you have.

Substance	Reaction

18. Have you smoked?

			If yes, #/day	Age Started	If you've quit, what age?
☐	☐	Cigarettes			
☐	☐	Cigars			
☐	☐	Pipes			

			If yes, how much?	How often?
☐	☐	19. Do you drink alcoholic beverages?		

20. Do you have a family history of any of the following problems? If yes, note who in the space provided.

- [ ] High blood pressure ____________
- [ ] High cholesterol ____________
- [ ] Diabetes ____________
- [ ] Heart disease ____________
- [ ] Kidney disease ____________
- [ ] Thyroid disease ____________

21. Please check the box next to any of the following body parts you have injured in the past and provide details.

- [ ] Head ____________
- [ ] Neck ____________
- [ ] Upper back ____________
- [ ] Lower back ____________
- [ ] Chest ____________
- [ ] Hip ____________
- [ ] Thigh ____________
- [ ] Knee ____________
- [ ] Ankle ____________
- [ ] Foot ____________
- [ ] Calf/shin ____________
- [ ] Shoulder ____________
- [ ] Upper arm ____________
- [ ] Elbow ____________
- [ ] Hand/fingers ____________

[ ] [ ] 22. Have you ever had a stress fracture?

[ ] [ ] 23. Have you ever had a disc injury in your back?

[ ] [ ] 24. Has a doctor ever restricted your exercise because of an injury?

[ ] [ ] 25. Do you currently have any injuries that are bothering you?

26. Do you consider your occupation as?

- [ ] Sedentary (no exercise)
- [ ] Inactive-occasional light activity (walking)
- [ ] Active-regular light activity and/or occasional vigorous activity (heavy lifting, running, etc.)
- [ ] Heavy Work-regular vigorous activity

27. List your regular physical activities

Activity	How often do you do it?	How long do you do it?	How long ago did you start?

ADDITIONAL DETAILS:

____

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Parental Permission Form for Participation in a Research Study

University of Connecticut

Student Investigator: Jay Hydren, BS, CSCS, CPT
Principal Investigator: William Kraemer, PhD, CSCS*D
Study Title: Balance and performance changes caused by altitude in youth lowlanders during an athletic camp.

Introduction

Your child is invited to participate in a research study to investigate changes in balance and performance due to acute altitude exposure while participating in a youth sport camp. Your child is being asked to participate because he/she is a ski racer on a ski team that is attending a sport camp at altitude and he/she is between the ages of 10-17.

This permission form will give you the information you will need to understand why this study is being done and why your child is being invited to participate. It will also describe what your child will be asked to do to participate and any known risks, inconveniences or discomforts that your child may have while participating. We encourage you to ask questions now and at any time. If you decide to participate, you will be asked to sign this form, your child will be asked to sign the form and it will be a record of your permission to allow your child to participate. You will be given a copy of this form.

Why is this study being done?

The purpose of this study is to investigate the effects of acute altitude exposure on balance and athletic performance, in youth lowlanders, at an athletic training camp.

Currently, thousands of adolescence travel to altitude to participate in recreational activities throughout the year. Youth athletes exhibit similar rates of Acute Mountain Sickness (AMS) as adults in Summit County Colorado of about 20%. AMS is not a medical condition that requires medical attention; typical treatment is going down in altitude (300 meters or about 1000 ft), such as a base camp that is below 9,800 ft. AMS is common among travelers from sea level to high altitude; with a few experiencing it bellow 7,874 ft, common above 9,842 ft and nearly all above 14,108 ft.

Acute altitude exposure has shown to cause a decrease in balance. Several studies have associated AMS with decreases in the ability to balance. In addition, several studies have also shown that hydration levels are not associated with AMS but they have been shown to change athletic performance.

The fluid shifts with in the bodies compartments that occur when individuals first arrive at altitude are currently thought to be the cause of AMS and decreases in balance ability. Because balance is fundamental to motor control and skilled tasks in sport, any decrement in balance will hinder sport performance, quality of training, and could increase risks associated with the sport. With the large number of youth lowlanders traveling to altitude for competitive and recreational reasons and the novelty of this study population, youth and athletic, this study will help further the understanding of acute altitude exposure.

What are the study procedures? What will my child be asked to do?

Prior to participation you and your child will be asked to fill out a medical history form. This will screen for possible medical complications that can be exacerbated by exercise and exposure to high altitude. These forms will be reviewed by the study's medical monitor. If your child is cleared for participation in this study the you will be notified as such and the study will progress as described below. Should the medical monitor deemed that your child is at greater than minimal risk for the specific physical requirements of this study the subject and parent/legal guardian will be notified that the child is ineligible to participate in the study or a specific part of this study.

If your child chooses to participate and you give permission for your child to take part in this study, he/she will be asked to complete a test session lasting approximately 45-90 minutes on a specified day as well as two other short visits before the start of the camp. In addition, at the camp your child will be asked to participate twice a day for 5-10 minutes to fill out a short questionnaire, provide a urine sample, be weighed and complete a balance test and vertical jump test. At the end of the camp, after all training is completed, your child will also be asked to perform a set of performance test that will take 45-90 minutes.

Before the first test session, you and your child will complete a brief questionnaire about what sports your child plays currently and has played in the past. This questionnaire will also include questions regarding your child's physical development. We will ask you to have you or your child answer questions to best identify your child's developmental stage. These questions are available for you to look at prior to the study. These answers are critical, so that we can better understand how biological age effects tolerance of altitude exposure. Your child will be instructed to bring this questionnaire to the first test session in a sealed envelope with his/her ID written on the envelope.

First Visit (New Hampshire)

When your child arrives for the first test session, he/she will listen to instructions about what will happen during the study to ensure he/she still wants to participate and has indicated this on this permission form. You are welcome to stay with your child and watch him/her perform any of the tasks. It is important that you do not coach or try to instruct your child. He/she will be asked to answer 6 short questions for acute mountain sickness. Then he/she will be asked to provide a urine sample, and have his/her height, seated height and weight measured and recorded. Your child will perform a balance test, reaction test, and vertical jump tests. He/she will perform a standardized warm-up consisting of jogging and performing any stretches that he/she wishes. After the warm up your child will perform a slightly different vertical jump tests, agility test, flexibility test, strength endurance test, and a maximum aerobic test during the session. Your child will receive instruction and see a demonstration of each of the tests followed by as many practice trials as your child would like, in order to feel comfortable with the tests and perform them correctly.

Second and Third Visits (New Hampshire)

During the second and third visits your child will be ask to provide a urine sample and have his/her body weight measured. These second two visits are important so that a standard hydration level can be measured.

Camp (Colorado)

During the camp, in Colorado, your child will be asked to fill out a short questionnaire. In addition, your child will perform the balance test and a vertical jump test, as well as provide a

urine sample and have his/her bodyweight measured. These short sessions, designed to not affect any activities at the camp will occur in the morning before physical activity and in the afternoon after a rest period. In addition if you child shows signs of dehydration they will be encourage to drink fluids to return to a normal hydration level but not so much to cause over hydration.

On the last day of the camp your child will be asked to repeat the performance tests done during the first visit. This testing session will be a few hours after any physical activity scheduled by the camp. Your child will perform a balance test, vertical jump test, agility test, flexibility test, strength endurance test, and an aerobic test during the session.

Questionnaires

Acute Mountain Sickness Questionnaire

The Lake Louise Scoring System for Acute Mountain Sickness is a series of 6 questions that your child will be asked both during the initial testing before the camp and during the camp. These questions will be used to measure signs and symptoms of acute mountain sickness by asking your child to rate his/her headache, gastrointestinal distress, fatigue/weakness, dizziness/lightheadedness, sleep, and overall effects on activities. In addition the student investigator will evaluate your child on three questions. These include 1) changes in mental status, 2) ataxia, where your child will walk heal-toe, and 3) an evaluation for peripheral edema.

Hydration Monitoring

Urine Analysis

Your child will be asked to provide a urine sample during the base line testing and the morning and afternoon during the camp. He or she will have access to a private bathroom or private area of a bathroom, such as a stall, when asked to provide a urine sample. This will only be used to assess the hydration of your child.

Body weight

At the same time as the urine sample is requested a body weight measurement will also be taken to assess hydration changes of your child. He/she will be asked to wear a t-shirt, shorts and socks.

Performance Tests

Your child will perform seven performance tests: Y-Balance, Vertical Jump, T-test, Sit & Reach, Pushup, Sit-up and the Multistage Fitness Test. Your child will receive instructions, view a demonstration of each test, and be able to practice each test until he/she feels comfortable with the tests.

Balance Test (3 repetitions of test)

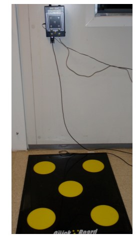
This test requires your child to balance on their dominant leg while reaching out their other leg in three directions, which will be indicated by tape on the ground. Your child will start with both feet in the center of the star and they must keep his/her hands on their hips. The goal is for them to reach his/her non-dominant foot as far as they can for each trial. The three directions include: in front, behind to the right, and behind to the left.

Your child will be asked to do this balance test in the morning and afternoon during the camp.

Reaction Test (1-3 repetitions of test)

Your Childs eye and foot coordination and reaction time will be assessed using the Quickboard™. This includes a set of 5 LED lights on a small plate placed in front of the your child that correspond with five yellow touch pads on board that the he/she stands on. The LED

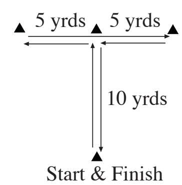
lights and touch sensors are in the formation similar to that seen on the side of a dice with five dots on it. The Quickboard™ randomly selects an LED to show and the subject uses their foot to touch the corresponding touch sensors on the Quickboard™ pad. The reaction time for each sensor and total successful and incorrect touches for a 10-20 second period is recorded and used for analysis.



Maximum vertical jump test (3 repetitions of test)
Your child will begin the maximum vertical jump test with their feet shoulder width apart on a mat. He/she will be instructed to jump for maximal vertical height. There are two variations of this test, one with hands that will remain on the hips, and one where arms will be allowed to move freely.

Your child will be asked to perform the former of the two in the morning and afternoon during the camp. The latter will be used during the performance test at baseline and at the end of the camp.

Agility Test (3 repetitions of test)
Your child will begin this test in a standing position and run out 10 yards touch the middle of three cones then laterally shuffle to a cone to one side. Then change direction and laterally shuffle 10 yards past the middle cone and trough the third cone. Finally he/she will change direction and shuffle laterally back to the middle cone, touch it, and then back pedal to the start/finish line.



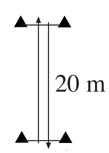
Flexibility Test (3 repetitions of test)
Your child will remove his/her shoes and sit with legs extended with their feet against a box. He/she will reach out bending at the waist and reach their arms as far down towards or passed their legs as possible.

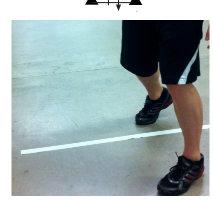
Strength Endurance Tests

Push ups (1 repetition of test)
He/she will complete as many as possible in one minute. He/she will perform a standard push up by holding their body off the ground holding a straight line from their feet to their shoulders. If your child is unable to successfully complete a standard pushup he/she will be permitted to attempt the test using the modified version. He/she will hold their body off the ground and maintain a straight line from their knees to the shoulders, with just the hands and knees on the ground.

Sit ups (1 repetition of test)
Your child will begin lying with their back on the ground, with their feet held feet and spaced so that their knees are at 90º. On "Go" your child will perform as many sit ups in one minute as possible by pulling their body up off the ground and touching their elbows to their knees.

Endurance Test (1 repetition of test)
Your child will perform this test by jogging then running between two cones 20 meters (22 yrds) apart. He/she will jog or run at a pace so they can touch their foot to the cone or line just before a beep is herd through a speaker system. As your child progresses through the test, the time between each beep decreases with each stage but not with in each stage. He/she will perform for as long as possible until they can no longer make it to the cone or line before a beep is sounded. Because this test is exhausting your child will be verbally





encouraged to keep moving slowly after the test as a cool down.

Coaches Survey

In addition, the coaches on the trip will be asked several questions about your child's participation in the sporting activities. These questions are independent of any coaching that your child will receive and will in no way effect participation in the sport or camp activities. Data collected in this survey will only be available to the investigators analyzing the data, in addition this data will be stored in a secure location with a coding system.

What are the risks or inconveniences of the study?

Your child will be unable to participate in the study if your physician and family choose to use dexamethasone or acetazolamide to offset the effects of acute altitude exposure. If you believe that your child is taking one of these drugs please decline participation.

There will be no additional risk placed on your child other than those already being assumed by you and your child when attending the preseason alpine ski camp and traveling to altitude. The additional risks of physical activities, Y-balance test, reaction test and single vertical jump test, are minimal and will contribute very little if any risk to the development of altitude sickness, (i.e. headaches, nausea, fatigue/weakness). A trained investigator will provide proper instruction, an opportunity for your child to become familiar with the test, and the use of a location that is free from hazards to minimize any risk of falling during these tests.

As it is anticipated that about 20% of the children participating in the study will show signs of acute altitude sickness (AMS) during the study, the order in which the physical test have been designed such that additional discomfort or risk will not effect day to day camp activities. Balance, reaction, and single jump tests are not anticipated to exacerbate any altitude sickness. In addition, there is some evidence to show that balance tests can be used a diagnostic tool for assessing levels of altitude sickness.

Because only exercise that involves extensive cardiovascular stress may increase symptoms of altitude sickness, all physically fatiguing tests are during baseline testing where there is no risk of altitude sickness and during the last day of the camp after all camp activities are over, where there is a low chance for altitude sickness. Most AMS usually resolves within the first 4 days at altitude and thus is not expected to be present during the last day (7^{th} day) of the camp. However, should your child still have significant symptoms of AMS they will not be asked to participate in the physically exhausting tests at the end of the camp.

The performance tests during baseline and at the end of the camp testing may introduce risks associated with vigorous activity and muscle soreness the next day. This will not be more than typical demanding workouts that your child participate in during preseason conditioning, and will be minimized because of his/her elevated fitness level from participating in sports.

In addition, there may be uncommon or previously unknown risks that might occur. You or your child should report any problems to the researchers.

The student investigator collecting this data is a Certified Strength and Conditioning Specialist through the National Strength and Conditioning Association and maintains both CPR and First

Aid and is trained to minimize risks. In particular, if any task is too challenging for your child, they will discontinue with that test and progress to the next task. The researcher will monitor testing procedures as well as provide verbal instructions to ensure that your child understands all testing procedures.

What are the benefits of the study?

Your child might not benefit directly from the study but will receive information and interpretation about their scores on the performance tests. In addition, the hydration monitoring and education of hydration in high altitude situations may improve your child's experience during the training camp. He/she will most likely benefit from the hydration feedback because past research has shown that young athletes at sport camps tend to stay chronically dehydrated. He/she may receive verbal instruction on technique of tests and thus may receive a benefit by improving their movement technique. Finally, there are potential benefits to society, as there have been few investigations into the understanding of the effects of acute altitude exposure on performance and health in youth. Understanding how acute altitude exposure effects changes in performance variables will help coaches to better design practices and camps to make them more effective for youth athletes.

Will my child receive payment for participation? Are there costs to participate?

There are no costs to you and your child for participating in this study other than time.

How will my child's information be protected?

The following procedures will be used to protect the confidentiality of the data collected from your child:

Your child will be assigned a random identification number that will be used on all data; this will be a numeric number that is unrelated to your child (i.e. name or birthday). A master key that links names and identification numbers will be maintained in a separate and secure location. The master key will be destroyed after 3 years.

The researcher will keep all study records (including any codes to your child's data) locked in a secure location (locked within his private bed room during the camp) and will remain in the student investigator's possession for transit back to the University of Connecticut.

All electronic files (e.g., database, spreadsheet, etc.) containing identifiable information will be password protected. Only the members of the research staff will have access to the passwords. Data that will be shared with others will be coded as described above to help protect your child's identity. At the conclusion of this study, the researchers may publish their findings. Information will be presented in summary format and your child will not be identified in any publications or presentations.

You should also know that the UConn Institutional Review Board (IRB) and the Office of Research Compliance may inspect study records as part of its auditing program, but these reviews will only focus on the researchers and not on your child's responses or involvement. The IRB is a group of people who review research studies to protect the rights and welfare of research participants.

Will there be pictures or images of my child taken during the study?

Because it is sometimes beneficial for participant's picture (i.e. the performance of the Y-balance test) to be presented at a research conference, you will be given a chance below to provide or deny permission to do so. Pictures will be taken during the study for use in scientific communication of the study findings but will not be used as part of the data analysis for this study.

What happens if my child is injured or sick because he/she took part in the study?

In the event your child becomes sick or injured during the course of the research study, you will be immediately notify as well as the principal investigator. If your child requires medical care for such sickness or injury, it will be provided using the already existing protocols of the camp. Your child's care will be billed to you or to your insurance company in the same manner as your child's other medical needs are addressed.

However, if you believe that your child's illness or injury directly resulted from the research procedures of this study, you may be eligible to file a claim on behalf of your child with the State of Connecticut Office of Claims Commissioner. For a description of this process, contact the Office of Research Compliance at the University of Connecticut at 860-486-8802.

Can my child stop being in the study and what are my and my child's rights?

Your child does not have to be in this study if you do not want him/her to participate. If you give permission for your child to be in the study, but later change your mind, you may withdraw your child at any time. Your child may also choose to withdraw himself/herself from the study at any time. There are no penalties or consequences of any kind if your child withdraws from the study or chooses not to participate. Your child may also choose to not participate in one part of the study but continue participating in other aspects of the study. Prior to each new round of measurements the investigator will ask for verbal assent from your child.

Should a situation arise that your child is not able to participate in one of the data collection sessions, this could lead to your child to be dropped from the study. In order to participate in this study your child is required to participate in at least the baseline testing and three testing sessions while in Colorado.

Who do I contact if I have questions about the study?

Take as long as you like before you make a decision. We will be happy to answer any questions you have about this study. If you have further questions about this study or if you have a research-related problem, you may contact the principal investigator, William Kraemer at 860-486-6892 or the student investigator, Jay Hydren at 508-954-9153. If you have any questions concerning your child's rights as a research participant, you may contact the University of Connecticut Institutional Review Board (IRB) at 860-486-8802.

Parental Permission Form for Participation in a Research Study

Principal Investigator: William Kraemer, PhD, CSCS*D
Student: Jay Hydren, BS, CSCS, CPT
Title of Study: Balance and performance changes caused by altitude in youth lowlanders during an athletic camp.

Documentation of Permission:

I have read this form and decided that I will give permission for my child to participate in the study described above. Its general purposes, the particulars of my child's involvement and possible risks and inconveniences have been explained to my satisfaction. I understand that I can withdraw my child at any time. My signature also indicates that I have received a copy of this parental permission form. Please return this form to the child's coach.

____________________	____________________	__________
Child Signature:	Print Name:	Date:
____________________	____________________	__________
Parent/Guardian Signature:	Print Name:	Date:

Relationship to Child (e.g. mother, father, guardian): ______________________________

____________________	____________________	__________
Signature of Person Obtaining Consent	Print Name:	Date:

Permission to show photos images at research conferences:

It is sometimes beneficial for a participant's picture to be presented at a research conference. I give permission for my child's picture to be taken during study activities and be shown during a research presentation and I understand that he/she will not be identified by name. I understand that my child can still participate in the research study if I do not sign below but that his/her picture will not be shown during any presentation.

____________________	____________________	__________
Child Signature:	Print Name:	Date:
____________________	____________________	__________
Parent/Guardian Signature:	Print Name:	Date:

Coach's Permission Form for Participation in a Research Study

University of Connecticut

Student Investigator: Jay Hydren, BS, CSCS, CPT
Principal Investigator: William Kraemer, PhD, CSCS*D
Study Title: Balance and performance changes caused by altitude in youth lowlanders during an athletic camp.

Introduction

You are invited to participate in this survey of performance changes in youth lowlanders during athletic camps at altitude. I am a graduate student at the University of Connecticut, and I am conducting this survey as part of my course work. I am interested in finding out the effects of acute altitude exposure on balance and athletic performance, in youth lowlanders, at an athletic training camp.

This permission form will give you the information you will need to understand why this study is being done and why you are being invited to participate. It will also describe what you will be asked to do to participate and inconveniences that you may have while participating. We encourage you to ask questions now and at any time. If you decide to participate, you will be asked to sign this form and it will be a record of your permission to participate. You will be given a copy of this form.

Why is this study being done?

The purpose of this study is to investigate the effects of acute altitude exposure on balance and athletic performance, in youth lowlanders, at an athletic training camp.

Currently, thousands of adolescence travel to altitude to participate in recreational activities throughout the year. Youth athletes exhibit similar rates of Acute Mountain Sickness (AMS) as adults in Summit County Colorado of about 20%. AMS is not a medical condition that requires medical attention; typical treatment is going down in altitude (300 meters or about 1000 ft), such as a base camp that is below 9,800 ft. AMS is common among travelers from sea level to high altitude; with a few experiencing it bellow 7,874 ft, common above 9,842 ft and nearly all above 14,108 ft.

Acute altitude exposure has shown to cause a decrease in balance ability. Several studies have associated AMS with decreases in the ability to balance. In addition several studies have also shown that hydration levels are not associated with AMS but they have been shown to change athletic performance.

The fluid shifts with in the bodies compartments that occur when individuals first arrive at altitude are currently thought to be the cause of AMS and decreases in balance ability. Because balance is fundamental to motor control and skilled tasks in sport, any decrement in balance will hinder sport performance, quality of training, and could increase risks associated with the sport. With the large number of youth lowlanders traveling to altitude for competitive and recreational reasons and the novelty of this study population, youth and athletic, this study will help further the understanding of acute altitude exposure.

What are the study procedures? What will you be asked to do?

Your participation in this study will require completion of the attached questionnaire. This should take approximately 10 minutes of your time per day for 8 days, one day during dry-land training, which will act as a baseline and 7 days at altitude. You will be asked to evaluate 8-15 athletes per day but it could be as high as 20.

You will be asked to fill out four questions including an optional comments section to report anything that you think would be important to the child's willingness to participate in the camps activities. These questions include a rating of 1-5 Likert scale of the child's quality of training, this is your overall perception about how well the child was prepared and ready to participate in that day's training, as well as an overall assessment about the quantity and physical energy the child displayed while participating in the camp activities.

You will also be asked to rate the child's mood on a 1-5 Likert scale, this is simply your perception on how focused, attitude, and attentiveness the child displayed while participating in activities to help improve their skiing.

The third question is a simple numeric value for the number of runs (one run equals one full descent of the training high and low altitudes on that days data sheet) for each child.

The fourth question you will be asked is from the Lake Louise Acute Mountain Sickness Questionnaire where a chaperon is asked to evaluate changes in mental status. This question is presented verbatim from the questionnaire and is intended to be used to help assess if a child is displaying sign or symptoms of acute mountain sickness.

Lastly there is a comments section where you can provide information that you feel might be important about a child's participation. For instance you may note that because of foot pain from new ski boots the child decided to take 3 less runs than he or she may normally have taken or the child reported a severe headache they decided to cut the day short.

What are the risks or inconveniences of the study?

Your participation will be anonymous and you will not be contacted again in the future. You will not be paid for being in this study. This survey does not involve any risk to you. However, the benefits of your participation may impact society by helping increase knowledge about sport performance during acute altitude exposure.

What are the benefits of the study?

You may not benefit directly from the study. But there are potential benefits to society, as there have been few investigations into the understanding of the effects of acute altitude exposure on performance and health in youth. Understanding how acute altitude exposure effects changes in performance variables will help coaches to better design practices and camps to make them more effective for youth athletes.

Will I receive payment for participation? Are there costs to participate?

You will not receive payment for participating. There are no costs to you for your participation in this study other than time.

How will my information be protected?

The following procedures will be used to protect the confidentiality of the data collected:

Each coach will be assigned a random identification number that will be used on all data; this will be a numeric number that is unrelated to you (i.e. name or birthday). A master key that links names and identification numbers will be maintained in a separate and secure location. The master key will be destroyed after 3 years.

The researcher will keep all study records (including any codes to your data) locked in a secure location (locked within his private bed room during the camp) and will remain in the student investigator's possession for transit back to the University of Connecticut.

All electronic files (e.g., database, spreadsheet, etc.) containing identifiable information will be password protected. Only the members of the research staff will have access to the passwords. Data that will be shared with others will be coded as described above to help protect your identity. At the conclusion of this study, the researchers may publish their findings. Information will be presented in summary format and you will not be identified in any publications or presentations.

You should also know that the UConn Institutional Review Board (IRB) and the Office of Research Compliance may inspect study records as part of its auditing program, but these reviews will only focus on the researchers and not on your responses or involvement. The IRB is a group of people who review research studies to protect the rights and welfare of research participants.

Can I stop being in the study and what are my rights?

You do not have to be in this study if you do not want to participate. If you give permission to be in the study, but later change your mind, you may withdraw at any time. You may also choose to withdraw from the study at any time. There are no penalties or consequences of any kind if you withdraw from the study or choose not to participate. You may also choose to not participate in one part of the study but continue participating in other aspects of the study. There are no minimum participation requirements for this study. Prior to each new round of measurements the investigator will ask for verbal assent to participate in the study.

Should a situation arise that you are not able to participate in one of the data collection sessions, this could lead to you being dropped from the study.

Who do I contact if I have questions about the study?

Take as long as you like before you make a decision. We will be happy to answer any questions you have about this study. If you have further questions about this study or if you have a research-related problem, you may contact the principal investigator, William Kraemer at 860-486-6892 or the student investigator, Jay Hydren at 508-954-9153. If you have any questions concerning your rights as a research participant, you may contact the University of Connecticut Institutional Review Board (IRB) at 860-486-8802.

Parental Permission Form for Participation in a Research Study

Principal Investigator: William Kraemer, PhD, CSCS*D
Student: Jay Hydren, BS, CSCS, CPT
Title of Study: Balance and performance changes caused by altitude in youth lowlanders during an athletic camp.

Documentation of Permission:

I have read this form and decided that I will give permission to participate in the study described above. Its general purposes, the particulars of my involvement and possible risks and inconveniences have been explained to my satisfaction. I understand that I can withdraw at any time. My signature also indicates that I have received a copy of this permission form. Please return this form to the student investigator.

______________________	______________________	___________
Participant's Signature:	Print Name:	Date:
______________________	______________________	___________
Signature of Person Obtaining Consent	Print Name:	Date:

Subject: _________________ Date: ___________________

Base Line Questionnaire

Please answer the following questions to the best of your ability regarding your child.

1. What is your child's date of birth? ____/____/______

2. What is your child's gender? (Please circle) M F

3. Do you feel your child has experienced a major growth spurt in the past year? Yes / No

   a. If yes, approximately how many inches do you think he/she has grown in the past year?

4. If known, how tall is your child's biological mother? ___________________

5. If known, how tall is your child's biological father? _____________________

6. Please complete the table below to list the sports your child has participated in at any time in their life and how long your child participated in them.

Sport	**Start date (approximate)**	**End date (approximate) or state "present" if applicable**

Subject: ________________ Date: __________________

Pubertal Maturation Observational Scale

Please mark an "X" next to any statement in the appropriate checklist (Female or Male) that you agree with regarding your child.

Female Characteristic Checklist

Agree?	**Characteristic**
	The adolescent has grown 3 to 3.5 inches in the past 6 months or is past this growth spurt.
	The adolescent has begun breast development.
	The adolescent has begun menarche.
	The adolescent has evidence of darker underarm hair or shaves.
	The adolescent has evidence of darker hair on her legs or shaves.
	The adolescent's calves are becoming defined.
	The adolescent has evidence of acne.
	There was evidence of sweating after physical activities.

Male Characteristic Checklist

Agree?	**Characteristic**
	The adolescent has evidence of darkening of facial hair or shaves.
	The adolescent's voice has gotten deeper or is currently breaking.
	The adolescent has grown 3 to 4 inches in the past 6 months or is past the growth spurt.
	The adolescent's biceps are becoming defined.
	The adolescent's calves are becoming defined.
	The adolescent has evidence of acne.
	There was evidence of sweating after physical activities.
	There is darkened underarm hair.

AMS Questionnaire

Symptom	Score	Description
Head Ache	0	None
	1	Mild
__________	2	Moderate
	3	Incapacitating
Gastrointestinal	0	Good Appetite
	1	Poor Appetite or Nausea
__________	2	Nausea and Vomiting
	3	Incapacitating
Fatigue / Weakness	0	None
	1	Mild
__________	2	Moderate
	3	Incapacitating
Dizziness / Lightheadedness	0	None
	1	Mild
	2	Moderate
__________	3	Incapacitating
Sleep	0	Sleep Well
	1	Sleep not as well as usual
__________	2	Poor Sleep
	3	No Sleep
Overall effect on activities	0	None
	1	Mild Reduction
	2	Moderate Reduction
__________	3	Severe Reduction
For Investigators only		
Change in Mental Status	0	None
	1	Lethargy
	2	Disorientation / Confusion
__________	3	Stupor
	4	Coma
Ataxia (heel-toe walking)	0	None
	1	Difficult Balancing
	2	Steps off line
__________	3	Falls down
	4	Unable to Stand
Peripheral edema	0	None
	1	One Location
__________	2	More than one Location
Balance Test Score		
Vertical Jump		

20m Bleep Test Conversion Chart

Level Shuttle to VO2max (mL•kg-1•min-1)

Level	Shuttle	VO2max
4	2	26.8
4	4	27.6
4	6	28.3
4	9	29.5
5	2	30.2
5	4	31.0
5	6	31.8
5	9	32.9
6	2	33.6
6	4	34.3
6	6	35.0
6	8	35.7
6	10	36.4
7	2	37.1
7	4	37.8
7	6	38.5
7	8	39.2
7	10	39.9
8	2	40.5
8	4	41.1
8	5	41.8
8	8	42.4
8	11	43.3
9	2	43.9
9	4	44.5
9	5	45.2
9	8	45.8
9	11	46.8
10	2	47.4
10	4	48.0
10	5	48.7
10	8	49.3
10	11	50.2
11	2	50.8
11	4	51.4
11	5	51.9
11	8	52.5
11	10	53.1
11	12	53.7
12	2	54.3
12	4	54.8
12	5	55.4
12	8	56.0
12	10	56.5
12	12	57.1
13	2	57.6
13	4	58.2
13	5	58.7
13	8	59.3
13	10	59.8
13	13	60.6
14	2	61.1
14	4	61.7
14	5	62.2
14	8	62.7
14	10	63.2
14	13	64.0
15	2	64.6
15	4	65.1
15	5	65.6
15	8	66.2
15	10	66.7
15	13	67.5
16	2	68.0
16	4	68.5
16	5	69.0
16	8	69.5
16	10	69.9
16	12	70.5
16	14	70.9
17	2	71.4
17	4	71.9
17	5	72.4
17	8	72.9
17	10	73.4
17	12	73.9
17	14	74.4
18	2	74.8
18	4	75.3
18	5	75.8
18	8	76.2
18	10	76.7
18	12	77.2
18	15	77.9
19	2	78.3
19	4	78.8
19	5	79.2
19	8	79.7
19	10	80.2
19	12	80.6
19	15	81.3
20	2	81.8
20	4	82.2
20	5	82.6
20	8	83.0
20	10	83.5
20	12	83.9
20	16	84.8

Adapted from: Rams, R, Brewer, J and Williams, C. A Progressive Shuttle Run Test to Estimate Maximal Oxygen Uptake. Brit. J. Sports Med. Vol 22, No. 4. 141-144, 1988.

Coaches Survey

Coach: ______________________ Lodging Altitude: _____________ Temperature: am: ____ pm: ____
Date:_______________________ Training High/Low: ________ / ________ Humidity: _________________
Training Duration: AM:_____ PM _____ Precipitation: _________________

Athlete	Did the athlete have a high quality day of training?	Was the athlete's mood at training happy and positive?	Number of Runs	Change in Mental Status	Comments
	Strongly Agree Strongly Disagree 1 2 3 4 5	Strongly Agree Strongly Disagree 1 2 3 4 5		0 1 2 3 4	
	1 2 3 4 5	1 2 3 4 5		0 1 2 3 4	
	1 2 3 4 5	1 2 3 4 5		0 1 2 3 4	
	1 2 3 4 5	1 2 3 4 5		0 1 2 3 4	
	1 2 3 4 5	1 2 3 4 5		0 1 2 3 4	
	1 2 3 4 5	1 2 3 4 5		0 1 2 3 4	
	1 2 3 4 5	1 2 3 4 5		0 1 2 3 4	
	1 2 3 4 5	1 2 3 4 5		0 1 2 3 4	
	1 2 3 4 5	1 2 3 4 5		0 1 2 3 4	

Strongly Agree	Agree	Neither	Disagree	Strongly Disagree
1	2	3	4	5

One run equal a full decent of the altitude range for training.

0 None
1 Lethargy
2 Disorientation / Confusion
3 Stupor
4 Coma