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KINETIC AND KINEMATIC SYMMETRY DURING UNLOADED AND LOADED STATIC JUMPS

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INTRODUCTION: Research on the topic of strength symmetry and asymmetry has been gaining popularity (Bailey et al., 2013, Benjanuvatra et al., 2013, Seibert et al., 2013). Much of the research has targeted possible relationships between strength asymmetry and injury, but the results remain unclear (Bennell et al., 1998, Knapik et al., 1991, Nadler et al., 2001).

Others have analyzed the relationship between symmetry and performance (Bailey et al. 2013, Yoshioka et al. 2011). In a simulation study, Yoshioka and colleagues found that bilateral strength asymmetry would not cause substantial alterations in jump height (JH) as the stronger leg compensated for the weaker leg. Even if the JH is unaffected, the direction of the center of mass displacement (COMd) may be altered. Many assume a strictly vertical direction for COMd, but an asymmetrical force production may result in increases in mediolateral or anteroposterior COMd. Unlike Yoshioka, Bailey et al. (2013) showed moderate to strong negative relationships between strength asymmetry and both jump height and peak power.

There also seems to be a paucity of research in the area of joint symmetry from a kinematic standpoint and its relationship with performance. Recently, Dai et al. (2013) found that ground reaction force asymmetry during stop-jumps could predict peak and average knee joint moment asymmetry in subjects who recently underwent ACL reconstruction, but the study did not report further on kinematic data. Thus, there is a need for further research examining the relationship between force production symmetry, kinematic symmetry and jumping performance. The purpose of this study was to determine if force production symmetry is related to measures of kinematic symmetry at the hip, knee and ankle. A secondary purpose was to determine if relationships exist between force production symmetry and COMd.

METHODS: Sixteen NCAA Division I baseball players participated in this study. All subjects read and signed informed consent documents approved by the University Institutional Review Board. Prior to activity, the subjects performed a standardized warm-up which consisted of 25 jumping jacks, one set of five mid-thigh pulls with 20 kg, and three sets of five mid-thigh pulls with 60 kg. Athletes then completed unloaded and lightly-loaded (20 kg bar) static jumps (SJ). Prior to each jump condition, athletes performed familiarization trials at 50% and 75% of perceived effort. Approximately one minute of rest was allowed between jumps and two jump trials were completed at each weight. A PVC pipe was used during the unloaded SJ and its weight was considered negligible. There was no arm swing in either of the jump conditions as either the PVC pipe or 20 kg bar was held by the hands just below the 7th cervical vertebrae. During both jump conditions the athlete descended to a position that was previously measured at 90° knee flexion and jumped once the command was given. Trials were considered successful if there was no detectable countermovement.

Along with the kinematic data, concurrent kinetic data were collected by two portable force plates (0.36 m x 0.36 m, PASCO Scientific PS-2142, Roseville, CA) collecting at 1,000 Hz. Variables derived from kinetic measurement included maximum propulsive force (MPF) and MPF symmetry index score (MPF-SI). The symmetry index score was calculated with the formula shown previously by Sato and Heise (2012), where SI = (larger value – smaller value)/total value * 100. The result was a percentage where 0% represented perfect symmetry and asymmetry increased with values away from zero. Kinematic data was collected via a six camera infrared 3D motion capture system during all jumps (Vicon Nexus, ver. 1.85, Centennial, CO). Prior to testing, reflective markers were placed on each athlete according to the full-body "Plug-in-Gait" model. Kinematic variables included joint (hip, knee, and ankle) range of motion (ROM), peak angular velocities (PV) and peak angular accelerations (PA), joint positions at which PV and PA occurred (deg@PV, deg@PA) and SI scores for all of the aforementioned kinematic variables. Data were collected at 200 Hz and raw position data were smoothed with a Woltring filter with the cut-off frequency established by an optimization method programmed into the motion capture software (Woltring 1985).

Pearson correlations were used to evaluate the relationships between kinetic and kinematic symmetry measures and to evaluate the relationship between force production symmetry and COMd in the mediolateral or anteroposterior directions. Statistical significance was set at $p \leq 0.05$.

RESULTS: Results from the Pearson correlations of both jump conditions are in Tables 1 and 2 below. Table 1 displays correlation values between MPF SI (0 kg and 20 kg conditions) and kinematic variable SI scores. Table 2 displays correlation values between MPF-SI and COMd in either the anteroposterior or mediolateral directions.

Table 1: Correlation Matrices between MPFSI and kinematic variables SI scores

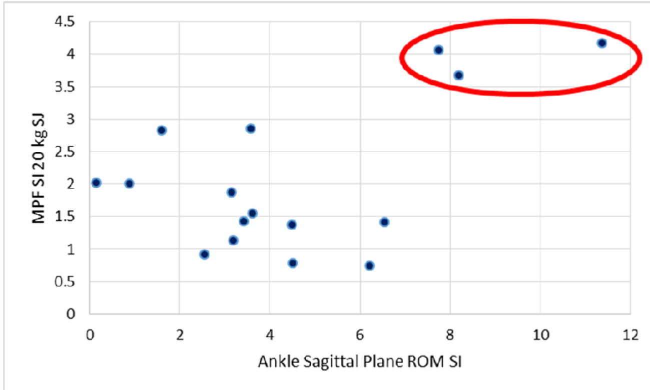
		MPF 0kg SI	MPF 20kg SI
Hip Kinematics	ROM	0.06	0.17
	PV	-0.19	0.08
	deg@PV	-0.17	0.06
	PA	-0.03	-0.32
	deg@PA	0.06	0.35
Knee Kinematics	ROM	-0.26	-0.01
	PV	-0.28	-0.13
	deg@PV	0.49*	0.39
	PA	-0.28	0.13
	deg@PA	-0.32	0.03
Ankle Kinematics	ROM	-0.11	0.51*
	PV	-0.1	-0.07
	deg@PV	-0.26	-0.14
	PA	0.04	0.11
	deg@PA	0.24	-0.15

Table 2. Correlations between center of mass displacement and max push force symmetry index score

	A/P COMd	M/L COMd
MPF 0kg SI	0.12	-0.01
MPF 20kg SI	-0.12	-0.16

A/P = anteroposterior, M/L = mediolateral, * indicates statistical significance ($p \leq 0.05$)

DISCUSSION: This study primarily sought to evaluate the relationship between selected kinematic variables, SI scores and ground reaction force symmetry during static jumps. Results showed a statistically significant and strong correlation between MPF SI and ankle sagittal plane ROM ($r=0.51$) in the 20 kg jump condition, but not in the 0 kg condition. One should be cautioned when considering the strength of this relationship, as a scatter plot (below) reveals one large grouping and three outliers which are likely inflating the magnitude of the relationship. The data for these three subjects only appear as outliers in this relationship, thus, they were not removed.



A statistically significant moderate relationship (r=0.49) was observed between MPF SI and knee deg@PV for the 0 kg jump condition, while a moderate relationship (r=0.39) that did not reach statistical significance was observed in the 20 kg condition. It appears that the symmetry of the position at which PV occurs is the only variable related to MPF SI.

A secondary purpose of this study was to evaluate the relationship of COMd and force production symmetry. Neither direction of COMd (anteroposterior or mediolateral) produced meaningful relationships with MPF SI. It appears that MPF SI was not related to alterations in COMd during either jump condition.

The lack of statistically significant relationships observed may indicate that either force production symmetry is not related to measures of kinematic symmetry and alterations in COMd, or it may indicate that peak force SI may not be a sufficient measure of symmetry during the propulsive phase of jumping in healthy populations. Future investigations should focus on variables that are not instantaneous force values, such as rate of force development, impulse or time to peak force, in order to get a more detailed view of overall jump symmetry.

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