ASYMMETRY IN JOINT WORK OF HEALTHY PARTICIPANTS DURING LANDING

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INTRODUCTION

It has long been known that human movements are not perfectly symmetrical, but 2-D methodologies often necessitated that bilateral symmetry be assumed. Some studies have investigated the symmetry of populations that could not be assumed to be symmetrical, such as patients with unilateral arthritis or joint replacements [1], but few studies have examined the symmetry of healthy populations. In studies that have used healthy subjects, studies employing a single subject design have concluded that there were asymmetries present while studies which have pooled the measurements of a group of subjects have often concluded that the subjects were symmetrical [2]. Due to the variety of movements studied and methodologies used in these studies, there currently is no consensus on what is considered normal symmetry in able-bodied people.

Bilateral landing is well suited to the study of asymmetry because it is a simple, reproducible movement in which perfect symmetry is the default assumption. The work done at each joint is primarily eccentric, and since joint work is additive it lends itself well to computing symmetry index variables. Therefore, the purpose of this study was to describe the symmetry of healthy participants during drop landing using joint work as the criteria.

METHODS

Sixteen right-leg dominant recreational athletes (8 male, 8 female, 22±3.6 years, 180.0±8.0 cm, 70.7±12.6 kg) with no history of major lower extremity injury were recruited for this study. All participants had a measured leg length discrepancy of less than 1 cm [3]. During data collection, participants performed a maximum vertical jump (MVJ), followed by 5 drop landings from an overhead bar at each of two heights (30cm and 60cm). A 7-camera motion analysis system (Vicon) was used to record 3D kinematics at 240 Hz. Two force platforms (AMTI) recorded the ground reaction forces at 1200 Hz. Joint power was computed in component form for the ankles, knees, and hips of each leg using Visual-3D software (C-Motion, Inc), and the sagittal plane component of the joint powers (P_J) were integrated to compute joint work.

Landing was considered to begin the first moment either foot touched the force platform (t_i) and end the moment the center of mass reached its lowest point (t_f). The work done by each joint was summed to compute the total work done by the right leg (TW_R) and left leg (TW_L). The symmetry index (SI_{TW}) was determined using Equation 1 [4].

$$SI_{TW} = \frac{(TW_R - TW_L)}{(TW_R + TW_L)} \qquad \textbf{(1)}$$

In order to see how the amount of work done by each leg varied through time, the work was computed in discrete intervals for right leg (DW_R) and left leg (DW_L) using Equation 2. The peak value of [$DW_R(t)$ - $DW_L(t)$] was ΔW_{peak}, and the time at which that occurred was $t_{\Delta Wp}$. A symmetry index at $t_{\Delta Wp}$ ($SI_{\Delta Wp}$) was calculated using Equation 3.

$$DW(t) = \sum_J \int_{t-\left(\frac{1}{240}\right)}^{t} P_J \, dt \, , t_i < t \leq t_f \qquad \textbf{(2)}$$

$$SI_{\Delta Wp} = \frac{\Delta W_{peak}}{[DW_R(t_{\Delta Wp}) + DW_L(t_{\Delta Wp})]} \qquad \textbf{(3)}$$

TW_R and TW_L were compared to one another in a 2x2 (side x landing height) repeated-measures ANOVA ($p < 0.05$). SI_{TW}, ΔW_{peak}, $t_{\Delta Wp}$, and $SI_{\Delta Wp}$ were compared between landing heights using a one-way ANOVA. Regression models were fitted to SI_{TW} and $SI_{\Delta Wp}$ beginning with a fully saturated model containing landing height, MVJ, gender, mass, and the difference in touchdown time between the right and left legs (ΔT_{TD}) as explanatory variables. The least significant terms were removed sequentially until a final hierarchical model with all remain terms significant at an α = 0.05 level was found.

RESULTS AND DISCUSSION

MVJ of the participants ranged from 25.7 to 68.1 cm, and ΔT_{TD} ranged from -8.4 to 16.8 ms, with positive values indicating that right foot touched down first.

TW_R and TW_L were significantly different from one another within subjects ($p<0.0001$, Table 1), and the landing height had no effect on this relationship (side x landing height p=0.9629). Using SI_{TW} as a criteria, the participants were significantly more asymmetric when landing from 30 cm than from 60 cm (p=0.0002). However, referring to Table 1 and equation 1, it is clear that the lower SI_{TW} at 60 cm was not due to a reduced difference between TW_R and TW_L, but due to the greater amount of work that must be done to land from the higher height.

Table 1: Mean values of total work done by the left and right legs and symmetry index (mean ± STD).

Landing Height	TW_R (J)†	TW_L (J)	SI_{TW}
30 cm	-147.5 ± 48.4	-92.5 ± 19.4	0.22 ± 0.10‡
60 cm	-251.8 ± 74.1	-196.0 ± 44.7	0.12 ± 0.08

† - Significantly greater than TW_L ($p<0.0001$)
‡ - Significantly greater than 60 cm (p=0.0002)

Mean values of ΔW_{peak} and $t_{\Delta Wp}$ were 4.5 ± 3.1 J and 56.2 ± 12.6 ms for landings form 30 cm, and 7.8 ± 4.1 J and 41.1 ± 15.1 ms for landing from 60 cm. Both variables were significantly different between landing heights ($p<0.0001$ for ΔW_{peak} and p=0.0002 for $T_{\Delta Wp}$). $SI_{\Delta Wp}$ was not significantly different between landing heights (mean 0.38 ± 0.16, p=0.57), indicating that at time $t_{\Delta Wp}$ participants performed 38% more work with the right leg than the left leg regardless of the landing height.

The final regression model for SI_{TW} (R^2 = 0.67, $p<0.0001$) contained terms for landing height, MVJ, ΔT_{TD}, and a MVJ x ΔT_{TD} interaction. In participants with a greater MVJ, SI_{TW} was very sensitive to changes in ΔT_{TD}, but this effect was not present for subjects with a small MVJ (Figure 1). This suggests that greater leg strength may allow participants to land with greater asymmetry.

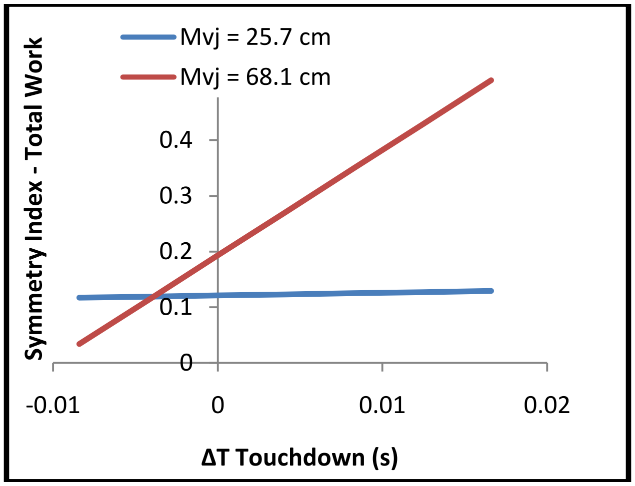

Figure 1: Interaction plot showing how SI_{TW} is related to M_{VJ} and ΔT_{TD}.

The final regression model for $SI_{\Delta Wp}$ (R^2 = 0.56, $p<0.0001$) contained only ΔT_{TD} as a significant factor such that $SI_{\Delta Wp}$ increased linearly as ΔT_{TD} increased. Asymmetry at time $t_{\Delta Wp}$ appears to be closely related to the initial conditions of landing.

CONCLUSIONS

Although the participants had no expectation of asymmetry, they did exhibit systematic asymmetry in the pattern of work performed during landing. All participants had a moment of peak asymmetry approximately 50 ms after touchdown that was closely related to the difference in contact times between the feet. After that point, participants with greater vertical jumping ability tended to remain asymmetrical while the participants with less jumping ability tended towards greater symmetry. More research is needed to determine if this is a natural characteristic of the way healthy people land or an artifact of landing in the lab environment.

REFERENCES

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