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RELIABILITY OF KINETIC VARIABLES OF SQUAT JUMPS WITH DIFFERENT STARTING POSITIONS

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The aims of the study were to compare dynamic variables (impulse, peak force, peak power and rate of force development) derived from squat jumps starting from self-selected and 90 degree knee angles as well as determining the reliability of these variables in the two conditions. Fourteen male junior volleyball players performed three Squat Jumps on a force platform while starting from each position. Intraclass Correlation Coefficients were calculated and t-tests were used to identify differences between the starting positions. In both conditions, most variables showed ICC coefficients greater than 0.85 and no significant differences between the starting conditions were found. It can be concluded that both conditions lead to reliable dynamic data without significant differences and therefore standardized knee angle is not necessary.

KEY WORDS: squat jump, starting position, standardization, ICC.

INTRODUCTION: Vertical jump performance is important in many sports and different jump tests are used for talent selection, training control, and monitoring posttraumatic treatment. For the assessment of jump performance different jump techniques like squat jump (SJ), countermovement jump (CMJ) and drop jump (DJ) are applied. While CMJ and DJ assess jump performance in more natural stretch-shortening-cycle muscle actions, the SJ allows testing leg explosiveness (force production) in primarily concentric muscle conditions (Maulder & Cronin, 2005). SJ are also used to investigate differences of dynamic strategies for vertical jumps (Amasay, 2008) or to identify performance differences between different sports (Ravn et al., 1999). This type of jump is an important diagnostic tool because the relationship between CMJ and SJ performance is an indicator for the utilization of muscle elasticity during vertical jumps (Bobbert, Gerritsen, Litjens, van Soest, 1996).

Furthermore, vertical jumps on a force platform can be applied to determine dynamic variables for the identification of bilateral strength asymmetries of lower limbs (Impellizzeri, Rampinini, Maffiuletti & Marcora, 2007, Newton, Gerber, Nimphius, Shin, Doan, Robertson, Pearson, Graig, Hakkinen & Kraemer, 2006). Despite the wide range of applications of SJ as a diagnostic tool, different squat positions are described in the literature. The knee angle of the initial squat position has been reported as self-selected (Amasay, 2008), 75^o (Driss, Vandewalle, Quiévre, Miller & Monod, 2001), 90^o (Moran & Wallace, 2007), 100^o (Hasson, Dugan, Doyle, Humphries & Newton, 2004), 110^o (Moran & Wallace, 2007) or 120^o (Gehri, Ricard, Kleiner & Kirkendall, 1998). Since the aims and methods of these studies were different, their results do not provide consistent information about possible differences of dynamic variables between the different squat positions. In order to verify the influence of squat depth on jump performance Domire & Challis (2007) determined kinematic characteristics and the moments of the hip, knee and ankle between deep squat (knee angle: 86.2 ± 16.0^o) and preferred squat (knee angle: 105.3 ± 10.3^o). No significant differences between the deep and preferred squat position could be found concerning jump height, and normalized maximal joint moments of hip, knee and ankle, whereas selected kinematic variables (elevation of center of mass during impulse phase, time to maximum angle and initial angles of hip, knee and ankle) showed significant differences between the two investigated conditions. Since Domire & Challis (2007) stated that the influence of squat depth on jump height has not yet been systematically examined, they investigated the effect of different squat positions on muscle model parameters and joint angles of the lower limbs, but ground reaction forces were not analyzed. In order to complement the knowledge about the influence of different squat positions and because of the importance of ground reaction forces during vertical jumps for the assessment physical conditions (Wisløff, Castagna, Helgerud, Jones, & Hoff, 2004) and for detecting bilateral strength differences of lower limbs (Impellizzeri, Rampinini, Maffiuletti & Marcora, 2007, Newton, Gerber, Nimphius, Shin, Doan, Robertson, Pearson, Graig, Hakkinen & Kraemer, 2006), the aims of this study were the determination of reliability of investigated variables at two different initial squat positions, self-selected and 90 degree knee angle, and identification of possible differences between the two conditions.

METHODS: The subjects of this study were 14 male young volleyball players (age: 15.4 ± 0.4 years, height: 174.3 ± 5.3 cm, mass: 65.6 ± 7.8 kg) from one team, with competition experience of more than 2 years. According to the self-report of the athletes, none of them had a medical history of injury of the lower limbs or hip joints during the prior 6 months. The research project was approved by the Ethical Committee for Research with Humans of the University, and all subjects provided written informed consent.
After 5 minutes of warm-up exercise, consisting of jogging with self-paced moderate velocity and three submaximal SJs, the subjects performed two sets of five SJs on a force platform (AMTI OR5-6), with a recovery interval of 2 minutes after each trial. One series consisted of SJs with self-selected initial squat position and the other series was composed by SJs with a 90 degree knee angle. Half of the athletes first performed the jumps with self selected squat position and the other half started the first series with the 90 degree knee angle. The knee angles of the self selected position were determined by digitized video frames and the 90 degree knee angles were verified by a manual goniometer. To prevent any influence of upper limb movements on the vertical impulse, the athletes' hands were fixed at their hips, and they were requested to jump as high as possible. The vertical ground reaction forces were recorded at a frequency of 1 KHz and low-pass filtered at 50 Hz with a fourth-order, zerolag Butterworth filter implemented in the software DASYLab 10.0

Table 1
Investigated variables

Variable	Symbol
Jump Height [m]	d
Impulse [Ns]	I
Maximal Force [N]	F_{max}
Mean Rate of Force Development [N/s]	MRFD
Work [Nm]	W
Acceleration Trajectory [m]	h_z
Peak Power [W]	P_{max}

Mean Rate of Force Development was defined as the difference between Maximal Force (F_{max}) and Minimal Force during downward movement divided by the time between these extreme values. Acceleration Trajectory (h_z) was the difference between initial (h_{min}) and take-off (h_{max}) height of Center of Gravity during the impulse phase and Work (W) was defined as shown in equation [1]:

$$W = \int_{h\min}^{h\max} F dh \qquad [1]$$

The instantaneous power (P_{ti}) was defined as shown in equation [2]:

$$P_{ti} = F_{ti} \cdot v_{ti} = F_{ti} \cdot \frac{1}{m} \int_{t0}^{ti} F dt \qquad [2]$$

F_{ti} is the instantaneous vertical ground reaction force, and v_{ti} is the instantaneous vertical velocity of the center of gravity. P_{max} is the maximal value of instantaneous power.

The force platform was calibrated by certified weights before each data collection session and was systematically checked between individual test sessions.
The reliability was verified by the determination of Intraclass Correlation Coefficient (ICC, (3,1)). According to Cichetti (1994), ICC values can be interpreted as follows: ICC<0.4 – poor; between 0.4 and 0.59 – fair; between 0.6 and 0.74 – good; between 0.75 and 1.0 – excellent. Since normal distribution is a condition for the above mentioned procedures, significant deviation from normal distribution was previously verified by the Shapiro-Wilk test. For the identification of differences between the squat conditions concerning the investigated variables, a paired samples t-test was performed. For all the procedures, $p < 0.05$ was considered significant and the software used was SPSS 18.0.

RESULTS: The mean and standard deviation (sd) of the knee angle of self-selected squat position of all individuals in the three repetitions was $98.9^{\circ} \pm 9.07^{\circ}$ with a range from 85° to 111°. For all investigated variables in the two conditions no significant deviation from normal distribution was found. ICC and respective p values are presented in table 2 for the 90 degree and self-selected squat position.

Table 2
ICC of the variables with 90 degree and self-selected squat position

	90^{o} squat position		Self-selected squat position	
Variable	ICC	p	ICC	p
d	0.97	0.001	0.95	0.001
I	0.93	0.001	0.89	0.001
F_{max}	0.91	0.001	0.98	0.001
MRFD	0.77	0.001	0.94	0.001
W	0.92	0.001	0.98	0.001
h_z	0.87	0.001	0.99	0.001
P_{max}	0.94	0.001	0.97	0.001

Table 3 shows the descriptive statistics of the variables for the two squat positions. No significant difference between the two squat conditions could be found for any of the investigated variables.

Table 3
Descriptive statistics

	90^{o} squat position		Self-selected squat position	
Variable	mean	sd	mean	sd
d	0.179	0.036	0.177	0.034
I	124.2	8.4	123.7	8.0
F_{max}	716.8	83.2	702.8	160.9
MRFD	2169.4	475.8	2264.1	1168.1
W	33.8	7.25	39.0	16.6
h_z	0.350	0.028	0.374	0.096
P_{max}	1191.8	154.7	1158.1	214.4

DISCUSSION: Even though different initial squat positions were used in the above cited publications, the reliability of dynamic variables has not yet been verified. In the study of Domire & Challis (2007) who investigated the effect of normal and deep squat positions on muscle model parameters and joint angles of the lower limbs, the mean of the knee angle in self selected position was about 6^{o} less and of the deep squat about 4^{o} less than the 90^{o} knee position in the present study. In accordance with Domire & Challis (2007), also the present study could not find significant differences of the jumping height and dynamic variables between the two conditions. Even the length of the vertical acceleration trajectory and work were not significantly different.

ICC values of all investigated variables with 90^o as well as self-selected squat position were higher than 0.75 (most of them higher than 0.87) which indicates excellent reliability, according to Cichetti (1994). Most variables had higher ICC values in the self-selected condition than in the 90^o squat position. For the MRFD which is an explosive strength parameter, the ICC in the self-selected position was a lot higher than in the 90^o position.

CONCLUSION: All investigated kinetic variables of squat jumps with self-selected and 90^o squat positions showed very good reliability. Therefore, squat jumps starting from these positions seem to be appropriate to analyze the investigated variables in order to obtain information for the organization of strength training. Since there were no significant differences between the investigated variables of the two squat positions it does not seem to be necessary to define a certain knee angle. From a practical point of view, self-selected squat position is easier to handle and reliability of the investigated variables seems to be slightly better. Further investigations for deeper and higher squat positions should be performed.

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