TELEMARK: PRESSURE ANALYSIS AND MOTION DURING DOWNHILL SKIING

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INTRODUCTION: The purpose of this study was to evaluate pressure inside ski boots and the athletic posture during Telemark skiing. Telemark skiing, which has gained much interest and is becoming popular among skiers, involves a wide variety of motions due to the fact it takes place on a slope. The motion necessary for Telemark skiing requires atypical use of thigh and hamstring muscles, creating unusual articular stress in the hip, knee, ankle and toes. Unlike normal downhill skiing, it consists in continual changes of the body's center of gravity in order to maintain balance and stability: this requires important use of the trunk and upper limb muscle-skeleton apparatus. In order to study Telemark skiing motion, the position of maximal stability was standardized to 90° degrees hip and knee flexion of the front leg. The other leg had 45° degree dorsiflexion of the metatarso-phalanx, a 135° degree flexion of the knee and a 20° degree flexion of the hip. The purpose of this position was to lower the body center of gravity and to maximize the support area by bringing the front ski forward to increase stability. An important lever arm of Telemark skiing is the binding of the boot to the ski. The binding to the ski allows dorsal flexion, but no rotation of the ski boot. It is therefore necessary that the ski boot should be designed to complement the athletic posture.

METHODS: The instrumentation used to measure insole pressure was the "Dinatto by Buratto" system, and the ski boots used were "Garmont Telemark Competition." The Dinatto System is composed of two insoles that contain 64 FSR sensors of 1mm thickness. These are connected by 2 screened cables with 8 IP65 connector pins to a dataloger which was worn in a pouchet attached to the subject's waist belt. The dataloger is able to run at a frequency between 20 and 250 Hz, it has 1 Megabyte of Ram memory and a memory card interface. The microprocessor is a Risk, 16 bit that runs at 20Mhz. It also has 8 analogical inputs, a clock and a radio frequency modulus. It has a display of 8x20 lines and 6 keys. The energy source is a 3 volt battery. In one of the 8 inputs we connected the clock to the videocamera. Two other inputs were connected to the pressure sensitive insoles that were placed inside the ski boots. The images were recorded with a Sony DVCAM videocamera at a shutter speed of1/1000 second. The ski boots were made of plastic with a hardness of xxx and 2 models of elasticity: one which deals with flexion at the metatarsophalangeal joint and the other deals with the rest of the boot. Testing was done on 14 November 1997 on the Val Senales glacier in Italy at an altitude of 3258 m. and at a temperature of -11°C, 69% humidity, and a wind speed of 16 m/s. A control station was positioned at the arrival point of the chair lift that enabled constant monitoring and functional control of all instrumentation. Two Pentium personal computers, 150 MHz, with 14" monitors and a memory card reader were used. A current generator and a stabilizer were used as a power source. Before recording data the athletes were asked to put the insoles and ski boots on inside the shelter so that all sensors could be checked with a portable personal computer. The athletes were then asked to run 4 slopes so that reference point could be selected. After the 4th run the datalogger was directly connected to a PC and the settings of the insoles were checked using bending, pronation and supination tests. The data registered was controlled with data obtained during laboratory testing. A series of runs were then registered and filmed using different frequencies : 50-75-90-100-125-150 Hz. The 90Hz frequency was chosen as the final testing frequency because it enabled registration of the total run without interruptions and without use of the memory card and allowed easy synchronization with the videocamera. The data regarding plantar pressure was then synchronized with the video images. The following areas were studied for each foot : anterior, posterior, medial-anterior, lateral-anterior, medial-posterior, lateral-posterior. This was rendered possible by previously marking the coordinates of the sensors that corresponded to the following plantar points on the skier's foot : I-III-V toes, the heads of the I-III-V metatarsals, plantar region of the cuneiform-metatarsal joint, plantar region proximal to the base of the V metatarsal, plantar region that corresponds to the head of the talus and center of the calcaneus. Average plantar pressure was then analyzed and a frame study was then undertaken to investigate a possible relationship between athletic posture and plantar pressure.

RESULTS: Three runs of Telemark skiing were recorded. The first run lasted 10.1 seconds and 905 frames were registered. It was done on a well groomed beginners slope where total control of the skis was possible. The second run lasted 62.7 seconds and registered 5.641 frames. This was done on an intermediate slope which also presented moogles. The velocity of skiing was at a relaxed speed. The third run lasted 55.9 sec. And registered 5.030 frames. The slope was the same one used for the second run; however, the skiers were asked to ski as fast as possible. Data analysis obtained the following results : Average pressure during the first run was 70Kpa in the left foot and 100.8 in the right foot. Maximal pressure was 246.4 Kpa in the left foot and 296.8 Kpa in the right foot. During the second run average pressure was 95.2 Kpa in the left foot and 78.4 Kpa in the right foot. Maximal pressure was 274.4 Kpa in the left foot and 316.4 Kpa in the right foot. During the third run average pressure was 98Kpa in the left foot and 84 in the right foot. Maximal pressure was 277.2 Kpa in the left foot and 333.2 Kpa in the right foot. As ski velocity increased, so did the average and maximal pressure. While there was only a moderate increase in average force of 1.64%, maximal force increased by 8.76%. As velocity increased average pressure increased by 4.84%, while average force increased by 3.32%. When examining the force distribution, increased force was measured in the rearfoot of the front leg, while in the other leg increased forces were measured in the forefoot area. The point at which maximal force is applied is on the rearfoot of the front ski because of the fact that the binding blocks the forefoot and the ski has to be controlled by the heel. The lever arm with which the force was applied to the foot, given the length at the femor, in combination with the 90° degree hip flexion and dorsal ankle flexion created increased pressures along the lateral border of the foot on the front ski.

CONCLUSIONS: In normal downhill skiing both skis are paralleled and have equal slope inclination, the downhill foot is pronated and the rearfoot is supinated. In

Telemark skiing there is a substantial difference due to the lateral angulation of both skis. The tests revealed that maximum pressure arises in the rearfoot. During the knee bending phase the foot supinates, which helps stabilize the knee. At the same time, the front foot creates a fulcrum with the binding which increases the load on the rearfoot. Both the front ski and rearfoot tend to supinate. Because the obtained data enabled us to study dynamically a very particular athletic posture, 36 other athletes were studied on 7 and 8 May 1998 on the slopes of Tofane, Cortina d'Ampezzo, Italy. The data was compared with our previous data. This evidenced a certain deficiency of information. The following problems emerged : 1-right and left turns were not homogeneous ; 2-the course followed by the skiers was not the same ; 3- absence of a videocamera near the skiers ; 4- absence of continuous reference points. We therefore outlined a slope with the same number of right and left turns and an ideal line to follow skiing. Every 10 meters reference points where visual and 2 videocameras were used to register each run; one positioned in the middle of the run and the other on a snowmobile in front of the skier. For comparative analysis 8 pairs of ski boots of the same type were equipped with pressure sensors in the same way so that no differences were present between athletes. The data obtained is currently being elaborated and analyzed and should be available this summer. This data consists of plantar pressure measured inside the ski boots synchronized with frontal and lateral two-dimensional video images of various runs. The data was collected using athletes who had similar run times, similar weight and similar shoe size.

REFERENCES:

The method with which we were able to acquire data was the same experimental technique used during the Paris Marathon in 1996 and Venezia Marathon in 1996 and 1997. The results of these studies were published at the World Congress of Bioengineering in Nice, France in September 1997.