RELIABILITY OF SYMMETRY DIFFERENCES OF DYNAMIC VARIABLES DURING COUNTERMOVEMENT JUMP

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The aim of the study was the determination of the reliability of symmetry differences of peak force, impulse and peak power during Countermovement Jump on a double force platform. The subjects were 12 Brazilian female professional volleyball players who performed five CMJs on a double force platform. Symmetry differences of peak force, impulse and peak power were determined. In order to verify the reliability, the Intraclass Correlation Coefficient was calculated. While symmetry difference of peak force and impulse present an ICC > 0.90, symmetry difference of peak power has only an ICC of 0.77. It can be concluded that the determination of symmetry differences by peak force and impulse during CMJ on a double force platform have higher reliability than symmetry differences of peak power.

KEY WORDS: bilateral differences, countermovement jump, ICC.

INTRODUCTION: The analysis of bilateral strength asymmetry is important because lateral asymmetries may affect performance (Young, James & Montgomery, 2002) and cause higher injury risk (Croisier, Ganteaume, Binet, Genty, & Ferret, 2008). Possible reasons for these asymmetries are specific motor demands of different sports and training methods (Mayer et al., 2003) or an inadequate or uncompleted rehabilitation program. Particularly for volleyball players, who usually have a preferred jumping leg, the analysis of bilateral strength asymmetry, which is the relative difference in strength between the two legs, is an important challenge to reduce the risk of injury (Croisier et al., 2008), to control the rehabilitation process after knee injuries (Dvir, 2004) and the effects of training methods (Mayer, Schlumberger, van Cingel, Henrotin, Laube & Schmidtbleicher, 2003). Common methods for the assessment of strength level and lateral asymmetries of the lower limbs include isokinetic knee extension dynamometry (Impellizzeri et al., 2007; Croisier et al., 2008), function hop and jump tests (Noyes, Barber & Mangine, 1991). The main limitation of isokinetic testing is the constant angular velocity during an open-chain movement, which does not characterize sport movements, in which the angular velocities vary constantly (Mayer et al, 2003). The disadvantage of static measurement, e.g. isometric maximal force, is the low similarity with sport movement patterns which are characterized by constantly changing muscular force. As a consequence of this limitation, the correlations between performance and isokinetic variables are reported to be quite low (Murphy & Wilson, 1996), and diagnostic methods using closed kinetic chain movements, such as vertical jumps, have become more important in the evaluation of athletes, as these movements are more similar to performance in sports (Augustsson & Thomeé, 2000; Newton et al., 2006; Impellizzeri et al., 2007). As the physical demands on volleyball players are composed of vertical jumps and locomotion with maximal acceleration over short distances, countermovement jump (CMJ) tests can be considered a more specific method for performance analysis (Wisløff, Castagna, Helgerud, Jones & Hoff, 2004) than isokinetic tests because of the higher movement similarity.

In the vertical jump test on a force platform, usually the peak ground reaction force (maximal force) is the only variable analyzed to determine lateral differences (Newton et al., 2006; Impellizzeri et al., 2007). Because the propulsion and change of velocity of the human body are mechanically determined by the impulse and not by maximal force, it seems to be essential to include at least the impulse production of each leg in the analysis of bilateral differences of strength.

Variability of movement and performance is a natural biological phenomenon (Hatze, 1986), and bilateral asymmetries are a consequence of this variability. From this perspective, the

methodological problem is the differentiation between natural and dysfunctional bilateral asymmetries.
Behm & Kibele (2007) reported an Intraclass Correlation Coefficient (ICC) for jumping height of CMJ higher than 0.90. But even if the performance of CMJ is highly reliable, the reliability of bilateral differences of dynamic variables must be proofed. Impellizzeri et al. (2007) determined the intraclass correlation coefficient (ICC) for bilateral strength asymmetry by the difference of peak force during CMJ and found an ICC of 0.91. Since the reliability of bilateral differences of impulse and peak power haven't yet been investigated, the aim of this study was the determination of the reliability of symmetry differences of peak force, impulse and peak power during CMJ on a double force platform.

METHODS: The subjects of this study were 12 female professional volleyball players (25.2 ±3.2 y, 180.2 ±5.2 cm, 73.7 ±6.4 kg) from one team competing in the First Brazilian National Volleyball League. 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 CMJs, the subjects performed five CMJs on two side-by-side mounted force platforms (AMTI OR5-6), with a recovery interval of 2 minutes after each trial. 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 registered separately for each leg at a frequency of 1 KHz. The peak force (F_{max}), the impulse (I) (calculated as the breaking impulse of countermovement and the acceleration impulse of upward acceleration minus the downward acceleration impulse of countermovement minus the takeoff deceleration impulse), and the peak power (P_{max}) were determined by the use of the software DASYLab 10.0. The instantaneous power was calculated using the following equation:

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

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 system was calibrated by certified weights before each data collection session and was systematically checked between individual test sessions to ensure that both platforms were measuring equally. A two-pole, low-pass, 1-kHz filter had been set by the manufacturer.
The bilateral strength asymmetry was quantified by the Lateral Symmetry Index (LSI), according to Clark (2001):

*LSI (%)= ((Value of the right limb – Value of the left limb) / greatest value of both limbs)*100*

A positive LSI indicates higher values of the right leg, and a negative LSI indicates higher values of the left leg, independent of the athlete's laterality.
Beside the LSI, that takes into consideration the lateral preference expressed by the positive (+) or negative (-) sign, the bilateral difference without consideration of the laterality (DIF) was also calculated. That way, the value of the variable DIF corresponds to the modulus of the LSI. That variable is also important for the interpretation, because signed values may result in a group mean close to zero while the mean for the modulus might be much higher.
Significant deviation from normal distribution was verified by Shapiro-Wilk test, since normal distribution is a condition for the calculation of ICC in order to verify the reliability of repeated measurements. The ICC was calculated for the bilateral difference of peak force (ΔF), impulse (ΔI), and peak power (ΔP) of the five CMJ and can be interpreted according to Cichetti (1994) 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.

RESULTS: The LSI and the relative differences without considering the direction of prevalence (DIF [%]) are shown in Table 1 and separated according to the variable and the five jumps. According to the results of the Shapiro-Wilk test no variable presented significant deviation from normal distribution.

Table 2 shows the ICC and the corresponding significance level for the repeated determination of symmetry differences of peak force (ΔF), peak power (ΔP) and impulse (ΔI).

Table 1
Mean and sd of LSI and differences (DIF) without considering the laterality

	CMJ	ΔF	ΔP	ΔI
LSI [%]	1	-0.62 ±7.42	6.56 ±27.39	6.47 ±24.64
	2	-0.59 ±6.98	6.08 ±28.09	6.85 ±26.74
	3	-0.64 ±7.27	6.33 ±27.08	6.61 ±26.34
	4	-0.66 ±7.06	6.78 ±27.92	6.09 ±25.37
	5	-0.64 ±6.81	6.72 ±26.45	5.88 ±25.61
DIF [%]	1	5.62 ± 4.31	23.40 ±15.32	20.66 ±14.68
	2	5.97 ± 4.17	22.89 ±16.13	21.23 ±13.88
	3	6.81 ± 4.20	23.16 ±14.92	21.84 ±14.18
	4	6.02 ± 4.52	23.28 ±15.41	22.74 ±15.82
	5	5.84 ± 4.47	23.02 ±16.68	23.17 ±16.02

LSI – Lateral Symmetry Index; DIF – Modulus of Lateral Symmetry Index

Table 2
ICC of symmetry differences of peak force, peak power and impulse

Variable	ICC	p
ΔF	0.91	0.001
ΔP	0.77	0.001
ΔI	0.93	0.001

DISCUSSION: Even though the isokinetic assessment of bilateral strength asymmetry is widely applied, only little information about reliability of this method is available. The study of Impellizzeri et al. (2008) show that the ICC of bilateral quadriceps ratio of the peak torque depends on the angular velocity, varying between 0.43 for 180°/s and 0.78 for 60°/s. These results indicate that the isokinetic assessment is only reliable at lower angular velocities. Because of the higher specificity in relation to sport movements, closed kinetic chain movements like CMJ on force platforms have recently become a tool for the determination of bilateral strength differences. Since force is the corresponding linear mechanical variable to torque at angular movements (like isokinetic measurement), the peak force had become the first variable to be investigated when ground reaction forces were used to identify bilateral strength differences. Impellizzeri et al. (2007) determined an ICC of 0.91 for peak force by five measurements. The present study with nearly the same design, using also 5 measurements, corroborates this result. This means that bilateral difference of peak reaction force has a higher reliability than bilateral difference of peak torque at 60°/s of isokinetic measurement.

Table 1 shows that the mean LSI for ΔF is slightly negative which indicates a mean preference of 0.6% of the left leg concerning maximal force. Nevertheless, this small difference does not seem to have any functional significance because the difference is so close to zero. In contrast, ΔP and ΔI indicate a preference of the right leg of about 6%.

Since the aim of dynamic muscle actions is the alteration of velocity, the impulse is the mechanical variable that determines performance and peak force is only a variable of influence for the impulse. Therefore, the reliability of symmetry difference of impulse and peak power was also determined. The results show that the bilateral difference of impulse presents a slightly higher reliability than difference of peak force. Difference of peak power presents the lowest ICC of the investigated variables, which is close to the ICC of difference of peak torque at 60°/s of isokinetic measurement.

CONCLUSION: The present study determined the reliability of lateral differences of peak force, impulse and peak power during CMJ on a double force platform by means of the ICC of 5 measurements. While symmetry difference of peak force and impulse present the variables with ICC > 0.90, symmetry difference of peak power has only an ICC of 0.77 which corresponds to the reliability of the difference of peak torque at 60^o/s of isokinetic measurement. Based on these findings it can be concluded that the determination of symmetry differences by peak force and impulse during CMJ on a double force platform have the highest reliability of all variables used for the identification of bilateral strength differences.

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