THE POWER THRESHOLD CONCEPT IN SKI SPECIFIC STRENGTH TRAINING.

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INTRODUCTION: To cope with the complex demands of alpine skiing the athletes need highly developed motoric abilities. Based on global motoric abilities elite alpine ski racers have to work on the ski specific fitness training. Their main interest should be based on technique specific strength, endurance and coordination training (Müller, 2002).
The skier should have reached a highly developed standard in his specific physical fitness, in order to being able to tolerate the volume and intensity of the first training session on snow (glacier) in the early summer time, since progressive fatigue during one week ski training can have negative effects on the quality of the training. Therefore the *level of physical fitness* highly influences a successful and continued improvement in competitive techniques.
To guarantee a fast and complete recovery after each run and each day of snow training we assume that the level of aerobic capacity is of high importance (Vogt, 2005; Hartmann, 2005). Elite alpine skiers spend a high amount of time in endurance training.
High velocities in addition to small turn radii lead to high forces (more than three times body weight) in all disciplines of alpine skiing. When steering the ski along its side cut the forces occur already at the beginning of the turn. In spite of the short phase of the edge switching the skier has to handle the forces during the whole turn without any chance to recover.
Highly developed skiing techniques include high forces on the inner leg (Fig. 2). In addition to this small knee angles (about 70 degrees) due to inward leaning (Fig. 1) lead to high demands on the skiers´ leg muscles.

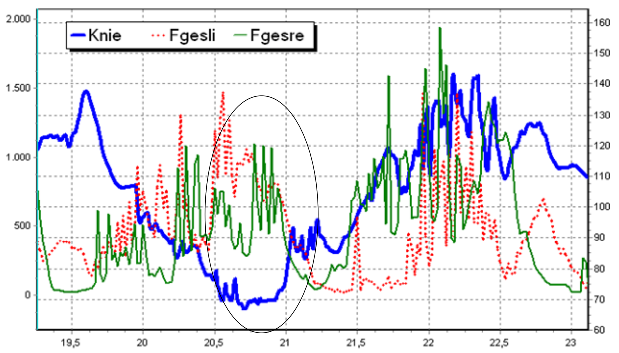

Fig. 1: small knee angle and high force inner leg

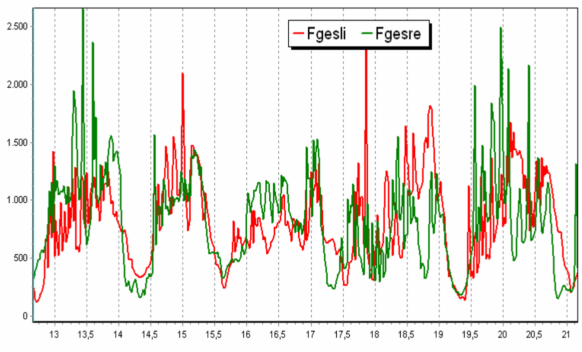

Fig. 2: equal force on inner and outer ski

To resist centrifugal and gravity forces the skier hast to improve his strength abilities. With a high level of maximum strength the skier can overcome the external forces even at the end of the run without loosing any quality due to fatigue in his steering abilities. This resistance against fatigue when dealing with high and repeated forces is highly determined by the level of *strength endurance.*Strength endurance is defined as the resistance against the loss of power during repeated exercise. (Harre, 1986; Nicolaus, 1995a; Martin, 1993).
In addition to the training of maximum strength (hypertrophy and intramuscular coordination) the skier also has to concentrate on the development of his strength endurance. Based on a global, unspecific strength endurance training, sport specific exercises should be of high importance in the skiers` fitness program.
Appropriate training devices help to realise specific exercises. (Raschner, 1997; Schiefermüller, 2005). One important criteria of specific training is to ensure the quality and quantity of the movement until the end of the exercise. The precision of the movement has to be guaranteed for each repetition. A decrease in the amount and in the velocity of motion due to fatigue should not occur (for example: less knee extension).

Power threshold:

One opportunity to control the intensity of motion is the **power threshold concept.** In contrast to traditional methods the intensity of the motion during exercise is not defined by a certain percentage of the maximum strength but by the power [watt] of each repetition during exercise (Pampus 1989, S. 5). The maximum power that can be realised when performing a certain exercise is called the **power threshold** (Nicolaus 1995a, S. 45-46).

Calculation of the power threshold:

The following parameters define the power P [W]:

Power (P)	[W]:	P = F x v
Force (F)	[N]	F = m x a
Mass (m)	[kg]	m = mass of athlete and additional weight
a	[m/s²]	a = acceleration of the system
v	[m/s]	v = velocity of the system

To calculate the power we have to measure the velocity v [m/s] of a certain movement and we have to know the mass m [kg] of the system. The power threshold will be calculated by a stepwise increase of the system load with extra weights. Fig. 3 for example shows the stepwise increase of the load from 10 to 40 kilogramm in 5 kg steps. The diagram shows that the athlete can realise his maximal power when moving the additional weight of 30 kg with the maximal possible velocity. His power threshold for this exercise is at 1030 Watt.

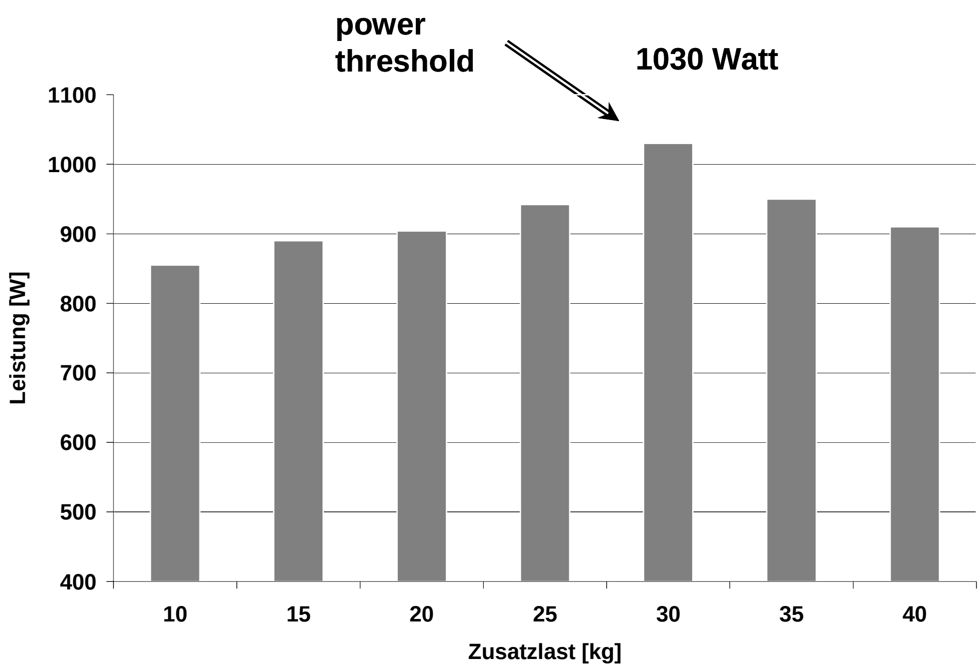

Fig. 3: calculation of power threshold

The following investigation describes the effects of seven weeks ski specific strength endurance training. Changes in heart rate, lactate and power threshold are described.

METHODS: In a first step a ski specific strength endurance device was constructed (Schiefermüller, 2005). In a following step 12 subjects participated in a 7 week training study:

Pre Test:	**Training intervention:**	**Post Test**:
Lactat, heart rate, Power threshold, 40 rep test	7 weeks strength endurance 12 subjects training gr. 12 subjects control group	Lakctat, heart rate Power threshold 40 rep test

Phase one pre Test:

The subjects conducted a pre test on a rollerboard and on a leg press. Heart rate, lactate and power threshold were measured. A strength endurance index and a fatigue index were computed. To determine the power threshold the additional weight on the rollerboard was increased stepwise for each subject. A 75 second strength endurance test had then to be conducted with 90 percent of the weight on the power threshold. The correct intensity (velocity) was controlled by a visual feedback system. The correct minimal knee angle was controlled by tactil feedback. Maximal heart rate and lactate (1.min, 3. min, 5. min) were measured. Strength endurance also was tested at a traditional leg press. The subjects performed 42 repetitions in 75 seconds with an additional weight of 1.7 times body weight. Heart rate and lactate were measured.

For measuring the rate of strength endurance (strength endurance index) a 40 repetition test (Nicolaus, 1995b) was used: In the first phase the athlete had to execute four repetitions at maximal speed. In the second phase of the test the subject had to perform 40 repetitions at maximal speed over each repetition (Stöggl, 2005). The strength endurance index was than calculated:

$$\frac{\text{max of 4Rep- mean of 40Rep}}{\text{max of 4Rep}} \quad \text{=strength endurance index [\%]}$$

To estimate strength endurance also a *fatigue index* was calculated. This index described the difference between the maximal power and the mean power over the 40 repetition test.

Phase two: Strength endurance training

This phase consisted of a seven week trainings intervention on the rollerboard. The additional weight was 90% of the weight at the power threshold. The critical level for velocity was defined as 85% of the maximal possible velocity. The subject controlled his speed through visual feedback (green light correct speed, red light too slow). The correct minimal knee angle was controlled also. The number of training sessions, number of sets and duration of the sets was systematically increased during the seven weeks training period. The intensity of motion was not changed during the whole period.

Phase three post test:

24 subjects (12 training group, 12 control group) executed the post test under the same conditions as the pre test. The same parameters were measured. Sufficient time of recovery after the last training session was given. To compare heart rate and lactate with the pre test, the strength endurance test on the rollerboard and in the leg press was performed with the same additional weight and velocity as in the pre test.

Fig. 4 movement on the rollerboard

RESULTS:

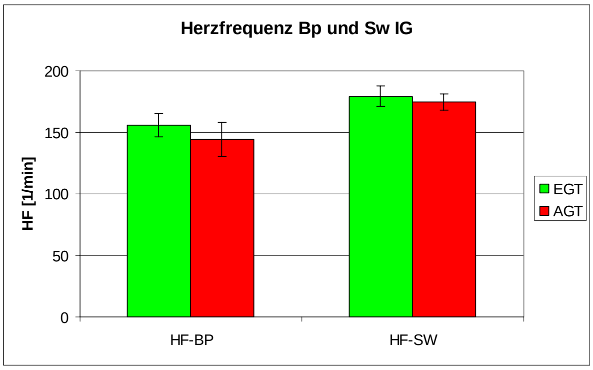

Fig. 5: heart rate (HF) pre test (EGT) and post test (AGT) on the leg press (BP) and the rollerboard (SW).

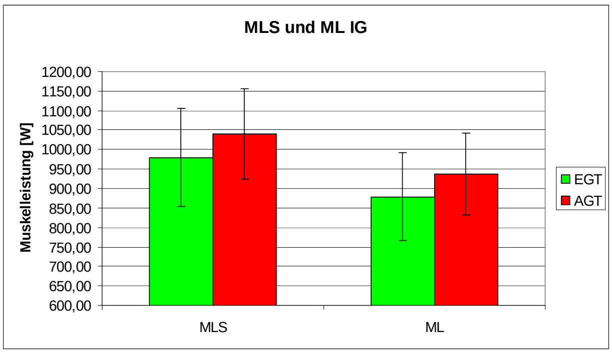

Fig. 6: Power threshold (MLS) and mean power (ML) over 75 seconds at pre test (EGT) and post test (AGT).

Fig. 5: shows that the mean value of the maximal heart rate after the strength endurance test on the leg press was lowered from 156 to 144.2 beats per minute. On the rollerboard from 179.3 to 174.5 beats per minute.

Fig. 6: shows that th power threshold (MLS) on the rollerboard increased about 60.75 Watt between the pre test (EGT) and the post test (AGT). The control group lowered the power threshold about 1.17 Watt. The mean power over the 75 seconds strength endurance test (ML) increased about 57.94 Watt in the training group.

The control group increased the mean power just about 1.17 Watt.Each subject could increase the average power over 40 repetitions. The mean difference between the maximal power and the mean power over 40 repetitions was in the pre test 114.9 Watt for the training group. In the post test the difference was lowered to 68,5 watt.

No significant changes between training and control group could be found in the lactate values.

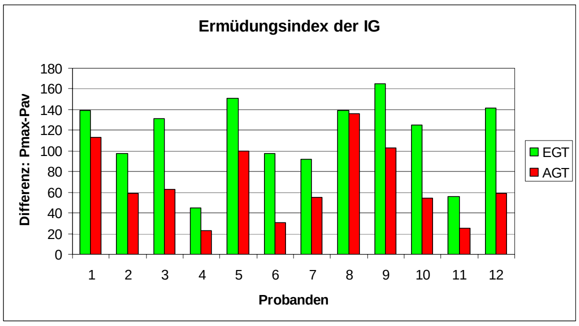

Fig. 7: fatigue index (Ermüdungsindex) for each subject, differences between maximal power (Pmax) and average power (Pav) in pre (EGT) and post (AGT) test.

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