SIDE-TO-SIDE ASYMMETRY OF LANDING KINETICS IN HEAVY AND LIGHT BASKETBALL PLAYERS DURING A DROP LANDING

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This study examined (1) the effect of body mass on impact forces during drop landings in basketball players, and (2) side-to-side asymmetry in landing kinetics between legs. Thirty male basketball players were assigned into "heavy" (n = 15, mass 82.7 ± 4.3 kg) or "light" (n = 15, mass 63.1 ± 2.8 kg) groups. Players performed five drop landings from a 0.42 m platform. Vertical ground reaction forces for both legs were sampled using two adjacent and embedded force plates. A mixed factorial analysis of variance (Body Mass × Side) was applied to normalised peak force and loading rate variables ($\alpha = .05$). The left leg experienced higher forefoot peak force (15.9%, $p = .001$), forefoot mean loading rate (10.9%, $p = .007$) and rearfoot mean loading rate (11.8%, $p = .014$) than the right leg, suggesting that side-to-side asymmetry exists. No body mass effect was found.

KEY WORDS: body mass, impact, ground reaction force, bilateral symmetry.

INTRODUCTION: Basketball is a sport which involves several jumping-related movements. As a result, it places a considerable amount of stress on the lower extremities of players. Vertical impact forces associated with landings in basketball movements have been found to be up to nine times an individual's body weight (McClay et al., 1994); and an inability to effectively attenuate these forces might lead to injury (Lephart, 2002). Several external risk factors of lower-limb injuries in basketball have been widely studied including the type of shoe worn (McKay, Goldie, Payne & Oakes, 2001) and playing position (Vanderlei et al., 2013). Fewer studies have focused on individual factors such as a player's physical and movement characteristics. Hreljac (1998) compared landing forces during a lateral jump task and found "morphogically diverse" participants to have distinct impact responses. Heavier players were also found to experience higher normalised impact forces than lighter players when performing a basketball layup (Nin, Lam & Kong, 2016). This suggests that body mass would play a role in influencing the risk of injury in basketball.

Several basketball movements such as the jump-shot and shot-block involve double-leg landings; and bilateral asymmetry of these landings has been associated with lower-limb injuries (Hewett et al., 2005). When landing from a jump, females were found to exhibit a higher degree of side-to-side asymmetry compared to males (Pappas & Carpes, 2012) and this may be due to the different landing strategies adopted by both genders (Decker, Torry, Wyland, Sterett & Steadman, 2003). However, considering the substantial difference in body mass between genders in these studies (e.g. males: 84 (11) kg vs females: 59 (7) kg, Pappas & Carpes, 2012), it is possible that body mass, rather than gender, contributed to the observed differences in landing asymmetry.

Basketball is a team sport with players of different physical traits (e.g. bigger stature of a centre player compared to a forward player). To better understand the injury risk among basketball players, it would be useful to investigate whether body mass would affect landing forces and side-to-side asymmetry between legs. Thus, the purpose of this study was to examine (1) the effect of body mass on normalised impact forces during drop landings in basketball players and (2) side-to-side asymmetry in landing kinetics between legs. It was hypothesised that heavier players would experience higher normalised impact forces and land with greater bilateral asymmetry.

METHODS: Thirty male university basketball players (age = 21.8 (2.8) years) with a minimum of five years of competitive playing experience participated in this study. Participants were evenly assigned to either "heavy" (n = 15, body mass = 82.7 (4.3) kg, height = 1.81 (0.03) m) or “light” (n = 15, body mass = 63.1 (2.8) kg, height = 1.74 (0.04) m) groups according to body mass (mean difference = 19.6 kg, 95% CI [16.8, 22.3], $P < .001$). The inclusion criteria for the “heavy” and “light” groups were a body mass of above 78 kg and below 66 kg respectively. All players were right-handed shooters. Participants performed five step-off drop landings from a 0.42 m (Makaruk & Sacewicz, 2011) platform in standard test shoes (Li Ning, 42 Shore C). The movement sequence for the drop landing is shown in Figure 1. Vertical ground reaction force (VGRF) for both legs was sampled at 1000 Hz using two 0.9 m by 0.9 m wooden-top force plates (Advanced Mechanical Technology Inc, Watertown, MA, USA) embedded adjacent to each other.

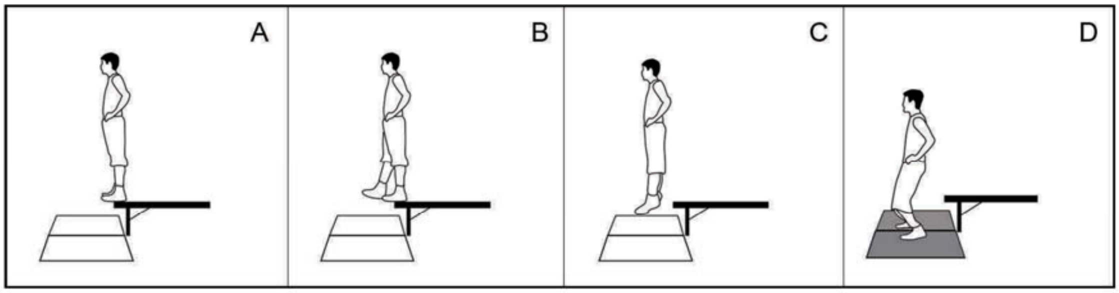

Figure 1: Movement sequence for drop landing task. A: Starting position on raised platform (0.42m); B: Forward step with right foot to initiate movement; C: Flight phase; D: Landing with both legs on adjacent embedded force platforms.

A custom MATLAB (Mathworks, Inc., Natwick, MA, USA) code was used to process all kinetic data. Raw VGRF data were passed through a fourth-order Butterworth low-pass filter. Cut-off frequency was set at 150 Hz based on previous similar studies (Sell et al., 2006) and visual inspection. The onset of the impact phase was determined when the VGRF exceeded a 10 N threshold. All data were normalised to body weight by division. Peak VGRFs and mean loading rates (0% to 100% before each impact peak) during forefoot and rearfoot contact for both legs were calculated (Figure 2). A mixed factorial analysis of variance (Body Mass × Side) was applied to all normalised kinetic variables ($\alpha = .05$).

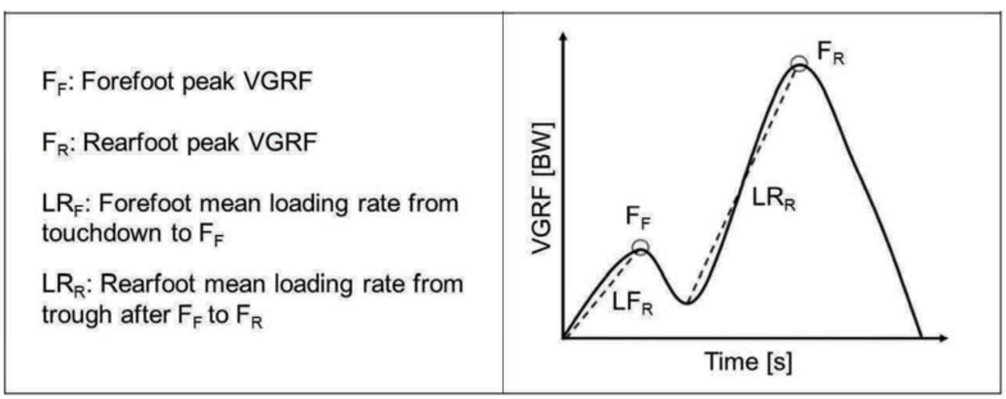

Figure 2. Definition of kinetic variables obtained from vertical ground reaction forces (VGRF).

RESULTS: When comparing between the “heavy” and “light” groups, no significant difference in any normalised kinetic variables was found (Table 1). Side-to-side asymmetry was observed in three out of four variables. The left leg experienced higher forefoot peak force (15.9%), forefoot mean loading rate (10.9%) and rearfoot mean loading rate (11.8%) than the right leg (Table 1). There was no significant Body Mass × Side interaction observed in any kinetic variable.

Table 1
Normalised kinetic variables expressed in mean (standard deviation). All forces are in units of body weight [BW] and mean loading rates are in units of body weight per second [BW/s].

	Left	Right	ANOVA Results								
			Side			Group			Interaction		
			P	η2	B	*P*	η2	β	*P*	η2	β
Forefoot peak force											
H	1.26 (0.26)	1.09 (0.22)	**.001**	.346	.960	.372	.029	.142	.792	.003	.058
L	1.36 (0.40)	1.17 (0.25)									
Rearfoot peak force											
H	3.65 (0.92)	3.45 (1.05)	.129	.081	.327	.869	.001	.053	.977	.000	.050
L	3.61 (0.57)	3.40 (0.97)									
Forefoot mean loading rate											
H	94.77 (19.87)	85.94 (19.14)	**.007**	.234	.806	.827	.002	.055	.855	.001	.054
L	96.90 (25.33)	86.88 (18.99)									
Rearfoot mean loading rate											
H	129.32 (54.36)	117.48 (56.25)	**.014**	.197	.716	.679	.006	.069	.671	.007	.070
L	139.05 (39.80)	122.58 (51.14)									

Notes: L = light; H = heavy; η2 = partial eta squared; β = observed power. Significant *P*-values ($P < .05$) are shown in bold.

DISCUSSION: The purpose of this study was to investigate the effect of body mass on impact forces during drop landings in basketball players and the asymmetry of these landings. Contrary to our hypotheses, body mass did not have an effect on landing kinetics or bilateral asymmetry. Both "heavy" and "light" players showed consistent side-to-side asymmetry in impact forces from a drop landing.

Our findings suggest that when basketball players perform a drop landing, side-to-side asymmetry exists regardless of body mass. Compared to the right leg, the left leg exhibited higher loading rates and forefoot peak force for both "heavy" and "light" groups. This result challenges the findings of previous studies which have either investigated the kinetics of drop landings with a double-leg contact on one force platform (Blackburn & Padua, 2008) or only obtained information from a single side (Decker et al., 2003). Although these studies provided insightful information on landing kinetics, the bilateral symmetry of landings should not be assumed in the interpretation of results. As the drop landing movement was initiated with a step-off using the right leg in this study, this observed asymmetry may be due to a procedural effect. While the exact mechanism was not specifically investigated, the step-off leg was able to more effectively attenuate impact forces than the contralateral leg. It was possible that the choice of step-off leg affected the order of foot contact with the force plates and the use of high speed video analyses in future studies would be necessary to confirm this effect. To better understand why bilateral asymmetry exists, it would also be necessary for further examination of side-to-side differences when initiating the drop landing movement with either foot.

In addition to the procedural effect, another possible explanation for the side-to-side asymmetry observed could be the inherent movement characteristics of basketball players. All participants in this study were right-handed (i.e. executed basketball shots with the right hand). This meant that the side-to-side asymmetry in landing forces was directed towards the non-shooting side. Although some studies have identified explosive force imbalances at the lower-limbs among basketball players (Schiltz et al., 2009), none of the studies have looked at the relationship of these imbalances with shooting-side preference. It is possible that this asymmetry might have resulted from prolonged participation in a sport which relies predominantly on unilateral upper-limb movement, for example, dribbling and shooting in basketball. It is possible that in the kinetic chain of different basketball movements, an extensive unilateral upper-limb usage might have an imbalanced strengthening effect on the lower-limbs, resulting in asymmetrical impact attenuation between legs. Future studies should consider investigating the effect of upper-limb dominance/preference on lower-limb biomechanics.

Based on the current findings, studies examining limb asymmetry should also provide clear standardised guidelines defining limb side. Concepts of "preferred" and "dominant" sides are often interchangeably used in literature, making it challenging to reconcile the results of different studies meaningfully. The authors suggest differentiating between "shooting" and "non-shooting" sides, which might be more relevant for sports where the unilateral upper-limb movement of individuals characterises play (e.g. basketball and handball).

Additionally, body mass did not have an effect on landing forces which suggests that individuals of different morphological characteristics adopt similar landing strategies from a drop landing. It would be useful for future studies to further investigate this effect across different drop heights and from different landing tasks.

CONCLUSION: Basketball players exhibited side-to-side asymmetry during double-leg drop landings, with the left side experiencing higher impact loading than the right side. Body mass has minimal effect on landing kinetic or side-to-side asymmetry. Future studies should examine the procedural effect of the choice of step-off leg in drop landings and the influence of prolonged unilateral upper limb use on lower limb biomechanics.

REFERENCES:

Blackburn, J. T., & Padua, D. A. (2008). Influence of trunk flexion on hip and knee joint kinematics during a controlled drop landing. *Clinical Biomechanics, 23*(3), 313-319.

Decker, M. J., Torry, M. R., Wyland, D. J., Sterett, W. I., & Richard Steadman, J. (2003). Gender differences in lower extremity kinematics, kinetics and energy absorption during landing. *Clinical Biomechanics (Bristol, Avon), 18*(7), 662–669.

Hewett, T. E., Myer, G. D., Ford, K. R., Heidt, R. S. Jr., Colosimo, A. J., McLean, S. G. ... Succop, P. (2005). Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. *American Journal of Sports Medicine, 33*(4), 492-501.

Hreljac, A. (1998). Individual effects on biomechanical variables during landing in tennis shoes with varying midsole density. *Journal of Sports Sciences, 16*, 531–537.

Lephart, S. (2002). Sensorimotor system 1: Physiological basis of joint stability. *Journal of Athletic Training, 37*, 71–79.

Makaruk, H., & Sacewicz, T. (2011). The effect of drop height and body mass on drop jump intensity. *Biology of Sport, 28*(1), 63–67.

McKay, G. D., Goldie, P. A., Payne, W. R., & Oakes, B. W. (2001). Ankle injuries in basketball: Injury rate and risk factors. *British Journal of Sports Medicine, 35*, 103–108.

Nin, Z. D., Lam, W. K., & Kong, P. W. (2016). Effect of body mass and midsole hardness on kinetic and perceptual variables during basketball landing manoeuvres. *Journal of Sports Sciences, 34*(8),*756-765.*

Pappas, E., & Carpes, F. P. (2012). Lower extremity kinematic asymmetry in male and female athletes performing jump-landing tasks. *Journal of Science and Medicine in Sport, 15,* 87-92.

Schiltz, M., Lehance, C., Maquet, D., Bury, T., Crielaard, J. M., & Crossier J. L. (2009). Explosive strength imbalances in professional basketball players. *Journal of Athletic Training, 44*(1), 39.

Sell, T. C., Ferris, C. M., Abt, J. P., Tsai, Y. S., Myers, J. B., Fu, F. H., & Lephard, S. M. (2006). The effect of direction and reaction on the neuromuscular and biomechanical characteristics of the knee during tasks that simulate the noncontact anterior cruciate ligament injury mechanism. *American Journal of Sports Medicine, 34*(1), 43–54.

Vanderlei, F. M., Bastos, F. M., de Lemes, I. R., Vanderlei, L. C. M., Junior, J. M., & Pastre, C. M. (2013). Sports injuries among adolescent basketball players according to position on the court. *International Archives of Medicine, 6*(5), 1-4. doi:10.1186/1755-7682-6-5.