BIOMECHANIC ASPECTS OF SPORT SPECIFIC TESTING IN ELITE ALPINE SKI RACERS

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The long record of consistent success in all age groups of Austrian alpine ski racers is due to an optimized training environment. One of many factors is physical preparation. The physical preparation program of the Austrian Ski Federation ski racers has for years included tests in which specially designed test devices and computer programs are utilized. The testing series for the Austrian ski team members include the following devices: Biodex balance and coordination tests, Isometric power tester (max. isometric strength tests of knee and hip extension), Back Check (max. isometric core strength tests), MLD (barbell squat jumps and counter movement jumps with varying loads), Kistler force plate (CMJ, special power jump tests & reactive strength), Contrex (concentric/eccentric maximal strength & strength endurance of the hip and knee extensors) & Ski start test (maximal force and impulse of right and left pole-pushes as well as the acceleration). The development of physical preparedness norms for ski racers at all age levels aids in performance prediction, but even of more consequence - assists in injury prevention. Necessary measures can then be undertaken to help the athlete make the gains needed.

KEY WORDS: alpine ski racing, testing, training optimization.

INTRODUCTION: The long record of consistent success in all age groups of Austrian alpine ski racers is due to an optimized training environment. Performance development in elite ski racing has not yet reached its peak. Even though improvements may be miniscule, it can be assumed that performance advancements will continue for a considerable time through developments in equipment, skiing technique and physical preparation. Better ski racing at the international level will be achieved mainly through an improved quality of training and not through an increased quantity of training.

Training quality can reach a high level only when exact knowledge of the kinematic, dynamic and electromyographic characteristics of modern racing techniques employed by elite racers is elicited biomechanical field research. The following training process should be systematically planned with training methods specifically tailored to the training goal. Tests which fully cover the sport specific parameters must control the training system so that test results can be classified to determine current individual performance and evaluate individual performance progress (Müller, 2001). Current literature of sport specific testing in ski racing is rare. Jump tests have been used to determine power in alpine skiers (Bosco, 1997; Bacharach, 2003).

METHOD: It is essential that racers are exposed to physical testing at an early age and at regular intervals. This has been done with Austrian ski racers. For example since 1996 all students at the Skigymnasiums Stams are tested three times annually through the use of innovative equipment and computer technology (e.g. max. isom. strength tests of knee-hip extension and core, jump tests, special power tests, reactive strength, jump coordination, strength endurance, and aerobic/anaerobic endurance). The positive reaction of ski coaches to this testing program has initiated its inclusion in various state ski federation programs for up and coming ski racers in the 12-14 age group.

In 2000, a cooperative project with the Austrian Ski Federation was initiated to develop a battery of physical tests for ski clubs, specially designed for 10-14 year old children. One aim of the project was that ski club coaches could administer the tests themselves.

High performance ski racing has changed in the last years due to recent equipment developments .These changes have affected the athletic demands placed upon ski racers. The physical preparation program of the Austrian Ski Federation ski racers has for years included tests in which specially designed test devices and computer programs are utilized. The tests are administered 2-3 times a year in the laboratories of the Institute of Sport Science, University of Innsbruck. The following tests were done with the different Austrian Ski Federation teams after a standardized warm up procedure. The endurance test (VO2max test) is carried out in the Innsbruck University Hospital.

RESULTS:

Biodex Stability System: This system allows quantification of neuromuscular proprioceptive performance under static and dynamic conditions. A monitor displays a cursor within crosshairs which moves when the platform is taken out of its level position. The objective is to keep the cursor in the middle of the crosshairs with as little movement as possible. With two integrated potentiometers a 3 dimensional measurement is possible. The athlete holds ski poles during the test. The test is performed at level 2 (8 is the easiest level, 1 the hardest) and is 30 seconds in length. Each leg has two trials, separated by a 1 minute rest interval, and the best (lowest) stability index is recorded. A stability index is calculated corresponding to the quantity of movement of the platform during the test. Anterior/posterior as well as medial/lateral indexes are computed also. For dynamic testing the subject independently positions herself/himself with both feet. The objective is to move the cursor into 9 blinking boxes as fast as possible through tilting and moving the platform with the feet. Once all boxes are reached, the test is over. This test is also performed with ski poles.

Isometric power tester: The isometric power tester (IPT) was developed to test isometric leg extension unilaterally. A footplate which slides laterally is connected to a high precision force transducer (Z7 load cell from HBM Inc.) and a Spider 8 integrated digital measurement system also from HBM Inc. The seat and footplate are adjustable so that the distance to the footplate and foot plate angle will allow the desired ankle, knee and hip angles. The tests are performed at 3 knee angles - 85°, 100° and 120°. The athletes perform 3 maximal isometric contractions against the footplate with a 10 second pause between. The highest value for each angle is recorded. For training prescription the absolute as well as the relative strength of the athletes is of interest.

Back Check: Maximal isometric strength of trunk flexors and extensors are measured. The subject is in an upright standing position, with knees slightly flexed and pelvis fixated. Pads are set at sternum level both anteriorally and posteriorly. They are connected to force transducers and an integrated digital measurement system. The subject flexes isometrically against the chest/back pad to measure trunk flexion/extension strength. Absolute strength values at the pads are recorded and the force moment is also calculated using the lever arm distance of sternum level to pelvis fixation.

Muscle power diagnosis (MLD): The two one dimensial force platforms enable many power parameters to be measured, and also enable forces produced by the right and left leg in a two-legged jump to be compared and analyzed. Squat jumps (SJ) and counter movement jumps (CMJ) with 0%, 25%, 50%, 75%, 100%, and 125% (125% males only) of bodyweight (BW) are performed with a barbell on the shoulders. The SJ is performed at a knee angle of 90°. When the bar was at the height where 90° knee angle is reached, a light beam is broken and a tone signal sounds. Through the measurement of the amplitude of the ground reaction force, the parameters average relative power (Prel), average power in the first 100ms of the jump (P01), average power in the first 200ms of the jump (P02), jump height, maximum force right leg (FmaxR), and maximum force left leg (FmaxL), are calculated. Post test calculations are made to determine Fmax differences between the stronger and weaker legs (Fmaxdiff) and percentage of the height of the best jump for each SJ (%Jump).

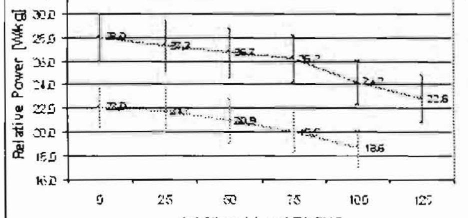

Figure 1: Relative power during barbell squat jumps with varied loads.

Kistler force platform: The vertical ground reaction forces are measured with a Kistler force platform with a sampling rate of 200Hz. Through the measurement of the amplitude of the ground reaction force, the parameters maximum force, impulse and jump height are calculated. The athletes perform three types of jumps - CMJ, Ski Specific Counter Movement Jump wearing ski jumping boots & Drop jump from a height of 40cm:

Contrex Legpress: Alpine ski racers require high eccentric and concentric force development and have demonstrated high leg strength when compared to other athletes. The Contrex linear leg press is utilized for closed-chain testing of the lower extremities. It can measure both concentric and eccentric forces up to 6kN and speeds up to 0.6 m/s. The dynamometer is a high dynamic disc type servo motor and zero backlash cycloidal speed reduction assembly. A carrier-frequency based torque measurement system allows for accuracy of better than 0.5% for force and 0.01% for position. Measurements are made unilaterally with the right and left legs.

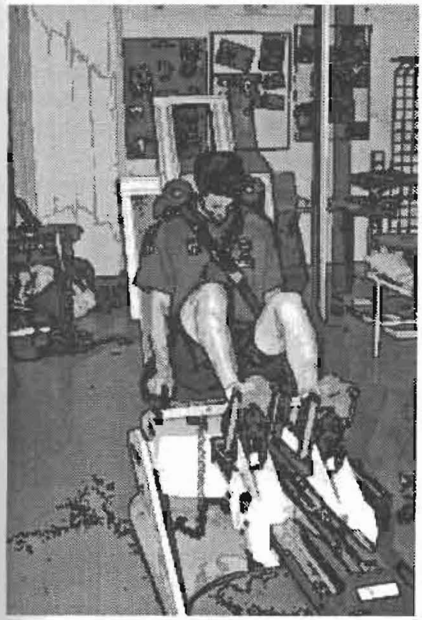

Figure 2: Contrex Legpress.

For the isokinetic maximal strength test the following adjustments are made: The range of motion is set between knee angles from 85° to 120°, with a testing speed of 0.2m/s. Each athlete is given a practice trial with 3 repetitions before the test is administered. Three maximal concentric/eccentric repetitions are performed and the best repetition is used for data analysis. Important parameters are the absolute and relative power and force, as well as the relationships between concentric and eccentric power and force.

For the isokinetic strength endurance test the range of motion is set at the same knee angles as for the maximal strength test. The testing speed, however, is set at 0.2m/s and 0.4m/s for the eccentric and the concentric contractions, respectively. The test consists of 30 maximal concentric/eccentric repetitions. All 30 repetitions are used for data analysis. The main parameters of interest are the mean absolute and relative power (concentric and eccentric) for every 5 reps over the 30 repetitions. The decrease of power is a good indication of strength endurance performance.

Ski start test (SST): In alpine ski racing a hundredth of a second can be the deciding factor in a race. Therefore an optimal start is important in reducing time on the course. Horizontal acceleration is provided mainly through the upper body. Recently, biomechanical analysis of the start has been made possible in the lab. The testing device is constructed with an ITEM frame and a sliding platform on which the athlete stands. The start impulse is measured through specially designed ski poles with built-in force transducers. A magnetic strip along the sliding track enables data collection (time and displacement). The data from the poles and the sliding platform are captured and then analysed with Labview software. The maximal force and impulse of right and left pole-pushes as well as the acceleration of the platform are useful feedback parameters for the athletes and coaches.

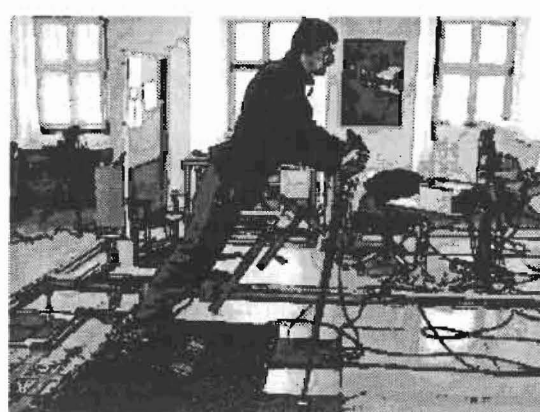

Figure 3: Ski start testing device.

DISCUSSION AND CONCLUSION: The development of physical preparedness norms for ski racers at all age levels aids in detecting possible future performance drop offs, but even of more consequence - assists in injury prevention. Necessary measures can then be undertaken to help the athlete make the adjustments needed. In high performance sport long term studies in the sport science literature are rare, especially sport specific long term studies and norm data in ski racing. Testing of training efficiency demands that the coaches continually critique and revise their programs but also acquaints the athletes with testing which they will encounter if they further their athletic careers.

It should be also noted that the 10 -18 years age group is very sensitive to training volume and intensity due to physical development changes which are occurring. Therefore it is imperative that training exercises and programs as well as test batteries are designed with the physical development and sensitivity of the athletes in mind.

The tests described in this abstract are also utilised for snowboarder testing. At the moment the ski start test is being modified to analyse snowboard starts.

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