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Randall L. Jensen
Northern Michigan University

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KINETIC RESPONSES DURING LANDINGS OF PLYOMETRIC EXERCISES

R. L. Jensen, E. P. Flanagan[1], N. L. Jensen[2], and W. P. Ebben[3]

Dept. HPER, Northern Michigan University, Marquette, MI, USA
[1] Biomechanics Research Unit, University of Limerick, Limerick, Ireland
[2] Dept. Physics, Northern Michigan University, Marquette, MI, USA
[3] Program in Exercise Science, Marquette University, Milwaukee, WI, USA

The objective of the current study was to compare landing impulse and peak ground reaction force (GRF) during a variety of plyometric exercises. Eight Division-I athletes who routinely trained plyometric exercises performed a single repetition each of countermovement jump (CMJ), drop jumps from 30 and 60 cm (DJ30 and DJ60), cone hop (CH), tuck jump (TJ), single leg CMJ (SLJ), and squat jump with 30% 1 RM dumbbell squat (SJ30). Landing impulses and peak GRF were evaluated on an AMTI force plate. One-way ANOVA indicated mean and total impulses and peak GRF differed across exercises ($p<0.05$), with CH and SLJ displaying lower values and DJ30 and SJ30 having higher values. Results indicate that when landing from various plyometric exercises landing impulses and GRF are different across the exercises.

KEY WORDS: Landing Techniques, Ground Reaction Force, Stretch Shortening Cycle Training

INTRODUCTION:

Plyometric exercises are widely used to augment explosiveness of athletic movements. Like other forms of training, plyometric training requires an understanding of a variety of program design variables such as exercise mode, frequency, volume, program length, recovery, progression and intensity (Potach & Chu, 2000). Intensity may be the most important of these variables. Typically, factors such as the number of points of contact during landing, the speed of the drill, the height of the jump, and the athlete's weight have been suggested as possible factors determining plyometric intensity (Potach & Chu, 2000). However, muscle activity, landing forces and knee joint reaction forces have also been suggested to be important determinants as they have been shown to differ across various exercises (Fowler & Lees, 1998; Jensen & Ebben, 2002; 2007; Simenz et al., 2005). Furthermore, these variables provide information on the nature of the overload associated with a variety of plyometric exercises. Much research on plyometrics exercise has examined intensity (or joint reaction forces etc) in the jumping phase of movement. However, all plyometric exercises include both a jumping phase and a landing phase of movement. A safe and successful landing phase has been identified as key in prevention of injury (Cortes et al., 2007). However, there has been limited research to date examining the forces and impulses incurred during the landing phases of plyometrics exercises. Therefore, the purpose of the current study was to evaluate landing impulse and peak ground reaction force (GRF) during a variety of plyometric exercises.

METHODS:

Eight NCAA Division-I track and field athletes (mean ± SD; age = 20.2±2.1 years, body mass = 82.3±14.9 kg) volunteered to serve as subjects for the study. All subjects used the studied exercises in their regular resistance-training regimen. Subjects had performed no resistance training in the 48 hours prior to data collection and signed an informed consent form prior to participating in the study. Approval from the university's Institutional Review Board was obtained prior to starting the study.

Subjects performed a standardized warm-up prior to the collection of data. Following the warm-up subjects performed a countermovement jump (CMJ), drop jump from 30 and 60 cm (DJ 30 and DJ 60 respectively), cone hop (CH), tuck jump (TJ), single leg CMJ with the dominant leg (SLJ), and a squat jump with 30% 1 RM squat (SJ30). A one minute rest interval was maintained to ensure sufficient recovery between jumps For the DJ30 and DJ60, subjects stepped forward off the box without stepping down, or jumping up and upon contact with the force platform jumped as high and as quickly as possible. For the CH subjects were instructed to jump laterally over a 15 cm tall cone as quickly as possible. For all other jumps subjects were asked to jump as high as possible. Arm position was not controlled throughout the movements as it was desired to keep the plyometric exercises as close as possible to that experienced in the training environment.

Ground reaction force measurements were obtained for each plyometric jump using a force plate BP 600-1200 AMTI, Watertown, MA, USA) sampling at 1000 Hz. Using the acquired ground reaction force traces, the points of initial ground contact upon landing and when body weight was achieved after landing were identified. For the drop jumps only the landing component after the jump was considered.

Peak GRF was defined as the peak force determined during the landing portion of the plyometric exercise. Total landing impulse was established as the summed GRF during the time from the point of landing to when the vertical force component reached the subject's body mass after peak GRF (see figure 1). Mean landing impulse was the total landing impulse divided by the time of the impulse.

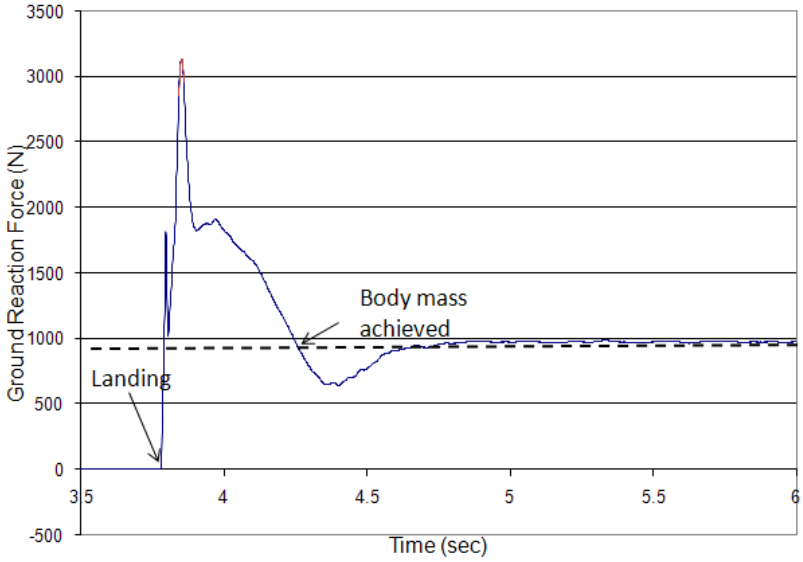

Figure 1: Graphical representation of acquired vertical ground reaction force traces and identified action points used to calculate impulse during the landing phase of a plyometric jump.

Statistical Analyses: All statistical analysis of the data was carried out in SPSS © (Version 15.0). A One-way repeated measures ANOVA was used to determine possible differences between the plyometric exercises. The criterion for significance was set at an alpha level of $p \leq 0.05$. The dependent variables were landing peak GRF, total landing impulse and mean landing impulse.

RESULTS & DISCUSSION:

Analysis of kinetic variables including landing peak GRF, total impulse and mean impulse revealed significant differences ($p<0.05$) between some plyometric exercises as shown in Table 1. The main findings indicated that SLJ was lower and SJ30% higher than a number of other plyometric exercises for all dependent variables. In contrast to the current research, Jensen and Ebben (2007) found no differences in peak GRF. Although the findings of the two studies were different concerning variations between the exercises, the values obtained for the exercises were similar in both studies. Findings of the current study were similar to those reported by Van Soest et al. (1985) who found lower jumping heights and GRF in one legged versus two legged jumps. Lower jumping heights would likely also result in lower kinetic values for the landing phase of the jumps. However, it should be noted that because the SLJ requires all the force to be absorbed by a single leg, the amount absorbed by that limb would be much higher than if it were distributed across two legs. Indeed Jensen and Ebben (2007) found differences in knee joint reaction forces were much higher in SLJ when expressed for the single limb. If the kinetic measures obtained for all jumps other than the SLJ in the current study were halved (similar to what would happen if both legs absorbed equal force), the values for the SLJ exercise would be higher than all other activities. This indicates that the intensity of SLJ may be quite high and should be considered when selecting exercises to maintain an intensity overload for training.

Table 1 Mean (± SD) for landing peak GRF, total impulse, and mean impulse for seven different plyometric exercises (n=8).

	Landing Peak GRF (N)	Total Landing Impulse (N·s)	Mean Landing Impulse (N·s)
CH	2207.5 ± 399.1	418981.2 ± 107841.6	1252.6 ± 207.3
SLJ	2208.4 ± 202.2 [a]	481135.4 ± 104406.4[c]	1132.0 ± 177.9[e]
DJ60	2431.1 ± 451.7	573914.7 ± 141347.7	1258.1 ± 237.7
TJ	2570.4 ± 259.5	624575.6 ± 151151.9	1326.4 ± 181.3
CMJ	2597.2 ± 366.1	651880.4 ± 214874.0	1242.6 ± 136.2
SJ30	2766.1 ± 303.6[b]	791471.7 ± 230782.1[d]	1496.9 ± 235.7[f]
DJ30	2837.9 ± 304.6	560080.3 ± 122811.1	1314.4 ± 201.6

[a] Significantly different ($p<0.05$) from DJ30 & SJ30
[b] Significantly different ($p<0.05$) from CH & SLJ
[c] Significantly different ($p<0.05$) from DJ60 & SJ30
[d] Significantly different ($p<0.05$) from DJ30, CH & SLJ
[e] Significantly different ($p<0.05$) from DJ30, TJ & SJ30
[f] Significantly different ($p<0.05$) from DJ60 & SLJ

Tsarouchas and colleagues (1995) found that GRF during weighted drop jumps were higher than those of unloaded drop jumps. Although the current study did not examine loaded drop jumps, the landing peak GRF, total landing impulse and mean landing impulse following most unloaded jumps were lower than the loaded SJ30%. Higher values of kinetic measures for the SJ30% is in contrast with the findings of Jensen and Ebben (2002; 2007) who found no differences in peak GRF across similar types of exercises. It should be noted that variability of landing forces during the SJ30% in the previous studies was quite large (three times that of the current study) which likely reduced the likelihood of finding a difference between the exercises.

Simenz and coworkers (2008) found that muscle activity, as measure via EMG, also differed between various plyometric exercises. Muscle activity changes likely reflect differences in technique used for the jumping action. However, because their study assessed EMG during the entire jump (takeoff as well as landing) a direct comparison to the current study is limited. Never-the-less, differences in takeoff, height of the jump, and type of jump (drop jumps from different heights vs. single leg jumps vs. cone hops vs. loaded jumps) quite likely cause alterations of the landing technique, which would then change the landing forces and impulses noted in the current study.

CONCLUSION:

Enhanced understanding of landing intensity is important in allowing the athlete and/or coach to select from a range of plyometric exercises with increasing intensity over the course of a training program. This information can be used along with periodization in designing an optimal training regimen. This paper provides the coach and athlete with additional means of quantifying plyometric exercises in addition to anecdotal recommendations such as the athlete's body mass, height of jump, speed of the drill, and points of contact.

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