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ASYMMETRIES BETWEEN LOWER LIMBS DURING JUMPING IN FEMALE ELITE ATHLETES FROM THE BRAZILIAN NATIONAL VOLLEYBALL TEAM

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The aim of this study was to assess the asymmetry during jumping between the lower limbs of female elite athletes from the Brazilian National Volleyball team. A biomechanical evaluation of two kinds of jumps (countermovement and drop) was carried out, leading to the calculation of kinetic and kinematic variables, which were related to the athletes' clinical complaints. We found important asymmetries in all athletes, and, in almost cases, it was possible to associate with their complaints. Additionally, the identified movement patterns have been described in the literature as being risky, potentially causing musculoskeletal lesions, or as indicators of a neuromuscular deficit. This investigation was useful in order to set up a physical training regime capable of minimizing asymmetries, and thus, decreasing the joint overload, aiming the prevention of injuries.

KEY WORDS: biomechanics, sport, injury prevention.

INTRODUCTION: Volleyball is one of the sports that can lead to movement asymmetries due to the nature of its training and technical skills. Tillman and Hass (2004), have shown that, in this sport, not only the upper limbs can show asymmetries, but also the lower limbs, since 45% of the offensive landings and 43% of the defensive landings are unilateral (Tillman & Hass, 2004). This difference in the demand between lower limbs is reflected in neuromuscular discrepancies, as for instance in the muscular strength, which has been shown to be asymmetric in elite volleyball athletes (Markou & Vagenas, 2006).
Apart from muscular strength, kinetic and kinematic variables are important factors to be considered as they can be predictors of injuries. Hewett and Myer (2005) assessed 205 female adolescent soccer, basketball and volleyball players, out of whom nine had injured their knee's anterior cruciate ligament (ACL) after a first evaluation involving kinematic and kinetic analyses of the drop jump. The authors found that the knee joint abduction angle, the internal adductor joint moment and the vertical ground reaction force (GRF) during the landing of the drop jump were greater in the injured athletes, indicating that knee joint moment is a good predictor of injury (Hewett & Myer, 2005).
The goal of the present study was to evaluate during jumping the asymmetry between the lower limbs of some Brazilian female players from the Brazilian national volleyball team, who are the current Olympic champions, and to relate the results with their clinical complaints in order to provide quantitative information to evaluate their individual performance and to set up specific physical training regimes.

METHOD: Four athletes from the Brazilian national volleyball team were evaluated: one setter, one middle hitter, one wing-spiker and one outside hitter. The clinical evaluation took into account each athlete's main complaints. To verify for the asymmetry in the inferior limbs, the athletes were asked to perform two kinds of jumps: countermovement (CM) and drop (D) jump, the latter preceded by a landing from a step 35 cm high. They were instructed to jump as high as possible with arms crossed over their chest. Each jump condition was repeated six times.
The kinematics of the participants were registered with a three-dimensional motion analysis system (Vicon 460, Oxford Metrics, Oxford, UK) operating at 120 Hz, and the ground reaction forces were measured with two force plates (OR6-2000, AMTI Inc., Watertown,

USA) operating at 600 Hz embedded in the floor. We modeled the lower limbs and pelvis as rigid solids and described their movements using retro-reflective markers placed bilaterally at anatomical points. For both kinds of jump, the following variables were computed: ranges of motion (ROM) and peaks of net internal joint moment and power of the ankle, knee and hip joints at the preparation phase of the jump. In addition, we calculated the ratio between the peak hip power and the peak knee power (hip-knee ratio for power) and the ratio between the peak hip moment and peak knee moment (hip-knee ratio for moment). For the countermovement jump the jump height, the proportion between eccentric and concentric work, the rate of force development (RFD) and the peak of the vertical component of GRF, this latter in the landing phase, were also calculated. For the drop jump, only the jump height and the peak of vertical GRF (in the landing phase) were calculated. All variables were normalized by the athletes' weight, and the asymmetries between limbs considered relevant were those that exceeded 20%.

RESULTS: All the athletes reported some kind of pain in the lower limbs during their performances and, through an interview, the main complaint was determined for each one. The setter reported pain in the right knee; the middle hitter reported pain in the left ankle; the wing-spiker reported pain in the right knee, and she had also been diagnosed as having chondromalacia (4th degree); and the outside hitter reported bilateral pain in the hips. The relevant asymmetries for each athlete are shown in Table 1. In Figure 1, the time series for the kinematic and kinetic variables for the wing-spiker are reported as representative of our analysis.

Table 1
Mean values (±1SD) for the variables with asymmetry over 20% for each athlete. GRF peak: peak of vertical ground reaction force, RFD: rate of force development, HJM: hip joint moment, KJM: knee joint moment, ROM H/F: range of motion of the hip in the frontal plane, HKRM: Hip-Knee ratio for the joint moment.

Athlete	Task	Variable	Left limb	Right Limb	Difference (%)
Setter	CM JUMP	*HKRM*	-2.84±0.17	-2.35±0.31	20 %
	D JUMP	*GRF peak*	1.19±0.26	1.66±0.41	23%
Middle Hitter	CM JUMP	*RFD*	2.64±1.37	1.15±0.57	56%
		HJM	-2.89±0.12	-2.21±0.22	30%
		KJM	2.12±0.07	1.66±0.13	21%
	D JUMP	*GRF peak*	2.52±0.54	1.90±0.34	23%
Wing-Spiker	CM JUMP	*RFD*	4.32±2.27	2.15±1.15	50%
		GRF peak	2.32±0.35	1.69±0.55	27%
		HJM	-1.04±0.04	-0.61±0.03	71%
		KJM	0.17±0.05	0.31±0.06	31%
	D JUMP	*GRF peak*	2.25±0.37	1.67±0.39	25%
		HJM	-0.99±0.10	-0.78±0.21	26%
Outside Hitter	CM JUMP	*ROM H/F*	20.00±3.23	9.55±1.56	52%
	D JUMP	*ROM H/F*	19.41±3.29	13.66±2.18	30%
		KJM	0.16±0.06	-0.18±0.10	212%

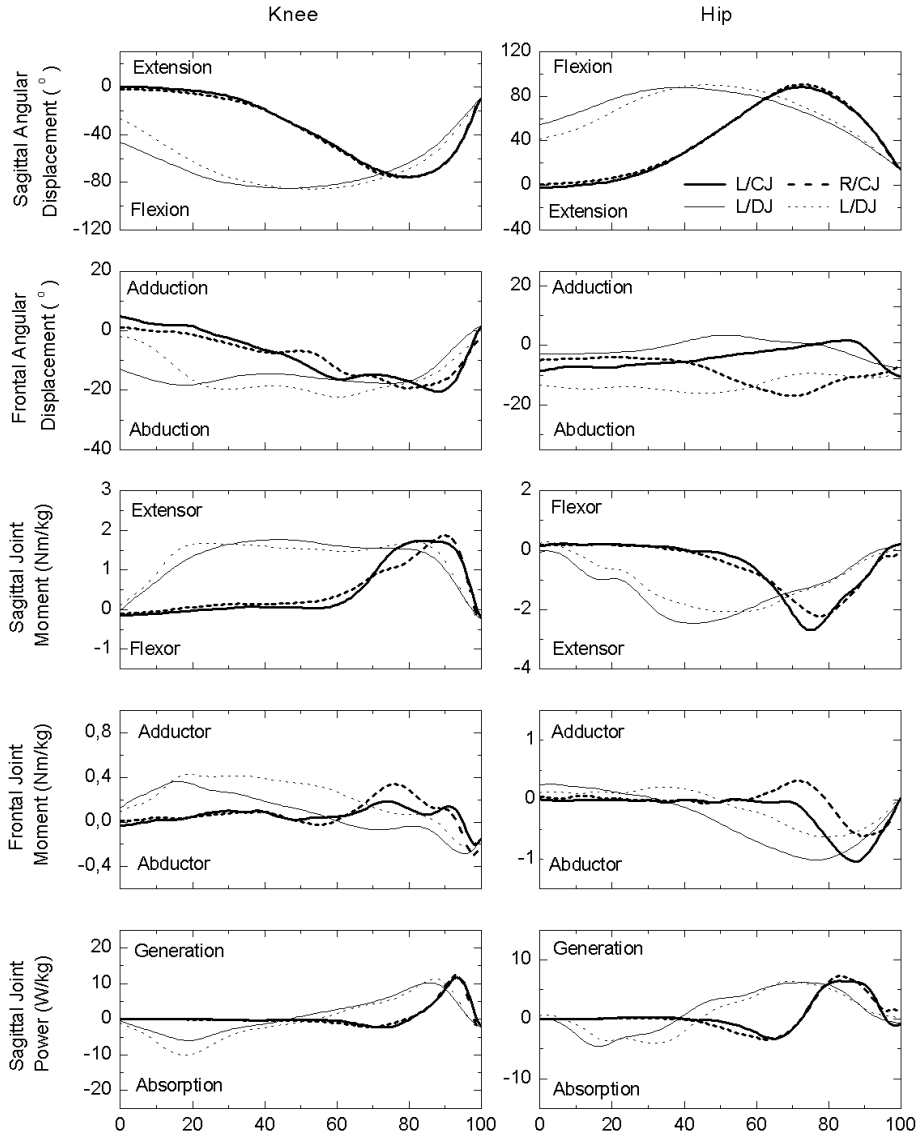

Figure 1: Time series of variables during the preparation phase (%) of the jump. L: left limb. R: right limb, CJ: countermovement jump, DJ: drop jump.

DISCUSSION: The results showed considerable asymmetries between the lower limbs of these elite female volleyball athletes concerning kinetic and kinematic variables (Table 1). Although only four athletes were evaluated, the asymmetries found corroborated the idea that the technical movement pattern can lead to asymmetries in the inferior limbs of volleyball players, as has been shown previously when muscular strength was the variable considered (Markou & Vagenas, 2006)..

The setter, who plays in a position where most jumps are symmetrical (both lower limbs act together), showed important asymmetries in less variables than the other players. Nevertheless, she showed an overload on her right knee when landing from the drop jump.

Moreover, the hip-knee ratio for moment in the countermovement jump was greater than 2 for both limbs. The right knee overload seems to be related with her pain complaint about this knee. In addition, the values of the hip-knee ratio for the moment calculated for both limbs was similar to the values reported by Salem and Salinas (2003) in a situation of neuromuscular deficit in the lower limb. As reported by this author, the results indicate that during the task the hip is greatly exerted, as compared with the knee, as a means of protecting the knee.

The middle hitter presented asymmetries mainly in variables related to the development of the jump, such as the strength development rate and the extensor moment (with greater values for the left side), which may be contributing to the athlete's complaints about pain in her left ankle. The knee-hip ratio for power revealed that the athlete requires the hip more than the knee in the right lower limb in comparison to the left limb. However, this asymmetry was not related with the athlete's complaints.

The results for the wing-spiker indicated that the knee adductor moment was 31% greater in the right side during the CJ, although, during the same task, the rate of force development and the hip abductor moment were greater in the left side (Figure 1). The results gathered here are in accord with some findings in the literature which point to an increased knee adductor moment as a predictor of injury and the hip abductor moment and an increased vertical GRF peak as correlated variables (Hewett & Myer, 2005), since this athlete had a rupture of the right anterior cruciate ligament after this evaluation, and she'd already presented chondromalacia in the same knee. Despite the athlete presenting an increased knee adductor moment on the right knee, indicating risk of injury on this side, the correlated variables were greater for the left lower limb, suggesting that in certain situations the athlete could be avoiding stressing the right lower limb which was subject of pain complaints.

The major asymmetry in the knee joint moment in the frontal plane was observed in the outside hitter during the drop jump. The results for this player showed an internal abductor moment acting on the knee during most of the preparation phase of the drop jump while an internal adductor moment acted on the left knee at same phase. This asymmetry in the knee frontal moment can be related with the asymmetry observed in the range of motion of her knee in the frontal plane (which was the greatest of all the four players above); during the drop jump the outside hitter developed the greater valgus in the left knee (this movement corresponding to an abduction of the knee an adduction of the hip) and an increase in the valgus angle has been shown to be related with an increase in the knee adductor moment (Hewett & Myer, 2005).

CONCLUSION: This work showed that Brazilian elite female volleyball players presented important asymmetries in lower limbs and these asymmetries could be related to their clinical complaints and injuries. Although this study provided useful information that could be used to evaluate the athletes' performance and to prescribe physical training regime capable of minimizing the individual asymmetries and decrease the joint overload, it is impossible to extend these results to other volleyball players since only four athletes were evaluated.

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