ISOKINETIC PEAK POWER AND PREDICTION OF PERFORMANCE

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The purpose of the present study was to examine the relationship between joint peak power during isokinetic concentric knee extension and during squat vertical jump performed on a Kistler force plate. Kinematic data from both tests were colleded. Peak power was measured as the product of angular velocity and moment at the knee joint in both tests. Rank order correlations revealed that there is no relationship between the two tests concerning the peak power output at the knee joint. It was concluded that isolated joint isokinetic tests cannot be used to predict functional performance because of the differences in muscle and joint function characteristics during the different movements.

KEY WORDS: biomechanics, moment (toque), jump, muscle function, joint function

INTRODUCTION: There are various laboratory and field tests that are widely used to measure peak power which is a measure of muscular capacity necessary for good performance in various explosive sport events, such as long jump and weight lifting. Frequently used laboratory tests are, for example, isokinetic peak power and the Wingate test and a widely used field test is the "jump and reach" vertical jump. Isokinetic power and measurements from different lab and field tests have been examined and contradictory results have been reported e.g. Trzaskoma et al. (1996). The contradictory results may be due to different isokinetic testing protocols, subjects, methods to measure power and lack of inertial correction. In a previous experiment in our lab four different methods were used to measure isokinetic peak power: a) preselected angular velocity and peak moment without considering the actual (true) angular velocity at peak moment b) actual angular velocity and the respective moment values at that time c) instant actual angular velocity at the point of peak moment and peak moment and d) actual constant angular velocity and the highest moment during this period. It was found that different peak power outputs were obtained using the different methods and it was recommended to use only the last method because it is the only one that produces the actual isokinetic peak power. Actual angular velocity refers to velocity derived from kinematic analysis and represents the true angular velocity of the limb. At moderate and high velocities the angular velocity from the dynamometer software does not represent the actual angular velocity (Iossifidou and Baltzopoulos, 1996).
Furthermore, the relationship between isokinetic peak power and peak power measured using various field tests depends on the mechanical characteristics of the two movements. Hence, different musculoskeletal system properties are assessed for example in isokinetic knee extension and in the vertical jump. More specifically, although in isokinetic knee tests the knee joint is isolated and only the thigh muscles contribute to the movement in the vertical jump all the segments are used and hip, knee, ankle etc joints are involved. Hence parameters such as velocity, length and force of the biarticular rectus femoris are affected only by knee joint position in isokinetic tests as opposed to both hip and knee joint position in the vertical jump. However, these factors are not considered in studies examining the application of isokinetic measurements to predict performance e.g. Ostenberg et al. (1998).
It is therefore essential to re-examine the relationship between isokinetic peak power – assuming it is measured accurately using appropriate methods- and other functional tests. The most widely used isokinetic test is knee extension and the functional test of jumping ability with similar characteristics, such as the initial and final knee angular position, is the squat vertical jump. Therefore the purpose of the present study was to examine the relationship between isokinetic knee extension and the squat vertical jump power using the last methods described above and considering the muscle-joint mechanical characteristics of the two movements.

METHODS: Five subjects (age:23.4±2.50 years, height:1.87±0.12m, mass:79.2±13.66kg) volunteered to participate in the study.

Isokinetic test (IT): The Lido Active isokinetic dynamometer was used (Loredan Biomedical, Davis, CA). The subjects performed five concentric knee extensions and flexions at four angular velocities: 30, 90, 180 and 300 deg/s. The analog moment data were collected and converted to digital via a 16 channel A/D card without using the Lido software. This was due to limitations in the analysis and data exporting options of the Lido software. The sampling frequency was 100 Hz. Two-dimensional kinematic analysis was performed to calculate the angular velocity of the knee. An optoelectronic system (ELITE) with one camera perpendicular to the plane of motion was used. A recursive second-order Butterworth digital filter was applied in forward and backward directions (zero phase lag) to smooth the data. The cut-off frequency was chosen automatically based on a power spectrum assessment method. Different cut-off frequencies were used for the angular displacement, velocity and acceleration (Giakas and Baltzopoulos, 1997). In order to assess the actual knee joint moment, inertial effects were considered using the procedure reported in Iossifidou and Baltzopoulos (1998). Gravity correction was based on the Lido dynamic method that is performed with the lever arm moving throughout the range of movement with the limb. Finally, power was defined as the product of constant angular velocity and the highest moment during this period.

Squat Vertical Jump (SVJ): The SVJ was performed on a Kistler force plate. At the starting position the subjects flexed their knees to approximately 90 degrees. Their hands were crossed in front of their chest. Then, without any other movement (hand or countermovement) they performed a vertical jump. The same procedure was followed for two more jumps. Two-dimensional kinematic analysis was performed to calculate the angular velocity of the knee, The ELITE optoelectronic system with one camera perpendicular to the plane of motion was used. The camera was placed approximately 6 m away from the subjects. Four reflective markers were placed approximately on the greater trochanter (hip), between the fibula and the lateral medial femoral condyle (knee), lateral malleolus (ankle) and great toe. Angular positions and X and Y coordinates were exported using the ELITE software. The smoothing procedures were similar to those used for the isokinetic data. The cut-off frequencies ranged from 7 to 10 Hz. The kinematic data together with the force readings from the force plate were used in a simple two-dimensional inverse dynamics model to calculate the moment and finally the power produced at the knee joint.

The best jump was further used to establish the differences and the relationship between the two tests based on their mechanical characteristics and power output.

Because during the SVJ both legs are used, power and moment outputs were divided by two in order to allow a better comparison to the one leg isokinetic test. Statistical analysis was performed using the Wilcoxon test to evaluate any differences between the SVJ and IT and the Spearman test to determine their relationship. The level of significance was set at 0.95. Peak power measurements using each one of the four methods in the IT were compared to the SVJ power.

RESULTS: Significant differences were found between power measures in the two tests ($p<0.05$). Mean peak power (±SD) for the isokinetic test was 749 ±300 W. The respective values for the SVJ were 2255 ±430 W. Spearman's r_s also revealed low correlations between the test at 30 and 90 deg/s, moderate at 300 deg/s and high at 180 deg/s. Knee angular velocity was significantly higher during the squat jump than during isokinetic tests even when the higher isokinetic velocity was considered. Furthermore, the development of knee joint angular velocity was different in the two tests (Figure 1). Mean angular velocity (±SD) where peak power was observed in the isokinetic test was 221 ±60 deg/s. In the SVJ mean angular velocity was 560 ±81 deg/s. Finally, the SVJ produced higher moment (231 ±41Nm)compared to the IT (191 ±35 Nm). These moment values are at the point of peak power.

DISCUSSION: In the present study the knee joint power output during a SVJ was isolated and examined because this is the joint used during the isokinetic test. This was the major difference between the present and previous studies in which the whole body power output, or the height change of the centre of mass during various vertical jumps (countermovement, squat or drop) were used to examine the relationship of isokinetic and vertical jump outputs (Ostenberg et al., 1998, Petschniget al., 1998).

A high correlation (r_s: 0.80, $p<0.05$) was found between isokinetic peak power at 180 degls and SVJ. However, the great difference in velocity (180 degls in IT versus >500 degls in SVJ) leads to the conclusion that the high correlation that was found at 180 degls is not significant from a functional point of view.

The low correlation coefficients were mainly due to differences in muscle and joint mechanics during the two movements. More specifically, combined extension of hip and knee results to different activity of the gluteus maximus, the semimembranosus, the vastus medialis and the rectus femoris compared to the isolated hip and knee extension (Yamashita, 1988). Yamashita (1988) concluded that EMG activities of the monoarticular (gluteus maximus and vastus medialis) and biarticular (semimembranosus and rectus femoris) thigh muscles change when there is a movement of the adjacent joint movement. Additionally, the jumping ability is influenced by the biarticularity of the gastrocnemius (Van Soest et al., 1993).

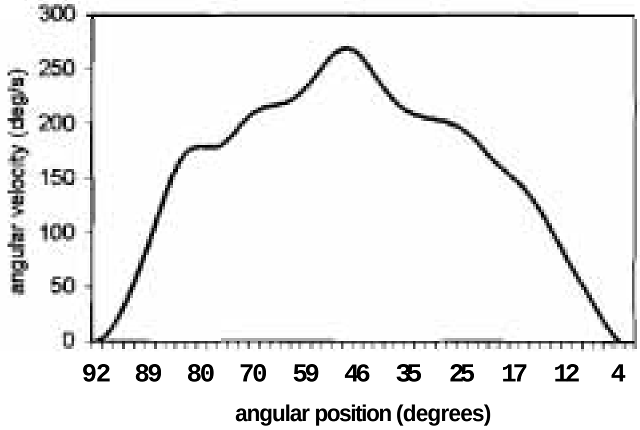
During the jump various joint and muscle groups are involved. There is transfer of energy between thigh, calf and foot and the mechanical output of the knee joint is affected. On the contrary, during the isokinetic test only the knee joint and the knee extensors are involved, assuming that appropriate stabilisation of the hip and trunk has been performed, and hence other joint movements do not influence the knee joint output. Finally during the SVJ both legs are used contrary to the isokinetic dynamometry tests.

Isokinetic tests limit the angular velocity whereas during the vertical jump there are no restrictions. Hence, the mean angular velocity at the point of peak power was approximately 200 degls during the IT and more than 500 degls during the SVJ. The variations mainly in angular velocity and moment are considered as the major factors responsible for the significant differences in peak power between IT and SVJ and these are due to different musculoskeletal system function characteristics in each test (Table 1).

CONCLUSION: It is concluded that, although isokinetic dynamometry is a very useful tool in rehabilitation and isolated joint and muscle function assessment, it cannot be used to predict functional performance because of the differences in muscle and joint characteristics during the various movements.

Table 1 The Major Musculoskeletal System Function Differences between IT and SVJ

Isokinetic Test	Squat Vertical Jump
Isolation and activation of one muscle group (quadriceps)	Various muscles are activated and contribute to the movement – transfer of energy between segments
Rectus femoris length changes depending on the angular position changes of the knee joint	Rectus femoris length changes depending on the angular position changes in both knee and hip joints
Restriction of the knee joint angular velocity	Free acceleration and deceleration
Open kinetic chain	Closed kinetic chain
One leg involved	Two legs involved



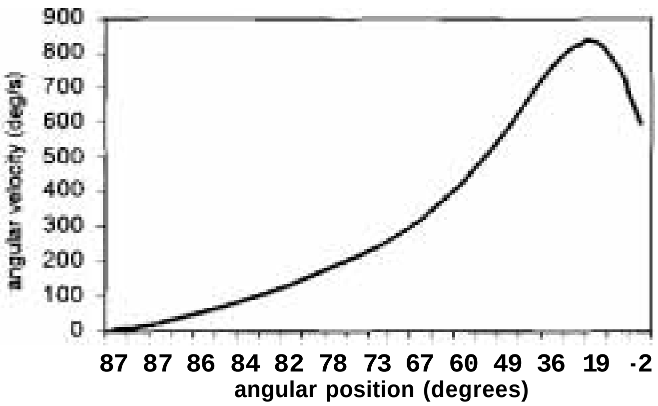


Figure **1 -** Angular velocity during the IT (a) and the SVJ (b). Initial position (flexed knee): **90** degrees, final position **(extended** knee): **0** degrees.

REFERENCES:

Giakas G. & Baltzopoulos V. (1997) Optimal digital filtering requires a different cut-off frequency strategy for the determination of the higher derivatives. Journal of Biomechanics, **30,** 851-855.

lossifidou A.N. & Baltzopoulos V. (1998) Inertial effects on the assessment of performance in isokinetic dynamometry. International Journal of Sports Medicine, **19,** 567-573.

lossifidou A.N. & Baltzopoulos V. (1996) Angular velocity in eccentric isokinetic dynamometry. *Isokinetics* and Exercise Science, **6**, 65-70.

Ostenberg A., Roos E., Ekdahl C. & Roos H. (1998) Isokinetic knee extensor strength and functional performance in healthy female soccer players. Scandinavian Journal of Medicine and Science in Sports, 8, 257-264.

Petschnig R., Baron R. & Albrecht M. (1998) The relationship between isokinetic quadriceps strength test and hop tests for distance and one-legged vertical jump test following anterior cruciate ligament reconstruction. Journal of Orthopaedics and Sport Physical Therapy, 28, 23-31.

Trzaskoma Z., Wit A. & Eliasz J. (1996) Comparison of three laboratory tests of short duration with respect to the mechanical power ouput by lower limbs of athletes. Biology of Sport, **13,** 61-70.

Van Soest A.J., Schwab A.L., Bobbert M.F. & Schenau G.J.V. (1993) The influence of **biarticularity** of the gastrocnemius muscle on the vertical jumping achievement. Journal of Biomechanics, 26. 1-8.

Yamashita N. (1988) EMG activities in mono- and bi- articular thigh muscles in combined hip and knee extension. European Journal of Applied Physiology, 58, 274-277.

Acknowledgement

This study was supported by the Greek State Scholarship Foundation (I.K.Y.)