IS A 20 KG LOAD SUFFICIENT TO SIMULATE FATIGUE IN SQUAT JUMPS?

[1]Bailey, C., [1]McInnis, T., [1]Sato, K., [2]Johnston, B., [2]Sha, Z., and [2]Stone, M.H.

[1]LaGrange College, Department of Exercise Science, LaGrange, GA, USA. [2]East Tennessee State University, Department of Exercise and Sport Sciences, Johnson City, TN USA

INTRODUCTION: Changes in jumping kinetics and kinematics from various loads and levels of fatigue have been noted in previous research (Cormie, McBride and McCaulley, 2008, Kraska, et al., 2009, Peng, 2011, Pupo et al., 2013). Specifically concerning fatigue, reductions in jump height, power output and vertical stiffness have been demonstrated along with increases in contact time and time to takeoff (Pupo et al., 2013). Fatigue has also been shown to decrease knee joint stability in females, possibly predisposing them to injury (Ortiz et al., 2010). Previous research has also examined the kinetic changes associated with adding load(s) to the squat jump and found that statistically lower values in rate of power development and peak power occur when loads of 40 kg or greater were applied (Cormie, McBride and McCaulley, 2008). The previously mentioned authors suggest that kinematic changes also occur, but these were not evaluated in trained athletes. Kraska and colleagues (2009) found decrements in collegiate athletes' jump height with adding a 20 kg load, but other kinematic variables were not evaluated and simulating fatigue was not the focus of the study.

To the knowledge of the authors, it is not known if a 20 kg load is sufficient to elicit performance alterations in kinematic variables and simulate a fatigued situation in athletes. Therefore, the purpose of this study was to determine if a light load (20 kg) would alter the jumping performance of athletes in a similar manner to the alterations observed during fatigued situations in previous investigations.

METHODS: Seventeen NCAA Division I baseball players participated in this study. Prior to testing, athletes read and signed informed consent documents, which were approved by the East Tennessee State University Institutional Review Board. Also prior to activity, athletes performed a standardized warm-up consisting of 25 jumping jacks and four sets of five dynamic mid-thigh pulls with two different loads (1x5 @ 20 kg, 3x5 @ 60 kg). Following the warm-up, reflective markers were positioned on athletes in accordance to the Vicon full-body "Plug-in-Gait" model in order to perform subsequent 3D motion capture data collection.

Following marker placement, athletes completed the unloaded and lightly-loaded squat jumps (SJ). The unloaded jump condition was completed while athletes held a PVC pipe and its weight was considered insignificant. The lightly-loaded jump condition (20 kg bar) was included to determine if it was sufficient to simulate how an athlete would perform during a fatigued situation. Both jump conditions were performed without the aid of an arm swing as athletes held either a PVC pipe or a bar behind the neck, similar to the high bar squat position. The starting position of each SJ was standardized at 90° knee of flexion and was measured with a goniometer. Prior to each of the maximal effort jumps, athletes performed a more specific warm-up of SJs at 50 and 75% of perceived maximal effort. During maximal effort jump conditions, athletes were instructed to descend to the starting position and wait for the jump command to be given. Two maximal effort jumps were completed for each condition and the results were averaged to better represent each athlete's typical performance (Henry 1967). Rest between jump trials was approximately one minute and SJ trials were counted successful if there was no observable countermovement. Unsuccessful jump trials were excluded, thus only the two successful trials at each load were used for analysis.

An infrared 3D motion capture system (Vicon Nexus, ver. 1.86, Centennial, CO) was used to complete kinematic data collection. Data were collected at 200 Hz via a six camera setup, where cameras were positioned in a circle surrounding the athlete at a distance of 7 m. The smoothing of raw position data was completed via Woltring filter with the cut-off frequency preprogrammed into the motion capture software, which was established by an optimization method (Woltring 1985).

Kinematic variables in this study included range of motion (ROM), peak angular velocity (PV), peak angular acceleration (PA), and the positions which PV and PA occur (deg@PV, deg@PA). These variables were expressed for the hip, knee, and ankle. Along with joint kinematics, jump height was also evaluated. Jump height (JH) was calculated as the difference between the maximum height of the center of mass during the jump and the height of the center of mass during subject static calibration.

All statistical analysis was performed with PASW software (SPSS version 17.0: AN IBM company, New York, NY). Dependent samples *t* tests were completed to evaluate statistical differences between the unloaded and loaded SJ trials. A Holm-Bonferroni sequential adjustment was applied as multiple *t* tests were performed and the chance for Type I error was likely inflated. Initial statistical significance was set at $p \leq 0.05$. Along with statistical significance, practical significance was also evaluated with Cohen's *d* effect size estimates. Effect size magnitude interpretation was completed with the scale provided by Hopkins (2013).

Table 1. Descriptive data for unloaded and loaded jump conditions (mean±standard deviation)

	Hip Kinematics		Knee Kinematics		Ankle Kinematics	
	0 kg	20 kg	0 kg	20 kg	0 kg	20 kg
ROM(°)	77.0 ±10.7	78.91 ±9.6	102.2 ±10.6	104.9 ±10.75	73.2 ±4.7	73.6 ±5.0
PV(°/s)	551.3 ±76.8*	498.5 ±83.6*	984.7 ±123.4*	905.0 ±109.5*	909.1 ±158.3*	831.6 ±143.5*
deg@PV	148.4 ±35.0	149.0 ±34.5	164.2 ±7.1	164.9 ±5.9	116.9 ±9.8	120.5 ±5.9
PA(°/s^2)	17671.2 ±4438.1*	15362.0 ±3706.8*	36062.1 ±10179.9	32865.6 ±8776.0	37124.0 ±14635.6	33132.5 ±11666.1
deg@PA	163.0 ±41.5	162.5 ±40.6	185.0 ±5.8	184.4 ±5.9	133.4 ±8.3	134.0 ±8.3

* denotes statistical significance, initial significance set at $p \leq 0.05$

RESULTS: Descriptive statistics, results of *t* tests, and Cohen's *d* effect size estimates are displayed in tables 1-3 above. Adding a 20 kg load produced statistically significant decrements in PV at all joints (hip 9.56%, knee 8.09%, and ankle 8.52%) and PA of the hip (13.02%). A decrement in JH was also observed in the loaded condition (17.39%).

Table 2. Cohen's *d* effect size estimates of joint kinematic differences between jump conditions.

Hip	Knee	Ankle
0.19	0.26	0.08
0.63	0.65	0.5
0.02	0.11	0.44
0.55	0.34	0.3
0.01	0.11	0.07

Table 3. Descriptive data (mean±standard deviation) and Cohen's *d* effect size estimate.

	mean±sd	Cohen's *d*
JH 0 kg (m)	0.46±0.06*	1.13
JH 20 kg (m)	0.38±0.05*	

* denotes statistical significance, initial significance set at $p \leq 0.05$

DISCUSSION: The purpose of this study was to determine if a 20 kg load would alter the jumping performance of athletes in a similar manner to the alterations observed during fatigued situations in previous investigations. Compared to the unloaded condition, the 20 kg load condition elicited statistically significant differences with moderate effect sizes in peak velocities of all joints and peak acceleration of the hip. Statistical decreases in jump height with a high-end moderate effect size estimate ($p<0.05$, $d=1.13$) were also observed. Findings of altered performance with an increased load are consistent with previous research

(Cormie, McBride and McCaulley, 2008). Previous research has also shown reductions in JH and power output associated with increased fatigue (Pupo et al., 2013). Although Pupo and colleagues observed a larger decrease in JH, both studies observed JH drop-off (Pupo et al., 2013 26% vs. the current study 17.39%). This may indicate that the relative intensity of the load is related to the level of fatigue that is to be simulated, but further research would be required to justify this notion. Concerning decrements in power, kinetic measurement was not assessed, but decrements in joint velocity were noted. As velocity is part of the formula for determining power, it is feasible that power output in the current investigation might have been decreased as well. Further investigation would be required to support this notion.

Based on the results of the current investigation, it appears that a 20 kg load is sufficient to induce jump performance alterations in squat jumps similar to those induced by fatigue. These findings are particularly important for coaches and sport scientists who wish to determine how their athletes will perform in fatigued situations, but without the adverse effects of fatigue. Applying a relatively light load to jump testing may be a viable option to simulate fatigued situations. It should be noted that the possible performance detriments associated with adding a light load to a countermovement jump were not evaluated in this investigation. Further research is warranted to determine if the same trend is noticeable in other jump types.

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