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The high-bar and low-bar back-squats: A biomechanical analysis

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ABSTRACT

No prior study has compared the joint angle and ground reaction force (*Fv)* differences between the high-bar back-squat (HBBS) and low-bar back-squat (LBBS) above 90% 1RM. Six male powerlifters (height: 179.2 ± 7.8 cm; bodyweight: 87.1 ± 8.0 kg; age: 27.3 ± 4.2 years) of international level, six male Olympic weightlifters (height: 176.7 ± 7.7 cm; bodyweight: 83.1 ± 13 kg; age: 25.3 ± 3.1 years) of national level, and six recreationally trained male athletes (height: 181.9 ± 8.7 cm; bodyweight: 87.9 ± 15.3 kg; age: 27.7 ± 3.8 years) performed the LBBS, HBBS, and both LBBS and HBBS (respectively) up to and including 100% 1RM. Small to moderate (d = 0.2-0.5) effect size differences were observed between the powerlifters and Olympic weightlifters in joint angles and *Fv*, although none were statistically significant. However, significant joint angle results were observed between the experienced powerlifters/weightlifters and the recreationally trained group. Our findings suggest that practitioners seeking to place emphasis on the stronger hip musculature should consider the LBBS. Also, when the goal is to lift the greatest load possible, the LBBS may be preferable. Conversely, the HBBS is more suited to replicate movements that exhibit a more upright torso position, such as the snatch and clean, or to place more emphasis on the associated musculature of the knee joint.

KEY WORDS: Joint angles; ground reaction forces; EMG; powerlifting; Olympic weightlifting

INTRODUCTION

The squat is one of the most common exercises in strength and conditioning. The movement is widely accepted as valid and reliable for the assessment, and improvement of lower-extremity/trunk strength, function, and resilience to injury (4, 9, 10), as well as an effective exercise in injury rehabilitation (19). These benefits are possible through the contributions of the quadriceps, hamstrings, gluteal, triceps surae, and lumbar erector muscle groups to the completion of the movement (9, 25). In fact, it is predicted that more than 200 muscles are active throughout the completion of a single repetition (31, 36). The squat itself is in essence a simple movement, despite the great number of active muscles throughout. In strength and conditioning, load can be applied to the squat movement via several methods, for example dumbbells, kettlebells, and a range of other weighted implements. However, perhaps most commonly load is applied via a barbell, and in one of two ways: 1) as a front-squat, where a barbell is placed anteriorly on the shoulder and 2) as a back-squat, where the barbell is placed posteriorly to the shoulder and across the trapezius musculature (16). The focus of this article will be the back-squat.

There are two different variations of the back-squat, differentiated by the placement of the barbell on the trapezius musculature. The traditional “high-bar” back-squat (HBBS) is performed with the barbell placed across the top of the trapezius, just below the process of the C7 vertebra, and is commonly used by Olympic weightlifters to simulate the catch position of the Olympic weightlifting competition lifts; the snatch and clean and jerk (41). Conversely, the “low-bar” back squat (LBBS) places the barbell on the lower trapezius, just over the posterior deltoid and along the spine of the scapula (41). The LBBS is commonly used in competitive powerlifting (where the back-squat is one of the three competition lifts), as it may enable higher loads to be lifted (32). This could be due to the maximization of posterior displacement of the hips, and increased force through the hip joints in comparison to the knee joints (37). The differences in bar position between the HBBS and LBBS result in an altered center of mass. Therefore, movement strategies result in order to maintain the bodies center of mass within its base of support. These movement strategies may manifest as: changes in 1) joint angles of the lower extremity kinetic chain and, 2) ground reaction forces (*Fv*).

When comparing the HBBS to LBBS, several differences present themselves. In powerlifting, there are competition regulations that each lifter must comply with in order for each lift to count towards their competition total (21). One such regulation is for sufficient 'depth' to be reached in the squat. That is, there must be sufficient flexion of the knees and lowering of the hips towards the ground, so that "the top surface of the legs at the hip joint are lower than the top of the knees" (21). In comparison, the HBBS is not directly included as a competition lift in Olympic weightlifting. Therefore, in training Olympic weightlifters typically squat to a depth that replicates the final catch position of the snatch and clean and jerk. This often manifests as a deeper squat position than powerlifting regulation depth, characterized by greater flexion at the hip, knee and ankle joints. Prior research has shown that the angle at peak knee flexion is generally smaller in the HBBS (e.g. 70-90°), in comparison to the LBBS (e.g. 100-120°) (5, 11, 13, 17, 18, 20, 24, 27, 37, 38). Interestingly, some studies have reported the reverse (17, 24, 37). These conflicting results (although not explicitly stated by the authors), are likely to be the raw joint angles and not the actual angle (Figure 1).

Figure 1 around here

Moreover, prior research specifically comparing the HBBS to the LBBS shows that the LBBS is defined by a smaller absolute trunk angle, and therefore greater forward lean in order to maintain the barbell over the center of mass (2, 14, 41). The unique position of the LBBS results in 1) a decreased trunk lever arm when placing the bar lower on the back, 2) a greater emphasis on the stronger musculature of the hip rather than the musculature of the knee joint and, 3) an increase in stability and a potential decrease in stress placed on the lumbar region and ankle, when compared to the HBBS (34, 37). These factors may contribute to understanding why the LBBS typically allows for greater loads to be lifted. However, these kinematic findings are not definitive and there are mixed results in the literature for the size of HBBS and LBBS trunk angles at peak hip flexion (5, 11, 13, 17, 20, 24, 27, 29, 37). Similarly, no conclusive differences between the HBBS and LBBS ankle joint angles can be drawn, in reference to prior literature (13, 17, 24, 34, 37).

As the position of the barbell on the trapezius influences the joint angles of the back-squat, there is also a resultant influence on the *Fv* produced. The position of the upper body (i.e. hip joint angle) has a large impact on the location and magnitude of the resultant *Fv* due to its larger mass. Due to the LBBS tending to allow for greater loads to be lifted, it would be expected that the *Fv* produced would be greater than with the HBBS. However, the two studies which have specifically compared the *Fv* profiles of the HBBS and LBBS, provide contradictory results to this expectation (15, 37). The results of these two studies may indicate that, although the LBBS typically allows for greater load to be lifted through apparent mechanical advantages such as a decreased trunk lever arm, these mechanical advantages are not effectively displayed by *Fv*. Furthermore, the results of these studies specifically may have arisen due to the level of expertise of the participant with performing the LBBS as the authors chose to target the HBBS in recruitment, as the focus for expertise.

Therefore, further research is warranted to understand the *Fv* differences between the HBBS and LBBS, in particular with loads greater than 90% 1RM.

The existing literature provides some insight into the kinematic and kinetic differences between the HBBS and LBBS. However, there is no consensus as to the differences between the two back-squat barbell positional variations. At present, no prior study has compared the joint angles and *Fv* of the HBBS and LBBS above 90% 1RM and some results may have been confounded by inadequate familiarization. Thus, the purpose of this study was to compare and contrast the differences in joint angles and *Fv* of the HBBS and LBBS, up to and including maximal effort, in an effort to create a full profile of the two BBS variations in groups both well versed and newly introduced to these movements. The results of this investigation will add to the current body of knowledge of Olympic weightlifting and powerlifting practice alike, as well as providing an understanding of why the LBBS may allow for a greater load to be lifted.

METHODS

Experimental Approach to the Problem

In order to determine why the LBBS may allow for greater loads to be lifted than the HBBS, both squat styles were performed by experienced and in-experienced lifters. The HBBS was performed by experienced Olympic weightlifters, and the LBBS by experienced powerlifters, up to and including 100% of 1RM. Recreationally trained athletes served as a comparison group and performed both the HBBS and LBBS. It is assumed that the experienced Olympic weightlifters and powerlifters have a better technique than the recreationally trained athlete, however it is important to acknowledge this may not be strictly true in practice. A profile of each squat was created through analysis of kinematic joint angles and kinetic *Fv* differences.

Subjects

Six male powerlifters (height: 179.2 ± 7.8 cm; bodyweight: 87.1 ± 8.0 kg; age: 27.3 ± 4.2 years) of international (i.e. Oceania championships) level volunteered to participate in the LBBS group. In addition, six male Olympic weightlifters (height: 176.7 ± 7.7 cm; bodyweight: 83.1 ± 13 kg; age: 25.3 ± 3.1 years) who had previously qualified for national championship level competition volunteered to participate in the HBBS group. All powerlifters routinely performed the LBBS in training and competition, and all Olympic weightlifters routinely performed the HBBS in training. Finally, six recreationally trained male athletes (height: 181.9 ± 8.7 cm; bodyweight: 87.9 ± 15.3 kg; age: 27.7 ± 3.8 years) volunteered as a comparison group and each participant was required to perform both the LBBS and HBBS in a randomized order, after two familiarization sessions with both types of squat. All participants were free of injury and had ≥ 1 year's strength training experience (powerlifters: 5.05 ± 4.56 years; Olympic weightlifters: 3.75 ± 2.72 years; recreational: 8.67 ± 3.5 years) consisting of ≥ 3 training sessions per week for the powerlifters and Olympic weightlifters. The comparison group volunteers were required to train the back-squat in ≥ 1 training sessions per week. Due to small participant numbers (n = 6 for each group), the results of this study may not provide a full representation of the differences between each squat type. Some differences may be due to sampling error.

Prior to testing, written informed consent was received from each participant and all testing conditions were examined and approved by the Auckland University of Technology Ethics Committee (14/398).