THE EFFECTS OF WEIGHTLIFTING SHOES ON SQUAT KINEMATICS

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Athletes may not always consider footwear when performing the barbell back squat during training. Several footwear companies have designed shoes claimed to enhance performance in weightlifting and powerlifting. The purpose of this study was to compare the kinematics of the barbell back squat wearing either running shoes (RS) or weightlifting shoes (WLS). Young, healthy active adult males (*N*=20) were filmed in the sagittal plane while performing barbell back squats for each shoe condition at an intensity of 60% of one repetition maximum (1RM). While a number of kinematic parameters were similar between conditions, the shank maintained a more vertical position and the bar and hip were displaced less when wearing WLS, suggesting a more erect trunk posture. WLS may make small changes that allow for a safer, more effective squat performance.

KEYWORDS: footwear, power lifting, bar path.

INTRODUCTION: The traditional barbell back squat is both a competitive lift in the sport of powerlifting and an exercise commonly incorporated in the regimens of those who participate in resistance training or who are rehabilitating a lower extremity injury. The National Strength & Conditioning Association (NSCA) published a position statement and review article on the squat (Chandler & Stone, 1991). This position statement suggested that poor squatting technique could increase the risk of injuries, particularly to the knees and low back. To prevent such injuries, the NSCA recommends that the lifter maintain a normal lordotic posture and keep the torso as vertical as possible throughout the entire lift. The descent should begin with a slight forward bend at the hips while keeping the weight towards the heels, “sitting back” rather than shifting forward. More recent biomechanical studies have further measured joint kinetics and kinematics of the squat, from both performance and clinical perspectives, and these studies have reported joint range of motions (ROMs) (Kongsgaard et al., 2006), peak flexion angles of the lower extremity joints and segments (Fry et al., 2003; Salem et al., 2003; Flanagan & Salem, 2007), and displacement of the barbell (Donnelly, Berg, & Fiske, 2006) to evaluate the lifting technique.

Nearly all sports use some type of equipment or apparel aimed to help enhance performance and/or reduce injury risk, and this includes the sports of powerlifting and weightlifting. Weightlifting shoes (WLS) are designed with the intent to increase power production during Olympic-style lifts (i.e. the clean and jerk and the snatch) and squats; their main features are hard, incompressible soles that quickly redirect force upward from the floor, and raised heels to facilitate ankle mobility (Charniga; Kilgore & Rippetoe). Though no studies have investigated the effects of WLS or any other type of shoe, studies have shown that body-weight squats performed on a slight decline angle (similar to the effect created by WLS) have increased lower extremity muscle activity (Kongsgaard et. al., 2006; Richards et. al., 2008).

The purpose of the current study was to examine differences in squat kinematics when wearing running shoes (RS) and WLS. It was hypothesized that the WLS would alter the lower body joint ranges of motion (ROMs), allowing lifters to have a more erect trunk posture and perform a more efficient squat. Results from this study will add scientific understanding to the current anecdotal information of the biomechanical effect of WLS on barbell back squats.

METHODS: Healthy, college-aged males volunteered for this study (20±3 yrs.; 180±6 cm; 87±11 kg). All participants were relatively experienced in resistance training including the barbell back squat. After signing a consent form, each participant had an adequate amount of stretching and warm-up to replicate a regular training session. A 60-Hz Panasonic digital camera (Osaka, Japan) was placed approximately 1.3 m high and 5 m away on the left side to capture the two-dimensional barbell back squat kinematics in the sagittal plane. Reflective markers were placed on left side of the participant's fifth metatarsal joint (toe), lateral malleolus (ankle), lateral femoral epicondyle (knee), and greater trochanter (hip). An additional marker was placed on the end of the barbell. These five markers were used to create trunk, thigh, shank, and foot segments to calculate joint angles of the (a) hip, (b) knee, and (c) ankle, as seen in Figure 1. A segment from the hip to the end of the barbell was used to approximate the trunk segment since the end of the barbell is in the fixed position of the shoulder joint (McLaughlin, Dillman, & Lardner, 1977; Fry et al., 2003).

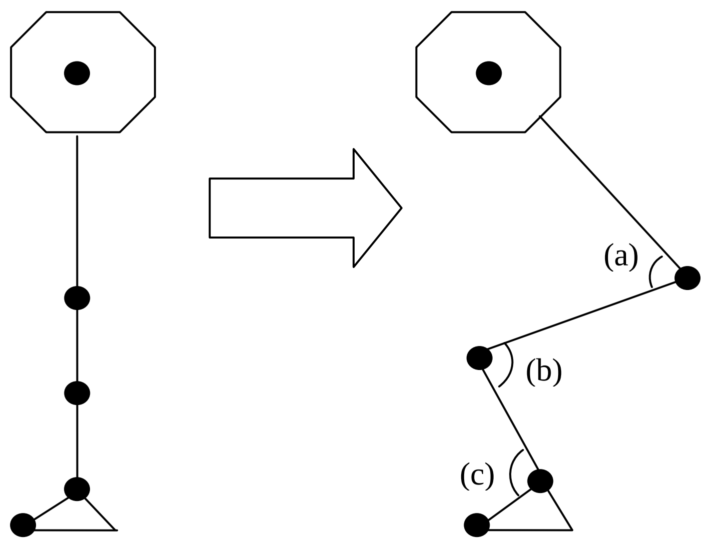

Figure 1: A diagram of the marker set up and joint angle measures.

As all participants were familiar with the barbell back squat, only a brief instruction was given to ensure the left foot was perpendicular to the camera position and the feet were pointed forward for proper tracking of the squat motion in the sagittal plane. If a participant felt uncomfortable with any aspect of the testing procedure, practice sets were offered. In order to achieve a comparable effort level from all participants, all trials were performed at 60% of their self-reported one repetition maximum (1RM). Each participant performed five repetitions using RS and five repetitions using WLS. All repetitions of a particular shoe type were completed together, but the order of shoe condition was randomized. For each squat repetition, participants began standing erect with the barbell on the upper back and descended until the thigh segment was roughly parallel to the floor, and then ascended back to the starting position.

The squat video was captured and the data were directly imported into Vicon Motus version 9.2 software (Centennial, CO). Two of the five repetitions were averaged and used for calculation purposes. The two repetitions chosen were the third and fourth repetitions in all participants. The kinematic variables measured were the posterior displacement of the hip and anterior displacement of the barbell from their initial positions, anterior displacement of the knee from the toe, ROM and peak flexion of the ankle, knee, and hip joints, and peak flexion of the trunk segment with respect to the vertical. The anterior bar displacement and posterior hip displacement were summed to create a variable termed "horizontal trunk displacement". Repeated-measures ANOVAs were conducted for horizontal trunk and anterior knee displacements, joint ROM, and joint peak flexion using Statistical Package for Social Sciences (SPSS) version 11.5 (Chicago, IL). To protect against Type I or II errors, $\alpha=0.05$ and $\beta=0.20$.

RESULTS: Joint ROM, peak flexion angles, anterior bar and knee displacement values are shown in Table 1. The p value and statistical power are also reported. Significantly less horizontal trunk displacement was seen while lifters performed with WLS. This indicates the lifters maintained a more erect trunk posture during when squatting. There was also a statistically significant difference in ankle peak flexion, equating to a more vertical shank position, in the WLS condition. No other significant differences were seen between conditions.

Table 1. Comparison of squat kinematics between RS and WLS

Variable	RS	WLS	p-value	power
*Horizontal trunk displacement (mm)	231 ± 52	207 ± 43	0.04	0.55
Anterior knee displacement (mm)	90 ± 28	94 ± 30	0.44	0.12
Ankle ROM (deg)	23 ± 4	24 ± 5	0.17	0.27
Knee ROM (deg)	92 ± 13	93 ± 14	0.32	0.16
Hip ROM (deg)	96 ± 23	99 ± 15	0.44	0.12
*Ankle peak flexion (deg)	100 ± 8	103 ± 7	0.02	0.64
Knee peak flexion (deg)	81 ± 14	81 ± 15	0.83	0.06
Hip peak flexion (deg)	73 ± 15	73 ± 14	0.71	0.07
Trunk peak flexion (deg)	52 ± 9	52 ± 9	0.61	0.08

*Significant difference between shoe conditions, $p<0.05$.

DISCUSSION: The barbell back squat is an effective strength training exercise, when done in moderation with proper technique (Chandler & Stone, 1991). This study investigated whether WLS, specifically designed to improve squat technique, would significantly affect squat kinematics. Joint ROM and peak flexion angles were very similar between conditions, though a significant difference in ankle peak flexion indicated a slightly more vertical shank position, which is consistent with the teachings of proper squat technique (Chandler & Stone, 1991). With no difference in ankle ROM, it is likely that this is the direct effect of raised heel in WLS. The knees were able to move slightly over the toes in both conditions, which has been shown as an effective way to minimize hip and knee joint torque (Fry, Smith, & Schilling, 2003).

The biggest practical difference may have been in the horizontal trunk movement. From a physics perspective, the optimal bar path for the squat is a completely vertical line. In reality, there will always be some anterior bar displacement accompanied by some posterior hip displacement, creating a forward trunk lean. The goal, then, is to minimize these movements to reduce the amount of trunk lean. In a previous biomechanical analysis of elite lifters (McLaughlin, Dillman, & Lardner, 1977), higher skilled lifters had less trunk lean than their lower skilled counterparts. Accordingly, the NSCA's position paper also recommended minimal trunk lean to improve performance and reduce injury risk (Chandler & Stone, 1991). In this study, the combined amount of anterior bar movement and posterior hip movement was significantly less when wearing WLS. This seemingly corresponds to a more erect trunk posture, which coaches believe should reduce stress on the low back. Unfortunately, the population of this study did not exhibit any other kinematic differences when using WLS versus running shoes. However, during testing nearly all participants mentioned to the research staff that they felt the squats were much easier to perform when wearing WLS. The initial findings of this study do suggest that further research on the effects of WLS is warranted. Possible studies might include analyzing movement patterns throughout the various phases of the squat, incorporating higher loads, measuring kinetic variables such as peak joint torques and work, and tracking excursion of the center of pressure to consider stability levels. It is also suggested to integrate a larger, more diverse population of subjects to explore WLS effects' on squat mechanics with respect to age, gender, and training experience.

CONCLUSION: This is the first known study on the effects of footwear on squatting technique. Lifters demonstrated significantly more peak ankle flexion and significantly less combined anterior bar and posterior hip displacement when wearing weightlifting shoes (WLS) as compared to running shoes. This suggests that WLS allow for the more vertical shank position and erect posture during squatting that strength coaches recommend.

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