RELIABILITY OF KINETIC VARIABLES OF SQUAT JUMPS WITH DIFFERENT STARTING POSITIONS AFTER CRITERION BASED FAMILIARIZATION

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The aim of this study were the verification of criterion based familiarization by Intraclass Correlation Coefficient (ICC) and Standard Error of Measurement (SEM) and the identification of possible differences of performance and dynamic variables at squat positions with 90° (SJ_{90}°) and 120° (SJ_{120}°) of knee angle. Fifteen male junior volleyball players performed three randomly performed jumps with maximal intensity from each squat position. SJ_{90}° results in lower peak force and higher vertical impulse, impulse duration and time for peak force than SJ_{120}°. ICC and SEM show that familiarization that consisted of three series of 5 jumps for each squat position with 1 minute of rest between the jumps, is sufficient to ensure adequate test conditions.

KEY WORDS: criterion, familiarization, squat jump, starting position

INTRODUCTION: 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, squat jump allows testing leg explosiveness (force production) in primarily concentric muscle conditions (Maulder & Cronin, 2005). SJ are also applied to investigate differences of dynamic strategies for vertical jumps (Amasay, 2008) or to identify performance differences between different sports (Ravn *et al*., 1999).

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 *et al*., 2007, Newton *et al*., 2006). Despite the wide range of application of SJ as diagnostic tool, different squat positions are described in the literature. The knee angle of the initial squat position is reported as self-selected (Amasay, 2008), 75° (Driss *et al.,* 2001), 90° (Moran & Wallace, 2007), 100° (Hasson *et al*., 2004), 110° (Moran & Wallace, 2007) or 120° (Gehri *et al*., 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 and Challis (2007) determined kinematic characteristics and the moments of hip, knee and ankle between deep squat (knee flexion angle: 86.2±16.0°) and preferred squat (knee flexion angle: 105.3±10.3°). 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 the 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 and 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. Since SJ is a technique mostly used for diagnostic purposes and rarely practiced as sports specific movement technique, familiarization is very important in order to get consistent and reliable performance and diagnostic results. Bobbert *et al*. (2008) who investigated five different initial positions, where the volunteers were familiarized only with the self-selected position, stated that the lack of familiarization might be the reason that no significant differences were found between SJ performance of the three lowest initial squat positions. The analysis of the above mentioned studies show, that no specific information could be found about any criterion for sufficient familiarization. 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 condition

(Wisløff *et al.*, 2004) and of bilateral strength differences of lower limbs (Impellizzeri *et al.*, 2007, Newton *et al.*, 2006), the aims of this study were the verification of familiarization based on criterion like Intraclass Correlation Coefficient (ICC) and Standard Error of Measurement (SEM) and the identification of possible differences of performance and dynamic variables at two different initial squat positions, 90° (SJ_{90}°) and 120° (SJ_{120}°) knee angle.

METHODS: Fifteen male volleyball players aged between 14 and 16 years (15.4 ± 0.6 years) with no lower limbs injury history participated in the study. The study consisted of two sessions, with 24-hour interval between familiarization and data collection. The familiarization consisted of three series of 5 jumps for two squat positions (90° and 120° knee angle) with 1 minute of rest between the jumps and three minutes between the series. To avoid any sequence effect, the jumps (SJ_{90}° and SJ_{120}°) were assigned randomly. Prior to the test protocol athletes performed a 5 minutes preparatory activity, consisting of moderate intensity running and aerobic exercises. The test protocol consisted of three randomly performed jumps with maximal intensity from squat positions with 90° or 120° knee angle. The initial position was controlled by measuring the knee angle with a manual goniometer (Noraxon). The rest interval between trials was one minute. The vertical GRF were measured separately for the right and left leg by two synchronized force platforms (*PLA3-1D-7KN/JBAZb, Staniak, Poland*), operating at 1000 Hz. Data acquisition and processing were performed with DasyLab 11 software.
Familiarization was determined by the Intraclass Correlation Coefficient ($ICC_{3,1}$) and the Standard Error of Measurement of the sample, both calculated by ANOVA for repeated measures analysis of variance. According to Weir (2005), the total error reflects systematic and random error (imprecision). That way, ICC is a measurement for the systematic error, which is represented in sport practice as the effect of motor learning. In the case of squat jump as diagnostic tool, motor learning should be concluded before the beginning of the test procedure. In the present study, the systematic error of the five SJ was assessed by a repeated measures analysis of variance (ANOVA). The maximal variation of the random error, which represents the minimal significant difference of measurements (MID),can be calculated as the SEM according to equation 1 (Weir, 2005).

$$MID = SEM \times 1.96 \times \sqrt{2} \qquad (1)$$

SEM = $\sqrt{}$mean square of error (MS error of ANOVA table)

1.96 = z score associated with a 95% Confidence Interval

Based on these criteria for systematic and random errors, the subjects were considered as sufficiently familiarized if the result of ANOVA F-test were not significant (Atkinson & Nevil, 1998) and if the performance were within the limits of Mean ± MID (Claudino et al., 2012), which menas that every trial fell within these performance limits.
Paired t-test was used to compare the jump height and kinetic variables between the two initial positions. The significance level for all analyzes was $p < 0.05$ and the statistical program used was SPSS 18.0.

RESULTS: Table 1 shows the descriptive data and the results of paired t-test (*) for jump height, impulse, impulse duration, time to peak force and peak force. Statistical results showed that peak force was significantly higher for $SJ_{120°}$ than $SJ_{90°}$ position and the time to reach peak force was lower for $SJ_{120°}$ position than $SJ_{90°}$. Impulse and impulse duration showed significantly higher means for $SJ_{90°}$ than for $SJ_{120°}$ position.
The results of ICC with p-value of F-test and the SEM with MID are shown in table 2 and confirm the adequate and sufficient familiarization. The results confirm high reliability of the SJ with different initial squat position because no significant difference between the repetitions could be identified. This means that no further motor learning effect occurred

during the experiment. Furthermore, the performance (jumping height) was within the limits of Mean ± MID, that means within the range of acceptable random error.

TABLE 1

Descriptive statistics and results of paired t-test (*)

I.P.	H (m)		Impulse (N.s)		Fmax (N)		Δt (s)		Δt_{Fmax} (s)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
$SJ_{90°}$	0.30*	0.12	180.2*	27.91	793.7	127.45	0.42*	0.03	0.35*	0.03
$SJ_{120°}$	0.25	0.18	153.7	34.86	1279.6*	259.57	0.26	0.06	0.19	0.07

I.P. – Initial position for squat jump; SD- Standard Deviation; $SJ_{120°}$ - SJ with 120° knee angle; $SJ_{90°}$ - SJ with 90° knee angle. H – Jump Height; Fmax – Peak Force; Δt – Impulse duration; Δt_{Fmax} – Time to Peak Force; * significant differences between groups with $p<0.05$

TABLE 2

Results of ICC, SEM and MID for jump height

	ICC	p-value of F test	SEM (m)	MID (m)	Mean ± MID (m)
$SJ_{90°}$	0.88	0.53	0.03	0.08	0.30 ± 0.08
$SJ_{120°}$	0.87	0.67	0.04	0.11	0.25 ± 0.11

ICC - Intraclass Correlation Coefficient; SEM - Standard Error of Measurement;
MID - Minimal difference; $SJ_{120°}$ - SJ with 120° knee angle; $SJ_{90°}$ - SJ with 90° knee angle.

DISCUSSION: Previous studies from Domire and Challis (2007) found no difference in jump height between 105.3º and 86.2º knee angle of initial squat position. However, Bobbert *et al.* (2008) investigated five positions (P1 = 124.39°, P2 =109.49° self-select = 95.73 °, P4 = 85.99°, P5 = 76.82°), and their results showed lower jump height at positions P1 and P2 than at self-selected, P4 and P5. One explanation given by the authors was that the lack of familiarization with SJ could have affected these results. The results of the present study, where adequate familiarization was verified by objective criteria, showed that the initial position affects SJ performance, and that deeper squat position ($SJ_{90°}$) leads to better jump height. The results corroborate those related by Kirby *et al.* (2011) that lower squat position leads to lower peak reaction force and a longer period to achieve it. Quantitative verification of familiarization by ICC with p-value of F-test and the Standard Error of Measurement permits the confirmation of concluded motor learning process and the estimation of random error that might be caused by different sources as motivation or varying test conditions (Weir, 2005). Results of the present study show that a familiarization that consisted of three series of 5 jumps for each squat position with 1 minute of rest between the jumps and three minutes between the series, is sufficient to ensure adequate test conditions for the experiment performed one day later.

CONCLUSION: Squat Jump performance and kinetic variables of ground reaction forces are related to the initial squat position. Deeper initial squat position up to 90°of knee angle leads to lower peak force and higher vertical impulse, impulse duration and time for peak force. Especially the inverse relation of peak force and vertical impulse (performance) with different squat depths is important and should be considered, since some authors use vertical jumps to analyze peak force (Impellizzeri *et al.*, 2007, Newton *et al.*, 2006), while others (Menzel *et al.*, 2013) consider the impulse as criterion for the analysis of bilateral differences. Familiarization of squat jump and different initial squat positions is essential and should be verified by objective criteria like Minimal Significant Difference of Measurements (MID) and ANOVA F-test.

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