POWER TESTING IN ELITE SPORT AND PRACTICAL APPLICATIONS FOR TRAINING

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The ability to produce force quickly is often a deciding factor in sport. Dynamic power assessment is related to complex aspects of muscle function as well as target performance in sports. In this sense, dynamic power testing includes multi-joint movements such as jumping under typical real life conditions. Testing of power is important, but understanding the results and ultimately using them to improve training is the goal of the testing process. The purpose of this paper is to describe a system of power testing and how the results are used in training.

KEY WORDS: power, jump, testing.

INTRODUCTION: Jumping power can be assessed with many methods, but measuring ground reaction forces with force plates allows detailed analysis of power parameters. A unique power testing system which was developed in the Institute of Sport Sciences at the University of Innsbruck (Pernitsch, 2000) enables the measurement of many power parameters, and analysis of right and left leg force production in a bilateral (BL) jump. This paper outlines the jump power testing which is a regular part of testing for many athletic groups tested at the University of Innsbruck's Institute of Sport Science.

METHOD:
Data Collection: 20 male athletes (10 weightlifters and 10 general power athletes) who use power cleans regularly in training were tested. Force and power data were collected and compared during the performance of power cleans, power hang cleans, loaded squat jumps (SJ) and loaded counter movement jumps (CMJ). The power parameters average relative power (P), average relative power during the first 100ms (P01) and average relative power during the first 200ms (P02) were used for analysis. Statistical analysis was conducted with independent t tests ($p < 0.05$).
9 male members of the Austrian Ski Team and 4 long jumpers (Austrian national level) were tested. SJ were performed as above, was well as CMJ with the same loads. The long jumpers jumped with a 110° knee angle (skiers with 90°) and did not jump with 125%BW. Due to the different knee angles of the skiers and the long jumpers, statistical analysis was not conducted.
13 female members of the Austrian Ski Team were tested on the Contrex leg press with isokinetic concentric (CT Con) and eccentric (CT Ecc) unilateral (UL) leg extensions, isometric UL leg press and BL SJ. 2 separate isometric leg press tests were performed, at knee angles 85° and 100°. The subjects performed unloaded SJ (SJ Unl) and loaded SJ (SJ L) (100% of bodyweight as additional load) with ground reaction forces measured by two separate force platforms. A L/R strength ratio was calculated from the maximal force results for each test. A factor analysis was used to analyse the data.
3 male members of the Austrian Ski Team were tested. The parameters P, P01, P02, and jump height were measured and analyzed.

RESULTS: The loaded jump squats (both CMJ and SJ) produced significantly higher power outputs than power cleans and power hang cleans ($p < 0.05$). This was evident in P01, P02 and P. When comparing the weightlifters to the general power athletes, no significant differences were found in most variables. However, the general power athletes had significantly higher power outputs in P01and P02.
In the next series of tests with long jumpers and skiers, no statistical analysis was made due to the difference in knee angles of the jumps, however trends can be seen. The jumpers

produced higher mean values in all parameters. Differences in jump heights were not great between the two groups, but differences in P and P01 were notably larger, especially P01.
In testing L/R differences, it was expected that each subject would have similar L/R ratios for each test, but this was not the case. The factor analysis extracted 3 factors, and the 3 types of tests (jumping, isokinetic, isometric) each loaded on a different factor.
The test results of three male ski racers are presented as an example of test interpretation. Refer to figures 1, 2, and 3.

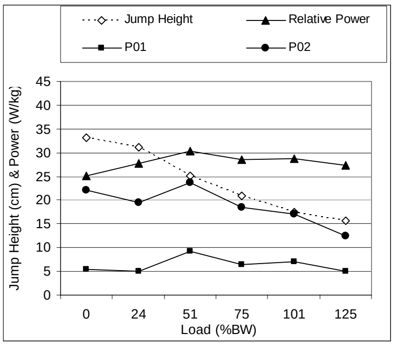

Figure 1: Subject B SJ Test

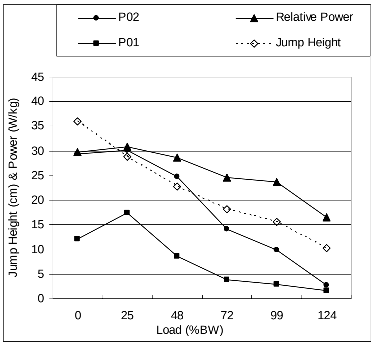

Figure 2: Subject S SJ Test

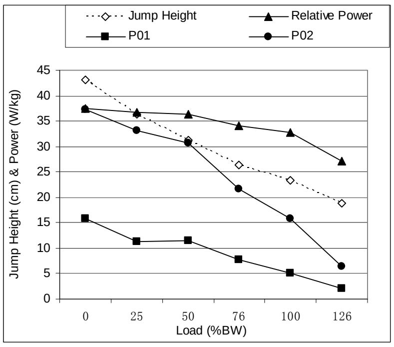

Figure 3: Subject N SJ Test

DISCUSSION: Power output was higher in jumps than in power cleans. With the bar on the back and shoulders there are less levers and body parts working than in cleans. During a clean the momentum generated by the legs and hips must be transmitted through the core, shoulders and arms as the bar is raised. In a jump the core is the only link from the legs to the bar. A jump is technically much easier to perform. Cleans can be a very useful training tool, teaching an athlete to generate power. However, the results here indicate that power outputs are higher with jumps and time spent teaching an athlete to perform cleans may be better utilized training for power with jumps. Some coaches use Olympic lifting in their strength programs, but with athletes who have problems learning the lifts, other forms of power training are employed.
In the second test series the long jumpers had higher power and jumps than the skiers, but jump heights differed less than P and P01, so jump height may not be the best testing parameter. Athletes requiring more range of motion and time to jump are less powerful than quick jumpers even if the jump heights are similar. It is very important to evaluate the power demands and time frame of the sport specific movement when testing jumping power. Board contact time in long jump is about 130ms (Seyfarth, Friedrichs & Wank, 1997), so P01 is more relevant than P or P02 for a jumper. Comparisons here must be made with caution, as 110° is a stronger position than 90° and the displacement is less so the movement should be quicker. Therefore power differences are likely due to a combination of knee angle and physiological differences between the jumpers and skiers. However, 100ms may be simply too quick for the skiers, as it has been found (Patterson, Raschner, Puehringer & Platzer, 2005) that male skiers produce significantly higher power outputs in many parameters than female skiers, but do not vary significantly in P01, suggesting that the skiers generally do not produce high levels of power in the first 100ms of the jumps. Perhaps skiing does not elicit a highly explosive power training effect, as slalom skiing has a stretch shortening cycle of 600ms (Frick, Schmidtbleicher, Raschner & Müller, 1997). It should be noted that ski design has radically changed in the last 5 – 10 years, and successful ski racers must be more athletic and explosive now.
The factor analysis suggests that BL imbalances in isometric, isokinetic and squat jump tests are not strongly related. Baker, Wilson & Carlyon (1994) and Kanehisa & Miyashita (1983) reported that isometric and dynamic strength are not related. Abernethy & Jurimae (1996) showed that the timing and magnitude of changes in isometric and isokinetic strength with training vary from person to person. Blazevich, Gill & Newton (2002) demonstrated that isometric leg strength tests correlate to 1RM squat, but the correlations are not high enough to be highly valid. We found that the L/R strength ratios vary by test for some athletes,

leading to this statistical analysis. It can only be speculated why differences occur between the tests. In all three types of tests, the maximal force was used for analysis. During the Contrex tests, there is high resistance throughout the full range of motion, so the highest forces are found at the largest knee angles. The isometric tests also produce greater forces at greater knee angles. During a counter movement jump the highest force values are usually found at the start of the concentric phase or shortly thereafter, in a position with a relatively small knee angle. As inertia is overcome and the mass is accelerated, the force decreases as the jump progresses. Also, muscle activation and recruitment is different in UL tests than in BL tests. These two factors may explain in part the difference in the BL imbalances found in the three forms of testing. (Schmidtbleicher, 2006). The variations in the structural, neural and mechanical mechanisms of the different types of muscle contractions and movements strongly influence commonalties and discrepancies between the tests.

Subject B has relatively low P at 0%BW and 25%BW. P01 is generally low at all loads, and his maximal P02 is reached first at 100%BW. His flat power curves with minimal drop offs indicate that he is lacking in speed and explosive power. He should train with no weight or with light weights to learn to move quickly and recruit his motor units faster and more efficiently.

Subject S has good P, P01 and P02 results up to 50%BW, but with higher loads power decreases substantially, especially in P01 and P02, indicating that he has a deficit in maximal strength and should train to increase his maximal strength and perhaps needs hypertrophy training as well.

Subject N has very good curves. His power drops off at 100%BW when observing P, but when observing P01 and P02, it drops off at 50%BW. He has high power and jump height results for a skier. His power and strength training program should be designed in collaboration with his ski coaches, to decide if he should focus more on speed and quickness, or maximum strength. If his skiing needs more explosive power, he should work with weights below or at about 50%BW for squat jumps. If he needs more strength, he can focus on maximal strength training.

The training for all 3 subjects in regards to strength and power must be designed by examining all test results with the total skier and his/her events in mind. Our testing battery includes tests which also explore maximal strength and strength endurance levels as well. The training should be tailored to improve the athlete's weaknesses and exploit their strengths. A slalom and GS skier has different physiological demands than a "speed" specialist who skis only downhill and super G. A trend in ski racing at the moment, for many ski nations, is to develop racers who can perform well in GS, super G and downhill. This is a conditioning challenge. Skiing is a complex activity and a dryland training program should aim at producing race results, not just results in the weight room or in the lab.

One goal of jump training is to improve an athlete's acceleration. However, it is known that forces decrease after an athlete has started the concentric phase of a jump. A training method popularized by Louie Simmons (a power lifting coach) to teach lifters to accelerate throughout the entire lift is the use of rubber bands. This method is known as accommodating resistance and in a squat the bands are stretched as the bar moves upward so that resistance is greater as the athlete moves into a stronger position. The athlete must consciously accelerate the bar throughout the squat. This method is being utilized at the University of Innsbruck.

CONCLUSION: Power cleans are useful training tools, but in our study loaded jumps produced higher power outputs, therefore coaches should evaluate using cleans in a power training program if the athletes are not technically proficient. Test analysis must consider the power demands of the sport of the athlete tested. BL imbalances should be tested, but can vary, depending upon the strength test used. The history of the individual athlete must be known and taken into consideration, as past injuries and sidedness inherent in the specific sport will influence BL imbalances. Power testing is one facet of the complex evaluation of an athlete. Very high level ski racers also use the power testing system described here as a regular part of their training program to provide instant feedback for left/right strength balance and power training.

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