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The effect of heel lift inserts on clean jump shrugs and loaded vertical countermovement jumps

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Abstract. The use of weightlifting with specific shoes (e.g. weightlifting shoes) have been advocated in the sports of powerlifting (PL) and weightlifting (WL) specifically. These shoes for WL commonly have a flat bottom, are made of solid sole (e,g. wood, hard molded plastic), have a raised heel, and may one or two straps that cross the dorsal side of the metatarsals. The purpose of this study is to examine the effects of heel lifts placed in shoes on the kinetic and kinematic variables of the clean jump shrug (CJS) and loaded countermovement jump (LCMJ). *Material and Method.* A total of 13 college-age subjects with at least 1 year of weight training experience and free of any skeletal or muscular injuries participated in the study. Subjects performed the CJS and LCMJ in a randomized testing progression utilizing loads with a PVC stick, 30% and 60% 1RM of the CDL and PVC stick, 30% and 60% for the two lifts respectively both with and without heel inserts. *Results.* All testing variables between test conditions at the corresponding loads demonstrated no statistically significant differences with the exception of CJS peak velocity (PV) with PVC bar only demonstrating a statistically significant difference. *Conclusion.* The current results suggest the use of heel lifts constructed of hard resin plastic placed in training shoes does not have a statistically significant effect on physical performance.
Key words: *power, velocity, countermovement jump, clean jump shrug.*

Introduction

The use of weightlifting with specific shoes (e.g. weightlifting shoes) have been advocated in the sports of powerlifting (PL) and weightlifting (WL) specifically. These shoes for WL commonly have a flat bottom, are made of solid sole (e,g, wood, hard molded plastic), have a raised heel), and may one or two straps that cross the dorsal side of the metatarsals. Coaches and weightlifters encourage the use of WL shoes for improved stability and kinematics when performing cleans, snatches and squats. Sato et al. (8) observed that wearing WL shoes may be beneficial in reducing the overall trunk lean that could contribute to the reduction of lumbar shear stress. Furthermore, increased relative foot-shank angle during the back squat (BSQ) with WL shoes may contribute to greater muscle excitation in the quadriceps muscle group (8). However, there are results that demonstrate an elevated heel with the aid of an angled platform or WL shoes does not significantly influence the spinal posture and activation of the selected muscles during the back squat in recreational weightlifters (5). Although the use of WL shoes may alter kinematics, the muscle activation of the involved musculature may remain the same regardless of the shoe or raised platform. As demonstrated by Fortenbaugh et al. (4), WL shoes in comparison to running shoes had significantly less anterior bar and posterior hip displacement, along with significantly less forward trunk lean when performing back squats with 60% 1RM. Altered lower body joint kinematics have been further demonstrated during back squats comparing raised heel conditions to non-wedged or barefoot conditions with significant changes to hip flexion, knee flexion, dorsiflexion and anterior trunk lean (3, 12). Specifically, Charlton et al (3) observed trunk and pelvis mean angles, 42.80° and 35.05° respectively, at peak knee flexion without a heel wedge during back squats while with a heel wedge had angles of 37.03° and 29.27°. These effects were further seen when heels were elevated on the conventional style deadlift yielded no statistical significance between heels elevated by wooden blocks ranging from 0.63 to 81 cm (11). Sunny (11) did not observe a significant change in absolute shank (shin) angle (64.12° to 63.02°) between athletes performing conventional deadlifts during the lift off phase with varying heel lift heights.

These shank angle results were also present when the bar passed the knee joints during bar ascent with no statistically significant differences in absolute and relative joint angles.
The lack of kinematic changes related to lower body joint angles with or without raised heels suggest that the conventional deadlift (CDL) would be a viable exercise for testing strength to determine loads for the clean jump shrug (CJS). Although there is literature that supports and refutes the similarity of the CJS and loaded vertical countermovement jump (LCMJ), these two movements from subjective face value both have a triple extension of the ankle, knee and hip joints (1,6).
The similarity between the CJS and LCMJ lower body joint angle actions are not necessarily the same for the force-velocity variables, thus using two different externally loaded power exercises provides a unique perspective. The use of specific WL exercises in different annual sport phases for development of muscular power should be based on their similar biomechanical and physiological characteristics to the sport (9).A training program that is focused on developing power would have different exercises assigned to stimulate different expressions of power. Moreover, these training programs using more than one exercise that progress from a WL exercise to a plyometric one could benefit from the ability of the athlete being able to shift their training shoe purpose by slipping inserts into them, without the need to carry extra pair of shoes with them. If these inserts additionally have minimal influence on performance variables would make the use of these inserts a logistical benefit. The use of WL shoes for competition is the same as a cyclist using shoes to "clip in" to the pedals, though the need of specific shoes during a training session is not necessarily warranted. The purpose of this study is to examine the effects of heel lifts placed in shoes on the kinetic and kinematic variables of the CJS and LCMJ.

Material and Method

A single group of volunteer participants were used in a randomized condition comparison that included an initial meeting, familiarization and testing days. The length of the study was approximately 3 weeks total with one session for completion of informed consent forms and briefing of the study, then followed by one maximal strength testing with familiarization of the experimental protocols, a follow-up familiarization session of experimental protocols, and finally two randomized testing sessions. The four sessions lasted 45 to 60 minutes with 48 – 72 hours between them. After completion of the initial meeting for the completion of study documents and obtainment of participant demographics, a familiarization of the experimental protocols that included maximal strength testing session took place. Each test session was completed in 45-60 minutes, 48 – 72 hours between and within one hour of the first testing session. At least 2 investigators were used for technique instruction and assistance with equipment preparation. All sessions were conducted under the supervision of a certified strength and conditioning specialist (CSCS) and at least two spotters will be used during all testing sessions.
Subjects. There were 15 subjects that initially volunteered to participate in the study and two were dropped as they were unable to complete all testing sessions due to time conflicts and missed sessions (Participant demographics can be seen in table 1). The two subjects were dropped due to illnesses and missed testing sessions and removed from final analysis. Subjects had at least 1 year of weight training experience and free of any skeletal or muscular injuries. Their height measured using a sliding wall ruler, while body mass (BM), lean body mass (LBM) and body fat percentage (BF%) was measured using a Tanita™ weight scale (DC-430U Dual Frequency Total Body Composition Analyzer, Tanita Corporation of America, Inc., Arlington Heights, Illinois).Subjects were instructed to refrain from lower-body training at least 24 hours before all testing sessions and to report any delayed onset muscle soreness prior to the start of a session. The experimental condition of the heel lift inserts, the CJS and LCMJ, and lift intensity order were all randomized. The CJS and LCMJ were performed with 10 minutes between each testing condition to reduce the chance of a potentiation affect.
Procedures. During this familiarization subjects were led through the dynamic warm-up (DWU) that included: body weight squats – 10 repetitions, lunges – 10 repetitions each leg, side to side leg swings – 15 repetitions each leg, forward to backward leg swings – 15 repetitions each leg, back squats with dowel rod – 10 repetitions, and clean jump shrugs with a dowel rod – 3 x 5 repetitions. Following the DWU subjects began a conventional deadlift (CDL) specific warm-up that began with performing the CDL with an unloaded bar for 10 repetitions. The same Pendlay™ weightlifting bars (20 or 15 kg) and weight discs were used for all sessions. The following lifts were completed with 30% of subjects estimated 1 repetition maximum (RM) for 5 repetitions, then single repetitions at 50%, 70% 80% and 90%.

The CDL 1RM followed the protocol as outlined by Caufield and Berniger (2) and included measuring the participant's CDL hand-grip distance from each of the participant's index finger. The CJS followed the technique as outlined by Suchomel et al. (10) while participant's self-selected foot placement and hand placement and the medial distance was measured during familiarization using a sliding anthropometric caliper (Lafayette, IN). Subjects were given the choice to use either a hook or overhand closed grip based on preference, while lifting straps were not be allowed during any part of the study but hand chalk was allowed as needed by subjects. The barbell kinetic (e.g. power) and kinematic (e.g. bar velocity) variables were measured by a linear position transducer (Gymaware™, Kinetic Performance Technology Pty Ltd. 8/26 Winchcombe court, Mitchell 2911, ACT, Australia). The Gymaware™ tether was attached to the end of the bar prior to the start of all testing repetitions. Subjects were instructed to wear the same shoe each testing session and were instructed to use heel lifts during familiarization sessions. Hard plastic insert heel lifts with a heel cushion adhered to the plastic were used in the experimental condition. Subjects had the choice of using the bar of their choice for the CJS to fit their hand size. The CJS was performed in a randomized progression for familiarization and testing utilizing a PVC stick, 30% and 60% 1RM of the CDL.
Subjects executed four repetitions at each load pausing for one to five seconds between repetitions to reset in the correct starting position. Following the 1st familiarization exercise (if the CJS), subjects performed the LCMJ placing a PVC stick and barbell across the upper trapezius and posterior deltoids while holding with a self-selected grip and foot placement width which were measured for consistency. Subjects rapidly lowered their center of mass, performing a countermovement action to a self-selected depth that was followed by a rapid upward vertical change of direction. Subjects were encouraged to jump with as much effort as possible to achieve maximal vertical displacement. Subjects were instructed to absorb the landing after each and take one to five seconds between repetitions to reset in the correct starting position. At least 2 spotters were used for safety and assistance with equipment preparation prior to testing. Subjects performed the LCMJ in a randomized progression PVC stick, 30% and 60% of the participant's body mass for 4 repetitions at each testing load. During testing sessions, subjects had 2 minutes between each load and a 10-minute rest period between the CJS and LCMJ testing conditions. Subjects were informed of their performance for each testing condition and were allowed ask questions regarding their results.
Statistical analysis. Descriptive analysis and a paired samples t-test was used for pre and post testing using IBM SPSS Statistics v23. A Pearson product moment correlation was used to assess relative reliability between the test conditions along with descriptive analysis.

Results

The CJS peak velocity (PV) with PVC bar was the only variable that demonstrated a statistically significant difference between conditions (Table 2a). All other variables between test conditions at the corresponding loads demonstrated no statistically significant differences. The CJS with the PVC bar had the highest PP with the heel lift and without respectively (5795.23 ± 2145.20 and 6286.31 ± 2308.58 W), in comparison to all other test conditions (Table 2b). The PP for CJS at 60% 1RM was 3084.00 ± 866.52 W for heel lift protocol and 3080.69 ± 811.57 W with normal shoe. The PP for LCMJ at 60% BM was 3642.08 ± 1260.19 W for heel lift protocol and 3723.08 ± 1116.50 W with normal shoe. Bar velocity for the CJS was highest in the unloaded condition (1.97 ± 0.24 $m \cdot s^{-1}$) and lowest in the 60% 1RM condition (0.93 ± 0.09 $m \cdot s^{-1}$). Relative reliability demonstrated high correlations for all test variables (r = .74 - .98), with the lowest reliability in the test conditions of LCMJ RPP 60% BM (r = .72), CJS 30% 1RM PV (r = .78), CJS 30% 1RM MV (r = .74) and CJS PVC bar 1RM MV (r = .74).

Table 1. Participant Characteristics

Characteristics	Female (n = 6) Mean ± SD	Male (n = 7) Mean ± SD
Age (yrs)	23.33 ± 3.68	20.86 ± 0.83
Height (cm)	163.23 ± 8.62	181.68 ± 6.72
Body mass (kg)	79.32 ± 29.39	99.20 ± 21.68
Body fat (%)	28.65 ± 5.70	23.62 ± 7.98

Table 2a. Power and velocity variables for CJS of varying loads

	PVC bar		30% 1RM		60% 1RM	
	Heel Lift	Norm	Heel Lift	Norm	Heel Lift	Norm
PP (W)	5795.23 ± 2145.20	6286.31 ± 2308.58	3939.23 ± 1206.53	4095.62 ± 1325.03	3084.00 ± 866.52	3080.69 ± 811.57
MP (W)	3317.92 ± 1300.02	3421.92 ± 1308.87	2160.23 ± 757.22	2253.77 ± 770.84	1651.31 ± 489.96	1606.92 ± 505.81
RPP ($W \cdot lbs^{-1}$)	32.05 ± 11.13	34.45 ± 10.23	21.55 ± 4.40	22.12 ± 4.42	16.87 ± 2.66	16.90 ± 2.49
PV($m \cdot s^{-1}$)	3.03 ± 0.50	3.20 ± 0.46*	2.11 ± 0.20	2.15 ± 0.19	1.49 ± 0.16	1.50 ± 0.16
MV ($m \cdot s^{-1}$)	1.90 ± 0.34	1.97 ± 0.24	1.31 ± 0.15	1.36 ± 0.16	0.94 ± 0.10	0.93 ± 0.09

**significant difference with Heel Lift ($p < .05$)*

Table 2b. Power and velocity variables for LCMJ of varying loads

	PVC bar		30% BM		60% BM	
	Heel Lift	Norm	Heel Lift	Norm	Heel Lift	Norm
PP (W)	4575.08 ± 1280.58	4505.15 ± 1256.50	4010.38 ± 1056.76	3886.54 ± 1198.58	3642.08 ± 1260.19	3723.08 ± 1116.50
MP (W)	2584.54 ± 747.13	2555.92 ± 789.71	2187.23 ± 654.97	2141.92 ± 692.57	1897.77 ± 724.86	1936.31 ± 645.65
RPP ($W \cdot lbs^{-1}$)	25.95 ± 5.88	24.87 ± 5.52	22.20 ± 4.58	21.28 ± 4.57	19.80 ± 5.12	19.54 ± 5.04
PV($m \cdot s^{-1}$)	2.93 ± 0.41	2.84 ± 0.42	2.31 ± 0.33	2.28 ± 0.40	1.91 ± 0.30	1.96 ± 0.30
MV ($m \cdot s^{-1}$)	1.75 ± 0.25	1.74 ± 0.29	1.38 ± 0.23	1.38 ± 0.28	1.12 ± 0.22	01.17 ± 0.18

**significant difference with Heel Lift ($p < .05$)*

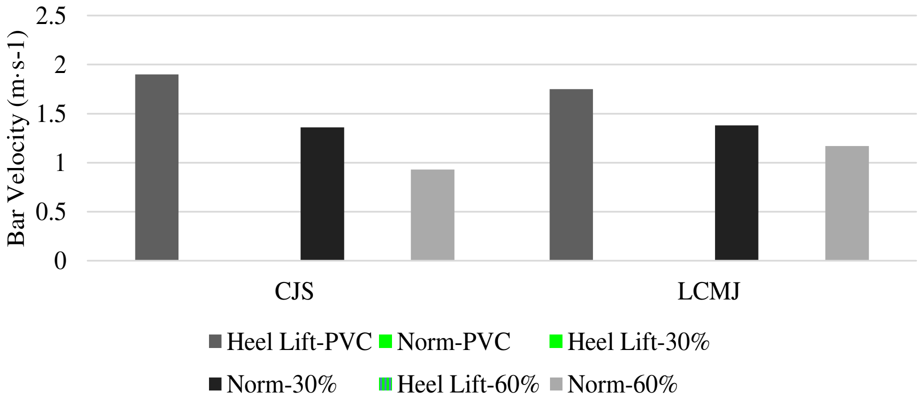

Figure 1. Bar velocities of the CJS and LCMJ at different loading schemes. (CJS based on % of CDL 1RM, LCMJ based on % of BM)

Discussion and Conclusion

The effects heel lifts in a standard training shoe had on power exercises demonstrated no statistically significant differences in the CJS and LCMJ performance variables when performed with heel lifts or absent of heel lifts. The current results suggest the use of heel lifts constructed of a hard resin plastic do not have a statistically significant effect on physical performance thus may be an alternative training method. Lack of statistical differences in PP among test conditions provide strength and conditioning coaches the flexibility to have their athletes use heel inserts in flat bottomed shoes to potentially provide a stable base during lifts. The ability for athletes to quickly shift training from WL exercises to locomotive drills (e.g. bounds) without carrying an additional shoe can save on time and cost to the athlete or program. The heel lifts used in the study are designed to be used within cross-training shoes that have a flat bottom sole and minimal heel cushioning for running. Strength and conditioning sessions that are comprised of predominately weightlifting movements and plyometric drills could benefit from the use of heel lifts reducing the need of having both weightlifting and cross-training shoes during the session. The lack of differences between conditions suggest that the use of heel lifts may be used for performing weightlifting or squatting actions in a strength training program with minimal impact on kinetic and kinematic variables of force, power, and barbell velocity as measured by linear position transducer. The current results correspond with previous studies, which demonstrated no significant difference when using a weightlifting shoe or elevated ramp (5,11,12). Lee et al. (5) compared the effects of barefoot training on a flat surface, barefoot training on a heel-raised platform, or the use of weightlifting shoes had on a person while performing a back squat. However, some studies that utilized video motion analysis have observed alterations to relative joint kinematics (e.g. ankle dorsiflexion angles), which may influence performance results secondary to athlete perceptual influences (3,6,8,12). The raised heels may have a greater impact on relative joint angles that effect athlete comfort rather than on force, power, and barbell velocity. Anecdotally, weightlifters have promoted the use of shoes with a solid, elevated heel to place themselves in an advantageous position to perform a lift. However, a limitation in the current study that warrants further investigation is whether there is a difference between standard training shoes with heel inserts and WL shoes when performing CJS or LCMJ. Additionally, the current study's subjects were not competitive weightlifters thus their weightlifting technique may not have been as proficient and familiarization from long term use of weightlifting shoes was absent. Subjects that have greater than one year of weightlifting training under the supervision of an experienced and certified weightlifting coach to develop proper lifting techniques may be able to display greater power and strength. The ability of the subjects to execute variations of weightlifting movements may also improve power or force production based on their experience. In addition to the current subjects not being weightlifters, the current study did not compare the heel lifts to WL shoes that have a built in solid raised heel. Whether experience wearing WL shoes would make a difference in the barbell kinetic and kinematic variables when compared to the heel lifts requires future investigation. Moreover, subjects did not wear the same shoes, but used the shoes that each one used during their own weight training or conditioning sessions. The structure of the different shoes may influence the performance variables as some may have great absorption properties (e.g. running) in comparison to others. Additionally, the condition of the shoes worn by the subjects were not controlled as some may have been used for years and others only a couple of months. This variable was not recorded thus specifics cannot be made regarding influence on performance.

The purpose of the study was not to compare the differences in the CJS and LCMJ as participant previous training experience, fitness level and sport level (e.g. NCAA Division II student-athlete) may influence results. However, from a practical perspective, a strength and condition coach should note that performance variables decreased as the external loading increased. An inverse relationship exists between bar velocity and external loading (Figure 1), which is evident in the decreased power output. The trend of decreasing velocity with increasing external load has been observed by Suchomel et al. (9) with the hang high pull. Lack of differences in the between conditions while maintaining the inverse relationship of load and velocity suggests support of using heel lifts in flat-bottomed training shoes. Furthermore, Newton and Jenkins (7) address the necessity for athletes that will be using weightlifting movements in a training program and testing need to have "proper preparation and coaching". This necessity requires time to be allotted for either training of test subjects prior to data collection or the subjects will have already been coached with the ability to safely and effectively execute weightlifting movements. The weightlifting experience and classification of future subjects should be examined as differences in physical performance may be observed between the lifts or types of shoes worn. Although, experience of the subjects may influence results it would be prudent to consider the exercises that are assessed.

Canavan et al. (1) observed a significant relationship in the kinetic variables between the hang snatch lift and the squatting vertical jump, whereas there was an absence of a relationship in the kinematic variables. These kinematic differences were also seen when comparing the power clean, vertical countermovement jump (CMJ) and a loaded squat jump (6). Moreover, the concentric power displayed between the hang power cleans and CMJ demonstrated was greater for the CMJ which demonstrates a difference in kinetics between exercises (6). Also regardless of different loading schemes these kinetic difference may still be evident suggesting that kinetic differences should be considered when assessing performance. Comparison of different exercises with or without heel lifts requires the examination of specific exercises as the effects between two different exercises are problematic. The current study compared the effects of heel lifts when comparing the CJS and LCMJ against itself as the goal was not to examine the relationship between the two exercises, rather influence of a heel lift on performance. The differences and similarities between exercises necessitate the examination of affects that heel lifts may have on a variety of commonly used weight training exercises (e.g. front squat). Alterations to angular kinematics and linear kinetics from the use of heel lifts in different shoes may influence the role of the performance on some exercises and have a minimal effect on others. The type of shoe along with heel lift thickness should be examined in future studies as this may benefit an athlete's range of motion, kinetic performance (e.g. peak force) or self-confidence. Improvements in training performance would maximize athletes' chronic physical adaptations and if the training improvements can be done using heel lifts would provide another method for the SCC to apply in programming.

Strength and conditioning coaches that are in search of economical, time saving, and effective training accessories may find plastic heel lift inserts an alternative to weightlifting shoes for sports teams. Athletes can utilize their traditional training shoes during S&C sessions that would allow coaches to program weightlifting movements and plyometric exercises in the same program. The storage and cleaning of the heel lifts would save space in training areas and are interchangeable with proper cleaning protocols. Based on the results of the study, a SCC could have athletes use heel lifts with no deleterious effect on kinetic variables CJS and LCMJ.

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