Hip and Knee Kinetics During a Back Squat and Deadlift

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Abstract

Choe, KH, Coburn, JW, Costa, PB, and Pamukoff, DN. Hip and knee kinetics during a back-squat and deadlift. *J Strength Cond Res* 35(5): 1364–1371, 2021—The back-squat and deadlift are performed to improve hip and knee extensor function. The purpose of this study was to compare lower extremity joint kinetics (peak net joint moments [NJMs] and positive joint work [PJW]) between the back-squat and deadlift. Twenty-eight resistance-trained subjects (17 men: 23.7 ± 4.3 years, 1.76 ± 0.09 m, 78.11 ± 10.91 kg; 11 women: 23.0 ± 1.9 years, 1.66 ± 0.06 m, 65.36 ± 7.84 kg) were recruited. One repetition maximum (1RM) testing and biomechanical analyses occurred on separate days. Three-dimensional biomechanics of the back-squat and deadlift were recorded at 70 and 85% 1RM for each exercise. The deadlift demonstrated larger hip extensor NJM than the back-squat {3.59 (95% confidence interval [CI]: 3.30–3.88) vs. 2.98 (95% CI: 2.72–3.23) $Nm\cdot kg^{-1}$, $d = 0.81$, $p < 0.001$}. However, the back-squat had a larger knee extensor NJM compared with the deadlift (2.14 [95% CI: 1.88–2.40] vs. 1.18 [95% CI: 0.99–1.37] $Nm\cdot kg^{-1}$, $d = 1.44$ $p < 0.001$). More knee PJW was performed during the back-squat compared with the deadlift (1.85 [95% CI: 1.60–2.09] vs. 0.46 [95% CI: 0.35–0.58] $J\cdot kg^{-1}$, $d = 2.10$, $p < 0.001$). However, there was more hip PJW during the deadlift compared with the back-squat (3.22 [95% CI: 2.97–3.47] vs. 2.37 [95% CI: 2.21–2.54] $J\cdot kg^{-1}$, $d = 1.30$, $p < 0.001$). Larger hip extensor NJM and PJW during the deadlift suggest that individuals targeting their hip extensors may yield greater benefit from the deadlift compared with the back-squat. However, larger knee extensor NJM and PJW during the back-squat suggest that individuals targeting their knee extensor muscles may benefit from incorporating the back-squat compared with the deadlift.

Key Words joint moment, resistance, torque

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Introduction

A reduction in lower extremity skeletal muscle mass and strength is associated with a decline in physical function, while increased mass and strength are associated with increased athletic performance (10,15,36). Exercises such as the back-squat (23) and deadlift (12) recruit muscle groups with the largest cross-sectional area (CSA) and are associated with metabolic and hormonal responses that contribute to muscle strength and hypertrophy (19). Therefore, the back-squat and deadlift are commonly performed to increase lower extremity strength.

The deadlift is an effective exercise for improving hip and knee extensor strength and has greater concentric rate of force development (RFD) compared with the squat (2,13). Many athletic tasks such as sprinting or jumping do not require maximal force, but a submaximal amount of force in a short time interval (31). Greater RFD in the deadlift compared with the squat implies that athletes who frequently perform quick tasks such as sprinting (34) and jumping (26) would benefit from performing the deadlift. Furthermore, individuals also use variations of the deadlift, such as the Romanian deadlift in rehabilitation settings, such as late-stage anterior cruciate ligament (ACL) injury recovery. The activation of the hamstrings in the deadlift may protect the ACL during knee rehabilitation because it provides an additional posterior force on the tibia (12,38). The back-squat also targets the hip and knee extensors and is effective in improving lower extremity strength and athletic performance (7,29,30). For example, greater squat strength is associated with greater performance in sprint and vertical jump tasks (25,37). To further exemplify the importance of squat ability, individuals who increased squat strength also decreased their sprint times (9,30). Trained individuals produce higher peak ground reaction force (GRF) during the back-squat compared with other lower extremity exercises including the deadlift, lunge, and step-up (13). Because the kinematics of the back-squat are similar to activities of daily living and athletic performance (e.g., lifting objects from the ground), improving squat strength can improve quality of life by increasing maximal strength, thus reducing the relative force production requirement to accomplish a task (16).

Despite these similarities, it is important to recognize subtle differences between the back-squat and deadlift that may have implications for exercise selection. For instance, a study comparing kinematics (18) found that hip and knee joint flexion angles are greater during the deadlift compared with the back-squat throughout the exercise. However, the study was not performed in a laboratory setting, and kinetic variables, such as joint moments, were not investigated (18). The hamstrings have higher electromyography (EMG) activity (38), but lower quadriceps EMG activity during the deadlift compared with the back-squat (11). There is paucity in the literature regarding joint kinetics of the back-squat and deadlift. For instance, the only available study (13) exclusively investigated peak GRF and RFD, with no regards toward individual joint loading. In moderately trained individuals, the back-squat produces higher peak GRF compared with the deadlift, but the deadlift results in a greater RFD than the back-squat (13).

Although there is evidence of greater GRF in the back-squat compared with the deadlift, and a greater RFD in the deadlift compared with the back-squat, examining individual joint kinetics provides valuable information to both clinicians and strength and conditioning coaches. Ground reaction force and RFD are indicative of the net forces exerted by the body without regards to specific joint or muscle contributions and can differ depending on the task as different joints or muscles are used. In addition, the ability to produce a high GRF or RFD in 1 activity may not be applicable to another activity. Therefore, examining joint kinetics such as net joint moments (NJMs) and positive joint work (PJW) may aid in exercise prescription by identifying the predominately used joint. Practitioners can use this information to develop training interventions that bias certain musculature depending on the needs of an individual.

Therefore, the purpose of this study was to evaluate the differences in lower limb kinetics (peak NJM and PJW) during the concentric phase of a deadlift and back-squat in a collegiate population. Because of the higher GRF, we hypothesized that there would be larger peak NJMs and more PJW performed during the back-squat at all joints compared with the deadlift.

Methods

Experimental Approach to the Problem

A cross-sectional design was used in this study to compare joint kinetics between the back-squat and deadlift exercises at 70% and 85% of 1 repetition maximum (1RM). Two visits separated by at least 48 hours were required from each subject, with day 1 consisting of 1RM testing, and day 2 consisting of biomechanics testing. Subjects were asked to refrain from exercise in between visits. Subjects were also asked to maintain normal dietary and hydration patterns.

Subjects

An a priori power analysis using data from a previous study (18) comparing back-squat and deadlift kinematics (absolute and relative lower extremity joint angles and barbell velocity) indicated that 23 subjects would be needed to achieve a power of 0.8 assuming a similar effect size ($d = 0.6$, $\beta = 0.2$, $\alpha = 0.05$). The kinematic comparisons of this study, such as joint angles, influence lower extremity kinetics such as NJMs. Therefore, 28 subjects (mean $\pm$ *SD*: 17 men −23.7 $\pm$ 4.0 years, 1.76 $\pm$ 0.09 m, 78.11 $\pm$ 10.91 kg, back-squat 1RM = 122.73 $\pm$ 23.25 kg, deadlift 1RM = 143.32 $\pm$ 22.93 and 11 women −23.0 $\pm$ 1.9 years, 1.66 $\pm$ 0.06 m, 65.36 $\pm$ 7.84 kg, back-squat 1RM = 88.02 $\pm$ 30.59 kg, deadlift 1RM = 95.04 $\pm$ 15.87 kg) were recruited to account for potential attrition and minor differences in study design. To be eligible for participation, subjects had to be between 18 and 35 years of age, performed the back-squat and deadlift exercises 1 time per week for the past 3 months, and had to be comfortable with 1RM testing. Subjects were excluded if they reported current pain anywhere in their body, musculoskeletal injury in the last year that required professional consultation, or any musculoskeletal surgery. The California State University, Fullerton institutional review board approved all methods used in this study, and all subjects were informed of potential risks and benefits of the study before providing written consent.

Procedures

During the first visit, subjects had their 1RM in the back-squat and deadlift tested in a random order, and testing procedures were identical. One repetition maximum testing began with a standardized warm-up that consisted of Frankenstein walks, walking knee pulls, and lungs spanning a distance of 30 m, followed by submaximal back-squat and deadlift sets (4). Subjects were asked for their estimated 1RM because they were experienced in both exercises. Warm-up back-squat and deadlift sets were performed for 8, 3, 1, 1, and 1 repetition at 50, 70, 80, 90, and 100% of estimated 1RM, respectively. On completion of the warm-up, attempts at a new 1RM were made. Rest periods of 1–5 minutes were given between every set to ensure proper rest and minimal fatigue. The same rest period was given between 1RM testing of the back-squat and deadlift (4). Testing ended when the subject failed to successfully lift a certain weight. A back-squat was considered successful when the bottom of subjects' thighs was parallel with the ground during the eccentric phase, reached resting position after the concentric phase, no excessive flexion or extension of the trunk occurred, and the researcher did not notice any compensation such as excessive frontal plane knee motion or anterior translation of the knee relative to the foot. Excessive anterior translation of the knee was defined as continual knee translation resulting in excessive ankle plantarflexion and visible balance issues. A deadlift was successful if lockout of the hip and knee occurred with the barbell in hand. Excessive lumbar flexion resulted in a failed lift. Excessive lumbar flexion was determined when the knee and hip joints were locked out, and motion came exclusively from lumbar spine flexion. Squat testing occurred in a squat rack with supporting side racks in case of failure, and deadlift testing occurred on

Table 1. Reliability data.*

Variable	Intrasession $ICC_{(3,1)}$	*SD*	*SEM*
BS70HM	0.92	0.07	0.02
BS70KM	0.94	0.05	0.01
BS85HM	0.95	0.11	0.02
BS85KM	0.73	0.06	0.03
DL70HM	0.96	0.09	0.02
DL70KM	0.43	0.04	0.03
DL85HM	0.57	0.06	0.04
DL85KM	0.90	0.03	0.01

*ICC = intraclass correlation coefficient; BS = back-squat; DL = deadlift; 70 = 70% 1RM; 85 = 85% 1RM; HM = hip moment; KM = knee moment.

a wooden platform where subjects dropped the weight if the weight was too heavy. A spotter and verbal encouragement were provided during all attempts. Accessories such as knee wraps or sleeves, weightlifting belts, or gloves were not used during either visit, and subjects were instructed to wear their own footwear, as long as they wore the same shoes for each visit.

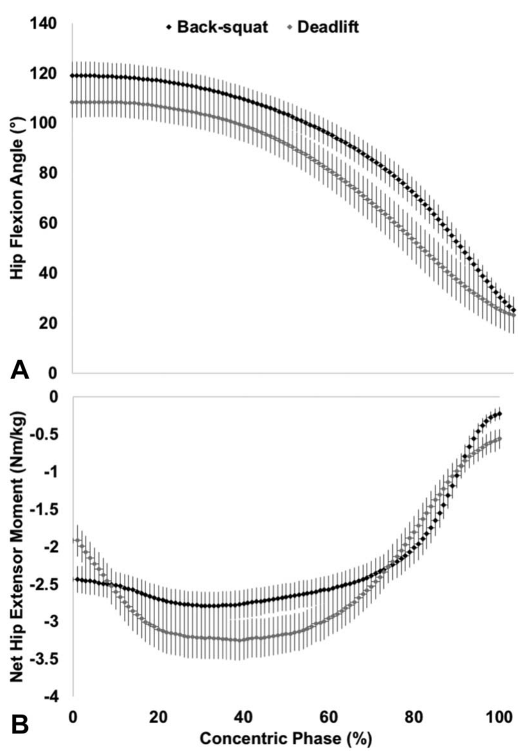

Figure 1. Ensemble average waveform of hip joint angle (A) and hip joint moment (B) in the back-squat and deadlift collapsed across load.

The second visit consisted of testing in the biomechanics laboratory. After performing the same warm-up as the first visit, subjects were fitted with retroreflective markers placed bilaterally on the anterior superior iliac spine and greater trochanter, the lateral and medial femoral epicondyles, lateral and medial malleoli, and first and fifth metatarsals. Additional cluster sets of 4 noncollinear markers were placed on the sacrum, bilaterally on the thigh and shank, and clusters of 3 noncollinear markers bilaterally on the feet. After a standing static trial, all individual markers were removed.

Marker position data were sampled at 240 Hz using a 9-camera Oqus 300 Qualisys (Software Version 2.13, Gothenburg, Sweden) motion capture system. Global and segmental axes systems were established with the mediolateral axis as the x-axis, anteroposterior axis as the y-axis, and the longitudinal axis as the z-axis. A men's Olympic barbell with a mass of 20 kg and a length of 2.1 m was used for both the squat and deadlift. Force plate data were sampled at 2,400 Hz using 2 AMTI force plates (Model Number MSA-6; AMTI, Watertown, MA).

Subjects performed 4 sets of each exercise, for 3 repetitions (2 sets of 3 repetitions at 70 and 85% 1RM) in a block-randomized order. Two different intensities were used to determine whether load lifted had an effect on joint loading. A rest period of 3 minutes was given between each set. A metronome was set to 55 beats per minute (55) to ensure that all exercises were performed at the same velocity. A standard velocity was used to attempt to control acceleration, which influences NJM magnitude. All lift attempts were successful and had the same success criteria as 1RM testing.

Data Reduction. Raw position and force plate data were exported to Visual 3D (Rockville, MD) for model construction. Position and force plate data were low-pass filtered (recursive fourth order Butterworth) at 12 Hz. Hip joint centers were estimated as 25% of the intertrochanteric distance, knee joint centers estimated using the midpoint between the femoral epicondyles, and ankle joint centers using the midpoint of the malleoli. Motion was defined as movement of the distal segment relative to the proximal segment. All NJM and PJW data were normalized to body mass. The second repetitions of each trial were averaged together for analysis. The subject's dominant limb, defined by the preferred limb used to kick a ball, was used for analysis.

Joint angles were calculated using the X-Y-Z Cardan sequence and defined as movement of the distal segment relative to the proximal segment. Peak NJMs were expressed as internal and calculated using standard inverse dynamics procedures. It should be noted that NJM data were taken as absolute values and reported as positive for comparative analysis. Positive joint work was calculated as the time

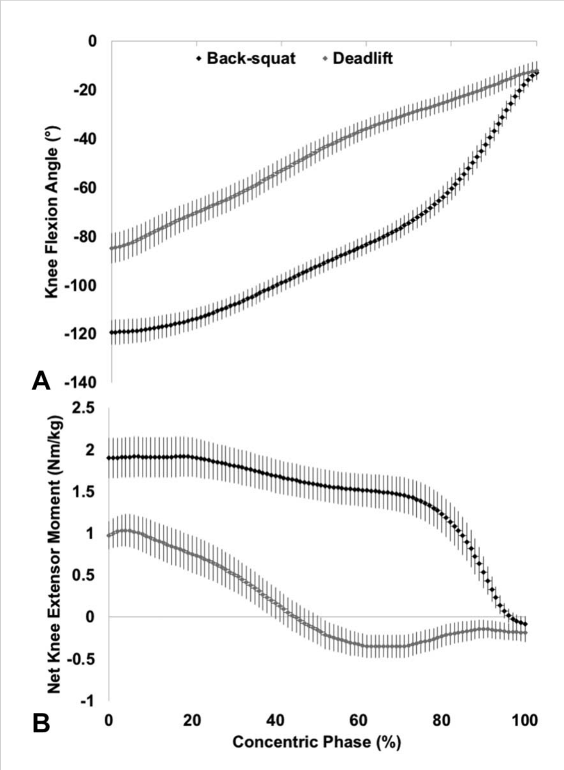

Figure 2. Ensemble average waveform of knee joint angle (A) and knee net joint moment (B) in the back-squat and deadlift at collapsed across load.

integral of joint power at each joint during the concentric phase of each exercise. All dependent variables were obtained from the concentric phase of the back-squat and deadlift. The concentric phase of the back-squat and deadlift were analyzed due to the similarity between concentric muscle actions (hip and knee extension) and the propulsive phase of various tasks in sport (running, jumping, and cutting). The minimum position of the pelvis center of mass (COM) indicated the start of the concentric phase, and the maximum position of the COM indicated the end. Concentric phase and peak values were obtained using a custom LabVIEW program (National Instruments, Austin, TX). Joint angle and NJM waveforms for each joint were time normalized to 100% of the concentric phase, and ensemble averages were plotted for inspection.

Statistical Analyses

All data were assessed for normality using the Kolmogorov-Smirnov test and inspection of skewness and kurtosis (ratio of statistic to *SE*). Reliability was assessed using intraclass correlation coefficient (model 3, 1). Separate 2 (exercise) by 2 (load) by 3 (joint) repeated measures of analysis of variance (ANOVA) were used to compare peak NJM and total PJW at the hip, knee, and ankle between the back-squat and deadlift at each load ($\alpha = 0.05$). *Post hoc* comparisons were assessed using a *Bonferroni* adjustment (0.05/6 comparisons, $\alpha = 0.008$). Cohen's d effect sizes were also reported, and an effect size of 0.2–0.4 was considered small, moderate as 0.4–0.7, and large as 0.7+. In addition, regions of the ensemble average waveforms where the 95% confidence intervals (CIs) of the back-squat and deadlift did not overlap were considered significantly different.

Results

Ankle NJM and PJW data at both intensities violated the assumption of sphericity, and a Greenhouse-Geisser correction was applied to the ANOVA model. All other data were normally distributed and were treated as such. All data demonstrated good to excellent reliability (Table 1).

Net Joint Moments

The 2 (exercise) by 2 (load) by 3 (joint) interaction was not significant for NJMs ($F_{2,54} = 0.71, p = 0.496$). However, there was a significant 2 (exercise) by 3 (joint) interaction for NJM after collapsing across load ($F_{2,54} = 136.14, p < 0.001$). *Post hoc* analyses of mean values collapsed across load indicated that the deadlift demonstrated a larger hip extensor NJM than the back-squat (3.59 [95% CI: 3.30–3.88] vs. 2.98 [95% CI: 2.72–3.23] $Nm \cdot kg^{-1}$, $d = 0.81$, $p < 0.001$). However, the back-squat had a larger knee extensor NJM compared with the deadlift (2.14 [95% CI: 1.88–2.40] vs. 1.18 [95% CI: 0.99–1.37] $Nm \cdot kg^{-1}$, $d = 1.44$ $p < 0.001$). No difference was found in the peak plantarflexor NJM between the back-squat and deadlift (1.26 [95% CI: 1.13–1.40] vs. 1.41 [95% CI: 1.27–1.56] $Nm \cdot kg^{-1}$, $d = 0.34$, $p = 0.271$).

Further analysis of the ensemble average waveforms indicated greater dorsiflexion throughout the concentric phase during the back-squat compared with the deadlift (Figure 1A). However, there was no difference in the plantarflexion NJM at any time point of the concentric phase (Figure 1B). There was greater knee flexion (Figure 2A) and a greater knee extensor NJM (Figure 2B) from 0 to 96% of the concentric phase during the back-squat compared with the deadlift. There was a greater hip flexion from 50 to 89% of the concentric phase in the back-squat compared with the deadlift (Figure 3A), but a greater hip extensor NJM from 37 to 57% of the concentric phase in the deadlift compared with the back-squat (Figure 1B).

Net Positive Work

The 2 (exercise) by 2 (load) by 3 (joint) interaction was not significant for PJW ($F_{2,54} = 0.70$, $p = 0.459$). There was a significant 2 (exercise) by 3 (joint) interaction for PJW at after collapsing across load ($F_{2,54} = 165.93$, $p < 0.001$). *Post hoc* analyses of the mean values collapsed across load indicated more PJW at the knee during the back-squat compared with the deadlift (1.85 [95% CI: 1.60–2.09] vs. 0.46 [95% CI: 0.35–0.58] $J \cdot kg^{-1}$, $d = 2.10$, $p < 0.001$). However, there was more PJW at the hip during the deadlift compared with the back-squat (3.22 [95% CI: 2.97–3.47] vs. 2.37 [95% CI: 2.21–2.54] $J \cdot kg^{-1}$, $d = 1.30$, $p < 0.001$). No differences were found

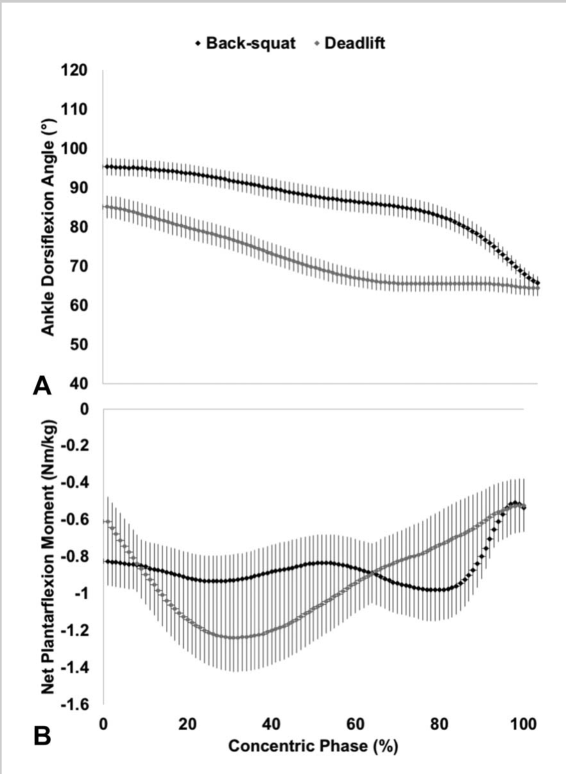

Figure 3. Ensemble average waveform of ankle joint angle (A) and ankle joint moment (B) in the back-squat and deadlift collapsed across load.

in PJW at the ankle between the back-squat and deadlift (0.38 [95% CI: 0.34–0.43] vs. 0.38 [95% CI: 0.32–0.45] $J \cdot kg^{-1}$, $d = 0.09$, $p = 0.741$).

Discussion

The purpose of this study was to evaluate lower extremity kinetics (peak NJM and total PJW) during the concentric phase of a deadlift and back-squat in college lifters. We hypothesized that the back-squat would result in greater NJM and PJW compared with the deadlift. Results demonstrate larger hip extensor NJMs and greater hip PJW during the deadlift compared with during the back-squat, but larger knee extensor NJMs and greater knee PJW during the back-squat compared with during the deadlift. In addition, no differences were found in ankle plantarflexor NJMs or ankle PJW between the 2 exercises.

Our findings regarding larger peak knee extensor NJMs and knee PJW during the back-squat compared with during the deadlift support our hypothesis. A potential explanation for the larger knee extensor NJM during the back squat compared with during the deadlift is the placement of the barbell relative to the hip and knee joint centers. During the back-squat, the barbell is placed further posteriorly to the individual compared with the deadlift. The difference in barbell placement could shift the COM of the system posteriorly, causing the GRF vector to move further posteriorly as well. This shift in COM location would cause the GRF vector to be further away from the knee joint center and closer to the hip joint center, thus creating a larger knee extensor NJM in the back-squat compared with the deadlift. This conclusion is supported by a previous investigation that found greater posterior loading contributes to greater knee extensor NJM compared with hip extensor NJM (23).

Knee joint kinematics also provide insight into our finding. For instance, there were greater knee flexion angles throughout the entire concentric phase of the back-squat compared with the deadlift. Analysis of ensemble average waveforms suggests that the knee joint range of motion (ROM) during the concentric phase during the back-squat was larger than during the deadlift exercise. The small amounts of knee joint ROM during the deadlift most likely contributed to larger knee extensor NJM and knee PJW in the back-squat. Because PJW is calculated as the product of NJM and angular displacement, the combination of larger knee extensor NJM and knee flexion ROM contributes to greater knee PJW during the back-squat compared with during the deadlift.

The ensemble average waveforms demonstrate that knee extensor NJM were greater during the back-squat compared with the deadlift throughout the entire concentric phase. This provides further evidence that knee joint loads are higher during the back-squat compared with the deadlift.

The back-squat or similar variations of the back-squat may not be the exercise of choice for individuals with knee pain. Weight-bearing activities involving high amounts of the knee flexion, such as the back-squat, contribute to patellofemoral joint stress, and may cause pain (27). Overall, the larger knee extensor NJM and greater knee PJW during the back-squat compared with the deadlift may be associated with greater muscular demand, and those aiming to bias and load the knee joint musculature may benefit from performing the back squat. Previous research supports this conclusion, as squats with high knee flexion angles as those in this study require greater knee extensor effort and result in greater knee extensor strength adaptations (3,6). In addition, the sit-to-stand (STS) task requires high contributions from the knee extensors, and more so than the hip extensors (24). The ability to maintain STS function is crucial because it is an activity of daily living. Therefore, training that incorporates the back-squat may aid in maintaining or improving STS ability. Although the effects of a back-squat on sports performance are well studied (25,37), future investigations should examine the specific effects of the back-squat on knee extensor strength and how that may aid in improved physical function across various populations.

There were larger peak hip extensor NJMs and greater hip PJW during the deadlift compared with the back-squat, which contradicted our hypothesis. The previous explanation regarding the effect of barbell placement on GRF vector location also applies to hip extensor NJM. During the deadlift, the barbell is placed much further anteriorly to the knee joint center than in the back squat. This would shift the COM of the system forward, causing the GRF vector to move anteriorly. The result is that the GRF vector is closer to the knee joint center and further from the hip joint center, contributing to a larger hip extensor NJM in the deadlift compared with the back-squat. This conclusion is supported by previous literature (23), which suggests that greater anterior barbell placement contributes to greater hip extensor NJM.

Analysis of ensemble average waveforms suggests that hip joint ROM was similar during the deadlift and back-squat. Therefore, the greater amount of hip PJW performed during the deadlift compared with during the back-squat is most likely due to the differences in hip extensor NJM rather than ROM. These results suggest that the movement patterns of the deadlift and back-squat are similar, but the placement of the barbell or external resistance has a large influence on the magnitude of joint loading. This can provide some insight into the clinical setting. For instance, clinicians could benefit from using variations of the back-squat and deadlift that manipulate placement of the external load or barbell to bias a joint of interest, or minimize joint loading.

Loading large muscle groups is crucial, as muscle CSA is highly correlated with force production ability (17). Compared with other joints, such as the knee, the hip joint musculature has a much larger CSA (20,35). Therefore, improving hip extensor strength and function can yield greater increases in overall lower extremity strength because of larger CSA. The idea of loading larger muscle groups also applies during resistance training. When external loads are increased in lower extremity exercises such as the deadlift, contributions from the hip extensors also increase (1,21).

Loading the hip joint musculature also has benefits to performance-oriented tasks such as higher vertical jumps (22) and faster running speeds (28). For example, greater hip extensor NJM are associated with greater force production and vertical jump height (22). A previous study investigated lower extremity contributions to vertical jump performance in soccer players. When comparing the players, those who had higher vertical jumps demonstrated greater hip extensor NJM and hip joint work than those who did not jump as high (33). Therefore, the ability to load the hip joint musculature is crucial in sport, especially those involving jumping. Therefore, individuals who participate in sports requiring substantial hip extensor contributions may benefit from the deadlift more than the back-squat.

There is ample evidence in the literature advocating deadlift training to improve performance in sport. For example, incorporating the deadlift into a training regimen contributes to an increase in the rate of knee extensor and flexor torque development as well as higher vertical jump heights in novice lifters (32). This finding suggests that because of the increase in rate of torque development, the deadlift may have positive transfer to highly explosive and time sensitive tasks. When considering findings of previous investigations (32,38), the deadlift seems to be an effective exercise that can benefit multiple populations. For example, strength and conditioning coaches would also benefit from this finding, as programming deadlifts into training regimens would benefit their athletes' performance. As previously mentioned, the benefits of deadlift training are multifactorial (32,38), as individuals who incorporate the deadlift observe increases in rate of quadricep and hamstring torque development, as well as jump height. However, future studies should aim to examine more advanced athletes or a clinical population to see whether the deadlift may benefit them as well.

No differences were found in peak ankle plantarflexor NJM and ankle PJW during the back-squat and deadlift. There was greater dorsiflexion throughout the entire concentric phase during the back-squat compared with the deadlift, but no differences were found between exercises in ankle plantarflexor NJMs throughout the entire concentric phase. In addition, ankle joint ROM was similar between the 2 exercises. The lack of joint ROM most likely contributed to the lack of differences in ankle NJM and PJW. In addition, the magnitude of ankle plantarflexor NJM was much smaller compared with the hip and knee extensor NJMs. Ankle plantarflexor NJM magnitudes in this investigation are smaller than those found in a single-heel raise task with no additional load (14), suggesting that neither the back-squat nor deadlift is the best exercise to target the ankle joint musculature. Therefore, future investigations aiming to improve ankle plantarflexor function may wish to consider using exercises, which require less contribution from the hip and knee and isolate the ankle joint.

There are limitations to consider when interpreting the results of this investigation. First, although eccentric training has multiple benefits including increased peak torque and strength (8), the eccentric portion of the exercises were not assessed. Second, the absolute load during the deadlift was different than the absolute load during the back-squat, and the difference in the magnitude may have influenced joint kinetics. However, although loads were different in an absolute sense, they were the same in as a percentage of maximum capacity. Therefore, the relative effort of each exercise was similar. In addition, we evaluated lower extremity kinetics without regard to upper extremity kinematics, such as trunk angle, which may influence joint loading. Finally, NJMs do not consider cocontraction from antagonist muscles. The gluteus maximus and hamstring muscles contribute to the hip extensor NJM during a maximum voluntary contraction at the hip (6). Therefore, during activities such as the back-squat, gluteus maximus and hamstring activation are required. However, cocontraction of the hamstrings with the quadriceps at the knee takes away from the knee extensor NJM, which becomes less than the quadriceps moment (5). Future studies should consider allowing subjects to perform both exercises at a self-selected velocity, use the same load for both exercises, evaluate upper extremity kinematics, or use EMG to estimate cocontraction. Joint loading in other planes of motion, such as the frontal and transverse planes, should also be investigated because they can provide valuable insight into performance enhancement or injury prevention.

Practical Applications

The results of this investigation indicate that the deadlift resulted in greater hip extensor NJM, hip PJW, and ankle NJM compared with the back-squat. However, the back-squat resulted in greater knee extensor NJM and PJW compared with the deadlift. These findings indicate that strength and conditioning professionals aiming to load the hip extensors may yield a larger training stimulus from incorporating deadlifts compared with back-squats when planning exercise regimens. Large hip extensor NJMs are associated with faster running speeds and higher jump heights, which are important factors in sport. However, if athletes have deficits in knee extensor strength and improving knee function is the goal, strength and conditioning professionals should consider incorporating back-squats into their programs, as the knee extensor NJM and PJW were larger compared with the deadlift.

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