BIOMECHANICAL DIFFERENCES DURING LANDING BETWEEN INDIVIDUALS WITH PROXIMAL AND COMBINED DEVIATIONS DURING LATERAL STEP DOWN

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We investigated the 3D biomechanical differences during landing between those who have proximal (PRO) only (frontal pelvis drop down) and combined (COM) proximal and distal (frontal pelvis drop down and medial knee displacement to 2nd toe) deviations during the lateral step down (LSD) test. Sixty-one recreational male athletes were assessed and those who met the criteria for the groups were tested in a 3D biomechanical laboratory (bilateral drop jump, unilateral forward and drop jump). We found higher hip abduction in the COM group during bilateral drop landings. The COM group also showed lower peak ground reaction force, higher impact absorption rate and higher knee frontal angular velocity during unilateral landings. Participants with LSD proximal and combined deviations differ on key kinetics during unilateral drop landings and hip kinematics during bilateral drop landings.

KEYWORDS: knee, adult, sports medicine, physiotherapy.

INTRODUCTION: The lateral step down (LSD) is a clinical test that assesses movement quality mainly used in healthy individuals (Silva et al., 2019). It is easy to perform in a clinical environment (Silva et al., 2019), and is used to assess arm strategy, trunk and pelvic alignment, knee position, and steady stance (Rabin et al., 2014). Pelvis horizontal plane loss and knee medialization are the most frequent compensations seen in the LSD performance (Rabin et al., 2014). A poor LSD performance is associated with lower knee extension and hip external rotation strength (Rabin et al., 2014), increased hip adduction and internal rotation (Mostaed et al., 2018). The activation of hip abductors and adductors to stabilize the pelvis (Gottschall et al., 2012) seems crucial to control step down movement. In this regard, LSD scores improve after strengthening of hip and trunk muscles (Araujo et al., 2017).
Movement patterns in performance of clinical tests could help to stratify individuals, especially when it comes to injury risk during sports activities. Alterations in movement kinetics and kinematics during landings can increase the risk of injuries in sports like floorball and basketball (Leppanen et al., 2017), and improving the application of clinical tests can help guide their use. However, the biomechanical differences during high risk athletic maneuvers (such as landing from a jump) between those who demonstrate proximal and combined proximal and distal deviations in the LSD test are currently unclear. This study investigated the 3D biomechanical differences during landing between those who have proximal (PRO) only (frontal pelvis drop down) and combined (COM) proximal and distal (frontal pelvis drop down and medial knee displacement to 2nd toe) deviations during the LSD.

METHODS: Recreational male athletes between 18 and 30 years old were recruited by convenience for this study. They were free of acute lower extremity injuries at least for the past six months, with no history of surgery or ligament/tendon ruptures in the lower extremity or neurological or musculoskeletal condition that could impair jump performance. Participants were excluded if their body mass index (BMI) was >35kg/m². The local institutional ethics committee approved this research (protocol number: 96793518.3.0000.5323) and all procedures followed the declaration of Helsinki.
One visit to the laboratory was needed for assessments. History and anthropometric measurements (body mass, height) were taken. Lateral step down task was performed with a box height varying according to height following previous study (Jones et al., 2014). An experienced assessor was 3m from the box, assessing one sequence of five-step downs. After the LSD test assessment, participants with no deviations were excluded from further investigation and the remaining participants were classified into the PRO and COM groups.

There were no demographic or anthropometric differences between the two groups (Table 1). Legs were classified as preferred and non-preferred by the preference to kick a ball.
For the biomechanical assessment of unilateral and bilateral drop jumps, the participants were standing upright on the top of a rigid box 30cm or 40cm high, respectively. They were instructed to drop off and immediately jump as high as possible, performing a countermovement and landing on a force plate (OR6-2000, AMTI Inc., USA). The second landing was analyzed. The motion was captured with 15 cameras (Bonita B10, VICON Motion Systems, Oxford, UK), sampling kinematic at 200 Hz and kinetic data at 3,000 Hz. According to the Plug-in Gait Full-Body model adapted, reference markers were fixed to participant's body. For unilateral forward jump assessment, participants stood on a force plate with the hands on waist and should jump as high as possible before landing on a second force platform placed in front of them.
At least three successful trials for each jump were recorded for each participant. A trial was successful when participants landed with one leg on each force platform without losing balance or double hopping. Kinematic and kinetic data were low pass filtered by a 4^{th} order zero-lag Butterworth filter with a cut-off frequency of 6Hz for forward and 8 Hz for drop jumps. Outcomes determined at the initial contact (IC, threshold of 50 N) and maximal knee flexion (MF) were: knee and hip angles in sagittal and frontal planes, knee moment in sagittal and frontal plane. In the landing phase measures determined were peak of knee and hip frontal plane angles, knee abduction moment, and vertical component of ground reaction force (GRF); frontal plane knee range of motion, time between IC and GRF peak, GRF impact absorption rate and sagittal and frontal planes knee angular velocity.
Demographic characteristics were compared between groups with an independent t-test. Kinematics and kinetics outcomes were compared between groups for each leg independently with an independent t-test or Mann-Whitney test (according to Shapiro-Wilk normality), considering a significance level of 0.05. The cohen effect size (*d*) was computed with interpretation: small to ≤0,2, medium between 0,2 and 0,5, and large to ≥0,8.

RESULTS: Sixty-one individuals took part in the study. Two participants were excluded due to BMI>35kg/m², and 8-9 according to LSD score of each leg. Additionally, 4-11 participants were excluded during group matching (see Figure 1) and four were unable to perform the unilateral drop jumps.

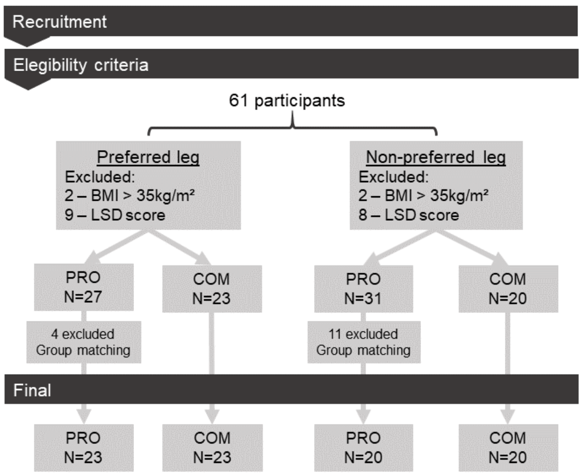

Figure 1: Flow diagram of the eligibility criteria. PRO: proximal deviations group; COM: combined deviations group; LSD: lateral step down; BMI: body mass index.

COM group presented a higher hip frontal angle at MF in preferred leg during bilateral drop jump (p=0.035, *d*=4.214, Figure 2). For unilateral drop jump, COM group presented decreased time to GRF peak (p=0.009, *d*=3.922, Figure 3A), increased impact absorption rate (p=0.020, *d*=3.470, Figure 3B) and knee frontal plane angular velocity (p=0.040, *d*=3.723, Figure 3C) in non-preferred leg. We did not find any differences between groups in the forward jump (p≥0.068).

Table 1. Participants characteristics. Data are presented as mean (DP; min-max).

	Legs					
	Preferred (n=46)		p value between groups*	Non-preferred (n=40)		p value between groups*
Characteristics	PRO	COM		PRO	COM	
Age (years)	25 (1; 19-30)	24 (1; 18-30)	0.134	25 (1; 19-30)	24 (1; 18-30)	0.314
Body mass (kg)	80 (2; 58-100)	78 (2; 52-107)	0.524	81 (2; 66-95)	80 (3; 52-107)	0.757
Height (cm)	176 (1; 162-192)	177 (1; 166-192)	0.953	178 (1; 170-192)	177 (1; 164-192)	0.424
BMI (kg/m²)	26 (1; 21-32)	25 (1; 18-29)	0.418	25 (1; 21-29)	25 (1; 18-33)	0.922

PRO: proximal deviations group; COM: combined deviations group; BMI: body mass index; *Independent t-test.

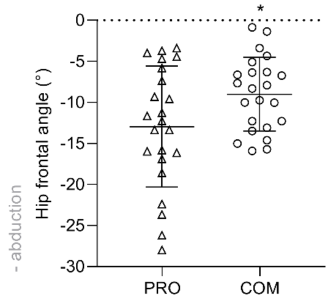

Figure 1. Hip abduction at maximal knee flexion in preferred leg during bilateral drop jump. The central line represents the mean value and dispersion lines to DP. PRO: proximal deviations group; COM: combined deviations group. * difference between groups.

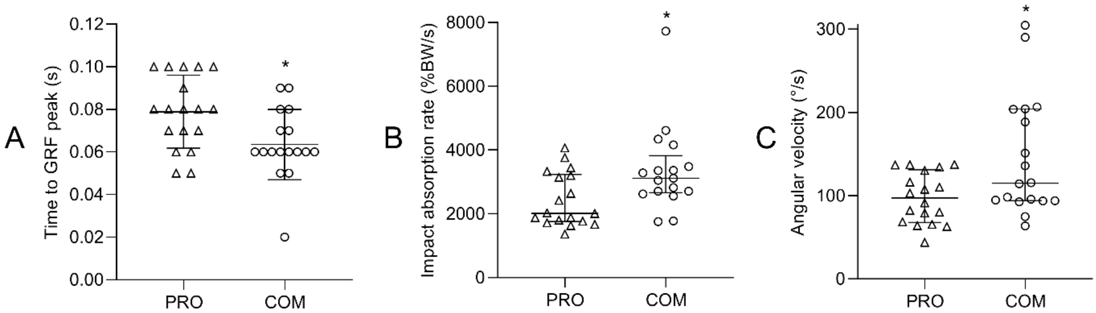

Figure 3. Outcomes of impact absorption in non-preferred leg during unilateral drop jump. A: Central line represents the mean value and dispersion lines to DP. B-C: Central line represents the median value and dispersion lines to interquartile. PRO: proximal deviations group; COM: combined deviations group. * difference between groups.

DISCUSSION: We identified key biomechanical differences between the groups that demonstrated proximal only deviations and the group that had both proximal and distal deviations at the LSD test. The combined group seems to land with biomechanics characteristics that may increase injury risk during unilateral drop landing.

Landing from a drop jump is dependent on strength production (Struzik et al., 2016) and range of motion (Maloney et al., 2018). These outcomes are related to better quality of movement (Rabin et al., 2014). It may help explaining individuals with combined scores showing worse impact absorption in unilateral drop jump. This compensation on COM group may increase injury risk related to landings strategies as worse landing absorption is associated with a high risk of injury (Leppanen et al., 2017).

LSD may have specific relation with performance of unilateral jump landing. As step-down tasks, squat movements elicit larger hip flexion, knee flexion, knee abduction, and hip abduction (Donohue et al., 2015). Besides that, the jumping tasks are substantially different. Unilateral jumps presented lower knee and hip flexion, hip abduction (Donohue et al., 2015; Taylor et al., 2016), and higher knee valgus (Pappas et al., 2007) than bilateral jumps. Forward jump also presented a different pattern from bilateral drop jump, lower knee and hip flexion, and higher hip abduction (Heebner et al., 2017). In sports practice there are several kinds of jumps; those different kinematics strategies between jumps can elucidate our different findings.

CONCLUSION: We identified key biomechanical differences between a group showing proximal only deviations and a group showing both proximal and distal deviations during the LSD. Male recreational athletes showing both proximal and distal deviations during the LSD performed landing tasks in a way that may increase the risk for injury in landing tasks common in sports practice. The grioup with combined deviations on LSD demonstrate lower hip abduction of the preferred leg and worse impact absorption of the non-preferred leg. We suggest special attention for LSD outcomes for preferred and non-preferred leg considering hip kinematics and impact absorption, respectively.

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