FACTORS IN UPPER EXTREMITY LOADING IN THE POWER DROP EXERCISE

Duane Knudson[1] and ChengTu Hsieh[2]
Texas State University, San Marcos, TX, USA[1]
California State University-Chico, Chico, CA, USA[2]

This case study examined the factors that were related to peak vertical force applied to a medicine ball in an upper body plyometric exercise. Sagittal plane video and force platform data were collected for two male athletes performing 30 power drop exercises with a 5 kg medicine ball. Force on the medicine ball, net joint torques, and several technique variables were analyzed with partial correlations. Drop height was related to the impulse of the exercise, but was not uniquely associated with higher peak forces measured by video or the force platform because of intercorrelations between joint torques. Peak forces on the medicine ball were 44 to 69% of the peak vertical ground reaction forces (600 Hz) and were not uniquely associated with drop height.

KEY WORDS: force, medicine ball, stretch-shorten cycle, plyometrics.

INTRODUCTION: Plyometrics are a common training strategy for improving performance in a variety of high-intensity and speed athletic events. Upper-body plyometrics (UBP) often use medicine balls, kettle bells, and instrumented Smith machines (Wilson, et al., 1993) to train stretch-shortening cycle (SSC) muscle actions. This ballistic throwing of a training mass results in greater muscle activation and larger percentages of the range of motion with positive acceleration, minimizing the negative acceleration phase in normal weight lifting (Newton et al., 1996, 1997). Forces applied to a medicine ball in UBP exercises are likely higher than the small weight of the resistance because of the large accelerations during the UBP movements (Knudson, 2001; Newton et al., 1996).

Previous research has attempted to estimate forces in UBP training for the power drop exercise by bouncing MB's off a force platform (Ebben et al., 1999). Knudson (2001) reported that this methodology was inaccurate because of the differences between a rigid platform and an exercising human. In fact, higher drop heights in the power drop did not always result in larger forces in some athletes (Knudson, 2001). Perceptual and technique variations may affect the duration and intensity of each power drop exercise as much as drop height (Knudson, 2001). Plyometric push-ups and power drop exercises have total contact times between 0.3 to 0.6 seconds (Jones et al., 1999; Knudson, 2001). Similar to lower extremity plyometrics (Bobbert et al., 1986), there is variation in how athletes perform UBP exercise that likely affects the training forces experienced in UBP (Knudson, 2001).

There is a need to understand the typical forces on the upper extremity in UBP exercises so that safe and effective training loads can be prescribed. The purpose of this case study was to examine the factors related to peak vertical force loading on the hands and peak joint torques in the power drop exercise for two experienced athletes. We also specifically examined how well the force platform method correlated with the more time intensive quantitative videography in documenting power drop loads. It was hypothesized that forces applied to the MB would vary according to interactions of exercise variables within each athlete.

METHODS: Two intercollegiate male athletes experienced in UBP exercise (94.6 and 88.4 kg) gave informed consent to participate in the study and attended a single testing session. Reflective markers were placed on the joint axes of the right arm. Following a warm-up the subjects performed 25 power drop UBP exercises with a 5 kg MB dropped from heights between 0.5 and 1.4 m. The heights were normally distributed and presented in a random order. There was approximately one minute of rest between each exercise. Subjects then performed 5 power drop exercises from the same height (0.8 m) to document the reliability of the dependent variables. The subjects were able to execute these exercises with the arms primarily in a sagittal plane.

Power drop exercises were performed in a supine position with flexed knees and hips on a small (100 by 33 cm) bench placed on top of a Kistler 9286 force platform. Vertical force data (600 Hz) was synchronized with kinematic data and analyzed with Kistler Bioware® software. To document the MB and upper extremity motion in the power drops, all trials were videotaped (60 Hz) in the sagittal plane. A two-dimensional rigid body model of the MB, hand, forearm, and upper arm of the left upper extremity was created. The center of the MB and the four markers were digitized from 10 fields before hand-ball contact to 10 fields after release using Vicon Motus® 9.2 software. All kinematic data were smoothed with a Butterworth digital filter using the automatic cut-off frequency selected by the system.

The loading variables examined were the vertical impulse (J) and peak vertical force measured by the force platform (PF_{FP}), and the peak net joint torques at the wrist (PT_W), elbow (PT_E), and shoulder (PT_S) from inverse dynamics with wrist extension, elbow and shoulder flexion defined as positive. Kinetics were calculated from the MB down the upper extremity. The peak vertical force on the MB (PF_V) was calculated from vertical acceleration measures of the MB and Newton's 2^{nd} Law of motion, and was then compared to PF_{FP}. The technique variables examined in the study were the drop height, vertical hand velocity one field prior to contact, duration of contact with the MB, and the percentage of contact with negative vertical MB velocity. The association between the dependent variables and technique variables were analyzed within-subject with correlation and partial correlations with statistical significance accepted at the $p < 0.05$ level. Data reliability were documented with coefficients of variation of the five repeated trials with the same drop height. Descriptive data are reported as means (SD).

RESULTS AND DISCUSSION: The dependent variables showed good consistency, although peak joint torques showed more variability than forces or impulse. Mean coefficients of variation for the loading variables were 4% J, 5% PF_{FP}, 10% PF_V, 18 % PT_W, 26% PT_E, and 9% PT_S.

Partial correlation analysis showed the variables that were significantly and uniquely ($p < 0.05$) associated with drop height were specific to each athlete. Drop height also had significant partial correlations with J of the exercise ($r = 0.81$) and T_S ($r = 0.41$) for subject 1. Drop height was significantly and uniquely associated with J ($r = 0.80$) and percentage contact with negative vertical MB velocity ($r = -0.51$) for subject 2. The lack of an association between drop height and PF_{FP} was in agreement with several of the subjects studied by Knudson (2001).

The zero-order correlation ($r = 0.60$) between drop height and PF_V also disappeared in the partial correlation analysis for subject 1. This could be due to significant intercorrelations ($|r| > 0.64$) between PF_V and all peak joint torques. Significant partial correlations between joint torques in both subjects confirmed technique interactions between joints that likely confound associations between drop height and loading in power drop exercises. The peak torque at the elbow was significantly associated with the torque at the wrist ($r = 0.45$ and 0.77) and the shoulder ($r = 0.57$ and 0.37) for subjects 1 and 2, respectively. Both subjects also had significant partial correlations ($r = 0.50$ and 0.44) between vertical hand velocity prior to contact and the percentage of contact with negative vertical MB velocity.

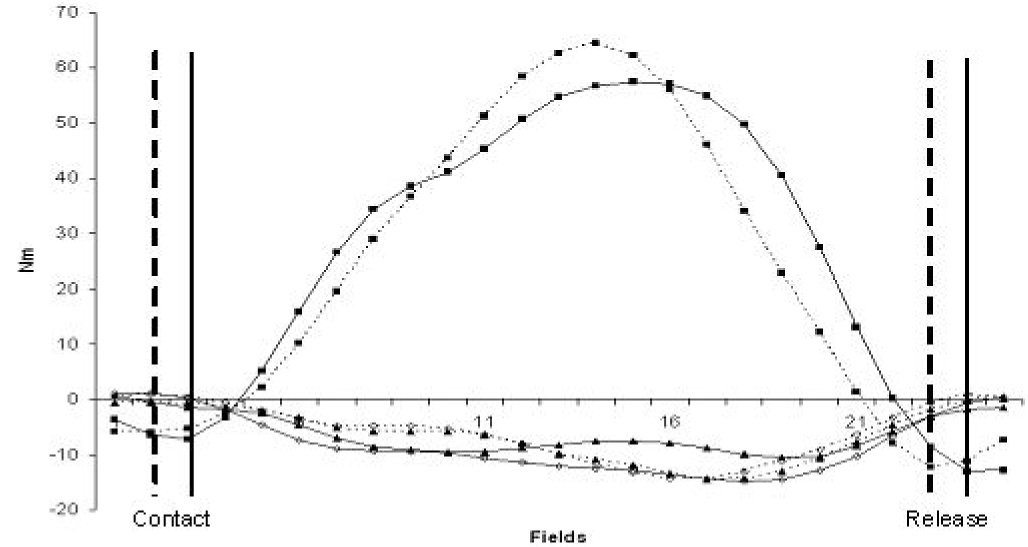

Figure 1. Typical patterns of net wrist ◊, elbow ▲, and shoulder ■ torques for both subjects (S1 – and S2 ---) in the power drop exercise. MB contact and release indicated by vertical lines.

Both subjects had similar patterns of net wrist and shoulder torques. There was, however, a different pattern of elbow torques between the subjects (Figure 1).It is possible the large variability of the elbow net torque is a result of the interaction of joint torques in this exercise for these subjects. These data support the hypothesis that loading in power drop exercise is not easily predicted by drop height because of complex interactions of technique variables. Descriptive data for the loading variables across all trials are reported in Table 1.

PF_{FP} was apparently correlated (r = 0.72 and 0.76) with PF_V for both subjects, but the partial correlations showed the unique associations were not statistically significant (r = 0.24 and 0.35, respectively). The interactions of technique variables and acceleration of upper extremity mass reduces the potential association between PF_{FP} and PF_V.

Table 1 Mean (SD) Loading Variables Over 30 Power Drop Exercises

—	J Ns	PF_{FP} N	PF_V N	PT_W Nm	PT_E Nm	PT_S Nm
—						
Sub 1 (9)	85 (6)	548 (111)	250 (23)	-19 (3)	-15 (4)	70
Sub 2 (8)	84 (6)	494 (69)	235 (21)	-13 (4)	-11 (4)	66
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* See method for abbreviations.

Knudson (2001) reported that estimating power drop exercise loads by dropping medicine balls on force platforms (Ebben et al., 1999) was inaccurate and unlikely to be useful in planning training. The results of the present study confirm and extend this observation. PF_{FP} over a 300 to 420 ms exercise would be different from the peak force of a MB bouncing off a rigid force platform in 40 to 50 ms. More importantly, PF_V were 44 to 69% of the PR_{FP} and were not significantly correlated for these two subjects. This overestimation using the force platform alone is likely related to not accounting for the acceleration of the mass of the arms and is consistent with research of this effect in bench press exercises (Rambaud et al., 2008).

Some of the limitations of this study were small sample size and the typical assumptions of 2D inverse dynamics. Despite these limitations, the subjects in this study confirmed the hypothesis of technique variations in power drop exercises that do not easily allow drop height or force platform measurements to predict athlete loading. This is consistent with research on indicating that desirable loading is difficult to establish because of interactions with machine restraints, duration, range of motion, and percentages of time that inertial resistances are accelerated and negatively accelerated (Frost et al., 2008a, 2008b; Newton et al., 1996).

CONCLUSION: Increasing MB drop height in power drop exercises for two experienced athletes was correlated with the vertical impulse of the exercise, but not peak vertical forces due to the interaction of technique factors acceleration of upper extremity mass. These data were consistent with previous research on ballistic exercises, and suggests that force platform data alone cannot be used to estimate loading in the power drop exercise.

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