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Review article

Barbell Hip Thrust, Muscular Activation and Performance: A Systematic Review

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Abstract
The present systematic review aimed to analyze the activation of the muscles involved in the barbell hip thrust (BHT) and its transfer to sports activities that include horizontal displacement. A search of the current literature was performed using the PubMed, SPORTDiscuss, Scopus and Google Scholar databases. The inclusion criteria were: (a) descriptive studies, (b) physically trained participants, (c) analyzed muscle activation using normalized EMG signals or as a percentage of maximal voluntary isometric contraction (MVIC) and (d) acute or chronic transfer of the BHT to horizontal displacement activity. Twelve articles met the inclusion criteria and the following results were found: 1) neuromuscular activation: hip extensor muscles (gluteus maximus and biceps femoris) demonstrated greater activation in the BHT compared to the squat. The straight bar deadlift exercise demonstrated greater biceps femoris activation than BHT; 2) Regardless of the BHT variation and intensity used, the muscle excitation sequence is gluteus maximus, erector spinae, biceps femoris, semitendinosus, vastus lateralis, gluteus medius, vastus medialis and rectus femoris; 3) acute transfer: four studies demonstrated a significant improvement in sprinting activities after BHT exercise; 4) as for the chronic transfer: two studies demonstrated improvement of the sprint time, while other two studies failed to present such effect. We concluded that: a) the mechanics of BHT favors greater activation of the hip extensor muscles compared to more conventional exercises; b) regardless of the variation of BHT used, the muscle excitation sequence is gluteus maximus, erector spinae, hamstrings, and quadriceps femoris; c) the acute transfer of the post-activation potentiation of the BHT is significant, improving the sprinting time; and d) despite training with BHT submaximal loads can improve sprint times, further investigations are needed.

Key words: Exercise, skeletal muscle, muscle contraction, athletic performance, sports.

Introduction

In recent decades, strength training has gained worldwide prominence, being recommended for both, health and aesthetic programs, and physical preparation of highly trained athletes (Freitas et al., 2018; Loturco et al., 2018; Vinstrup et al., 2017). This fact is related to the various possibilities of applying strength exercises, and their variations. For this, it is essential to understand the patterns of recruitment, neuromuscular activation and multifunctional transfer level of some types of strengthening exercise.

The use of strength exercises varies according to their level of neuromuscular excitation, whose standards can be measured using the electromyography method [EMG] (Contreras et al., 2015, Andersen et al., 2018; Vigotsky et al., 2018). According to Vigotsky et al. (2018), EMG can be defined as an electrophysiological recording technology used for detection of the electric potential resulting from the transmembrane current of the muscle fibers (muscular excitation). Thus, EMG studies enable us to infer which muscles are excitaded in certain movements, being able to compare exercises with different mechanical patterns. Contreras et al. (2015) demonstrated different levels of muscular excitation when comparing barbell hip thrust and traditional squat exercises. In this way, muscles such as the gluteus maximus and quadriceps femoris, being activated differently, have different practical applications regarding their structure (Contreras et al., 2017; Williams et al., 2018). Thus, the interpretation of these data leads us to the possibility of new forms of training prescription, and therefore, more practical results. Nevertheless, kinesiology studies help us to understand, and better interpret, the strategies of exercise choices for specific sports modalities (Hales et al., 2009). Of course, the physical preparation of athletes should use the best tools to improve motor performance, thus making the choice of exercises fundamental to the success of the training program, whether health, aesthetic or athletic. Moreover, it is also suggested that the specificity in the direction of the production of force in certain exercises, causes a more direct transference for certain motor activities. (Loturco et al., 2018; Williams et al., 2018).

It is possible to affirm that despite the mechanical differences between barbell hip thrust (BHT) and more traditional exercises, such as squatting, the inclusion of these in a strength training program can produce summative effects on the performance of international level speed athletes (Loturco et al., 2018). According to Loturco et al. (2018) and Williams et al. (2018), BHT is an exercise whose predominance of hip extension and excitation of its specific muscles is transferred to explosive and short duration exercises as sprints of high speed and short duration, clearly demonstrating the applied principles of specificity and transference.

Recently, BHT has gained considerable attention from the scientific community, and from physical trainers, due to its mechanical nature and the highly neuromuscular demand of the hip extensor muscles (Contreras et al., 2011; Dello Iacono et al., 2018; Dello Iacono and Seitz, 2018; Eckert and Snarr, 2014; Loturco et al., 2018; Williams et al., 2018). This strengthening exercise has muscle activation different from those associated with more traditional exercises such as squatting (front or back barbell), split squats, deadlifts and others (Andersen et al., 2018; Bishop et al., 2017; Williams et al., 2018). As a result, a growing number of researches show that there is a possibility of cute

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transferring gains from this exercise to horizontal displacement motor activities (Dello Iacono et al., 2018; Dello Iacono and Seitz, 2018; Loturco et al., 2018; Williams et al., 2018). However, it is not clear if BHT training can induce positive chronic effects as seen in the acute type investigations.

The aim of this systematic review was to analyze the activation of the muscles recruited in the BHT and its transfer to sports activities that include horizontal displacement at maximum velocities.

Methods

The preferred item declaration guide for systematic review and meta-analysis reports (PRISMA) was used to conduct this systematic review (Moher et al., 2009). In addition, the quality of all eligible studies included was assessed by WKN, TLV, and EFG using the PEDro quality scale. The PEDro scale consists of eleven questions and scores proportional to the number of questions. However, due to the inability to "blind" coaches and practitioners, we excluded 3 questions, determining 8 points as the maximum score. Thus, studies with a score equal to or greater than 5 points were considered of good methodological quality.

A search of the current literature was conducted using the PubMed/Medline, SportDiscuss, Scopus and Google Scholar electronic databases, without restriction of languages and dates until August 6th, 2018. The MeSH descriptors, along with their related terms and keywords included, were used as follows: ((hip thrust OR hip thrusts OR pelvic exercise) AND (resistance training OR resistance exercise OR training, resistance OR strength training OR training, strength OR weight-lifting strengthening program OR strengthening program, weight-lifting OR strengthening programs, weight-lifting OR weight lifting strengthening program OR weight-lifting strengthening programs OR weight-lifting exercise program OR exercise program, weight-lifting OR exercise programs, weight-lifting OR weight lifting exercise program OR weight-lifting exercise programs OR weight-bearing strengthening program OR strengthening program, weight-bearing OR strengthening programs, weight-bearing OR weight bearing strengthening program OR weight-bearing strengthening programs OR weight-bearing exercise program OR exercise program, weight-bearing OR exercise programs, weight-bearing OR weight bearing exercise program OR weight-bearing exercise programs)) AND ((muscle development OR development, muscle OR muscular development OR development, muscular OR myogenesis OR myofibrillogenesis OR muscle hypertrophy OR hypertrophy OR hypertrophies OR electromyography OR electromyographies OR surface electromyography OR electromyographies, surface OR electromyography, surface OR surface electromyographies OR electromyogram OR electromyograms OR muscle strength OR power output OR force OR strength OR horizontal forces OR maximum speed OR fast movement)).

The inclusion criteria were: (a) descriptive studies, (b) studies using physically trained participants, (c) studies that analyzed muscle activation using normalized EMG signals or as a percentage of maximal voluntary isometric contraction (MVIC) during BHT exercise and their respective comparisons and (d) studies that analyzed the acute or chronic transfer of the effects of BHT exercise to horizontal displacement activity. Studies with insufficient data, review, samples formed by ill individuals, poor data presentation, unclear or vague descriptions of protocols applied and with more than one exercise per group were excluded.

Authors WKN, TLV and EFG independently performed the analysis of the data, with a subsequent meeting to decide on the inclusion in the final text of the eligible articles. First, a pre-reading was performed to become familiar with the terminology used in the studies. Then, each article was re-read and the following information was extracted: (1) intervention exercises, (2) sample size, (3) gender, (4) age, (5) experience time, (6) type of study, (7) outcomes and (8) main findings. From this moment, the studies were separated into two types of analysis: (1) neuromuscular recruitment and (2) analysis of the practical transfer of the intervention. Included in this study were articles that analyzed these outcomes separately. Regarding the EMG signal, all articles analyzed reported the MVIC protocol used. These protocols used isometric contraction against a combined resistance for each muscle examined. Likewise, all included articles used surface EMG and reported muscle activation of each muscle separately.

In relation to performance transfer, articles of an acute (potentialization post-activation) and chronic nature (duration between 6 and 8 weeks) were included. The analyzed tests included horizontal jumps and sprints with varying distances (10-150 m).

Results

Search results

Three independent reviewers identified a total of 498 articles in the initial survey. Two hundred and thirty-five articles were duplicates, which left 263 articles included for analysis. After sorting the title/abstract and full text, 252 articles were eliminated because they did not meet the inclusion criteria, leaving a total of 11 articles selected for review (Figure 1). However, during the review process of this manuscript, a new article was published and included in the final analysis of the study on November 22nd, totaling 12 articles in this systematic review. Of which, five of these studies compared neuromuscular activity of the BHT with other exercises or variations (Andersen et al., 2018; Collazo Garcia et al., 2018; Contreras et al., 2015; 2017; Williams et al., 2018) and eight studies verified the functional transfer for practical activities (Bishop et al., 2017; Contreras et al., 2017; Della Iacono et al., 2018; Della Iacono and Seitz, 2018; Lin et al., 2017; Loturco et al., 2018; Williams et al., 2018; Zweifel et al., 2017). Although there was no time limit as an inclusion criterion, all articles included here were published between the years 2015 and 2018. After the quality analysis, all studies were classified as having good/excellent methodological quality (grades 6-8).

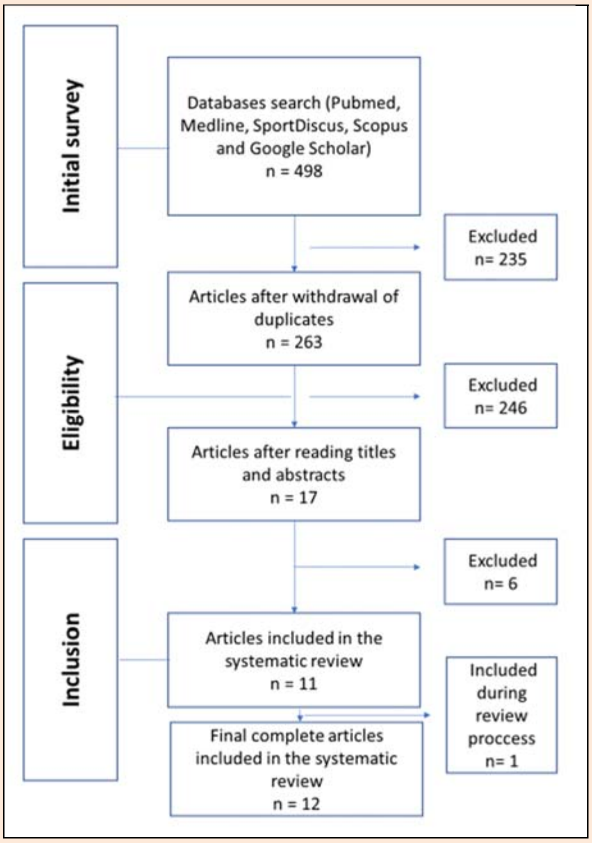

Figure 1. **Flowchart.**

Muscle activation

Data referring to general studies description and main findings and neuromuscular activity are presented in Table 1 and 2. The gluteus maximus muscle showed greater activation in the BHT (independent of the analysis being of mean or peak activation, isometric or dynamic) compared to squatting (Contreras et al., 2015; Williams et al., 2018), barbell deadlift (Andersen et al., 2018) and hex bar deadlift (Andersen et al., 2018). When comparing BHT with other variations, such as American (shorter hip joint amplitude with posterior pelvic tilt) and elastic bands resistance, the results demonstrated that BHT elicitated higher excitation levels only for the analysis of the EMG amplitudes of the upper gluteus maximus fibers (Contreras et al., 2017). However, Collazo Garcia et al. (2018) showed that BHT with feet external rotation presented higher gluteus maximus excitation than traditional BHT.

As for the biceps femoris muscle, the BHT presented a greater neuromuscular excitation than the squat exercise (Contreras et al., 2015). On the other hand, the traditional deadlift exercise demonstrates greater activation of biceps femoris compared to BHT (Andersen et al., 2018). Comparing the positioning of the feet during the BHT exercises, the variation with feet forward showed higher values of neuromuscular excitation for the biceps femoris and semitendinosus muscles than the traditional BHT variation (Collazo Garcia et al., 2018). As for the gluteus medius muscle, there were no differences between BHT exercise variations (Collazo Garcia et al., 2018).

In relation to the vastus lateralis, there was no significant difference in neuromuscular demand between BHT and squat exercises (Contreras et al., 2015). The same result was demonstrated when evaluating the excitation of spinal erector muscles between BHT, traditional or hex bar deadlift exercises (Andersen et al., 2018).

Regarding the variations in the positioning of the feet of the BHT, placing the feet forward has shown to decrease the excitatory activity of the rectus femoris, vastus lateralis and vastus medialis muscles compared to traditional BHT (Collazo Garcia et al., 2018).

Figure 2 presents the EMG mean activity among the muscles mobilized in the BHT, measured by each study included here. Although the studies used different intensities to evaluate muscular excitation, the following values were demonstrated. The mean EMG activity of gluteus maximus and biceps femoris muscles varied between 55 and 105% MVIC and 40 and 85% MVIC, respectively.

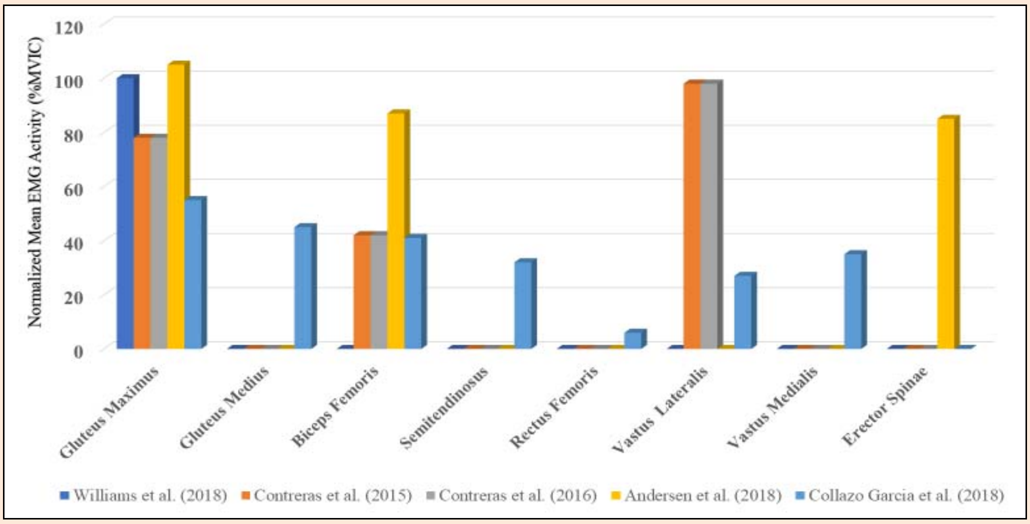

Figure 2. **Mean EMG activity for gluteus maximus, gluteus medius, biceps femoris, semitendinosus, rectus femoris, vastus lateralis, vastus medialis and erector spinae measured during barbell hip thrust according to the included studies.** Data are expressed as the mean percentage of the maximum isometric voluntary contraction (%MVIC).

Table 1. Description of data extracted from each article regarding neuromuscular activity, in relation to subtopics: type of intervention, sample, gender, age, experience time, type of study, outcomes, main findings and PEDro quality scale score (0-8).

Reference	Intervention	Sample (n)	Gender	Age (years)	Experience (years)	Type of study	Outcomes	Main findings	PEDro
Contreras et al. (2015)	Barbell hip thrust versus back squat	13	Female	28.9±5.11	7.0±5.8	Acute	Activity EMG of the muscles gluteus maximus upper and lower fibers, biceps femoris and vastus lateralis	Hip thrust ↑ EMG significantly for gluteus maximus muscle (both portions) and biceps femoris	7
Contreras et al. (2016)	Hip thrust Variations (traditional, American and band)	13	Female	28.9±5.11	7.0±5.8	Acute	Activity EMG of the muscles gluteus maximus upper and lower fibers, biceps femoris and vastus lateralis	Variation with full amplitude demonstrated ↑ EMG for mean and peak activation of the upper gluteus maximus fibers	7
Andersen et al. (2018)	Barbell hip thrust versus straight and hex bar deadlift	13	Male	21.9±1.6	4.5±1.9	Acute	Activity EMG of the muscles gluteus maximus upper and lower fibers, biceps femoris and erector spinae	Barbell hip thrust: ↑ EMG gluteus maximus Deadlift straight bar: ↑ EMG biceps femoris * there was no difference for erector spinae	7
Williams et al. (2018)	Barbell hip thrust versus back squat e Split squat	12	Male	25.0±4.0	4.0±1.0	Acute	Activity EMG of the muscle gluteus maximus	Significantly ↑ EMG in the Barbell hip thrust	7
Collazo García et al. (2018)	Barbell hip thrust feet position variations (original hip thrust, pull hip thrust [PHT], rotation hip thrust [RHT], and feet away hip thrust [FHT]	7	Male	29.4±4.6	Not indicated	Acute	Activity EMG of the rectus femoris (RF), vastus medialis (VM), vastus lateralis (VL), gluteus maximus (GMax), gluteus medius (GMed), biceps femoris (BF), and semitendinosus (ST) muscles	Significant differences in EMG in all muscles except for the gluteus medius, where no differences were observed among variations. In comparison with the original variation: RHT = ↑ Gmax FHT = ↑ BF, ST and ↓RF, VM, VL	7

Gluteus medius presented mean EMG activity of 45% MVIC. As for semitendinosus muscle, mean EMG activity was about 35% MVIC. For the vastus lateralis the average EMG activity remained between 35 and 100% MVIC. Rectus femoris and vastus medialis presented mean excitation of 5 and 35% MVIC, respectively. Erector spinae muscle presented approximately 85% MVIC. This large variation in the mean EMG activity found for some muscles was due to the large load variance used to evaluate each condition.

Motor performance

Data from studies evaluating the efficiency of BHT on functional transfer for practical activities are presented in Table 3.

As for the acute transfer, four studies demonstrated a significant improvement in the sprint times (Dello Iacono et al., 2018; Dello Iacono and Seitz, 2018; Loturco et al., 2018; Williams et al., 2018).

As for the chronic transfer, two studies have shown improved sprint time (Contreras et al., 2017; Zweifel et al., 2017), whereas two other studies have failed to present such an effect (Bishop et al., 2017; Lin et al., 2017).

Discussion

According to the data presented here, BHT exercise can induce a high neuromuscular activity of the hip extensor muscles, especially the gluteus maximus, in comparison with the more traditional exercises. In addition, variations in the positioning of the feet during the execution of the BHT may present different levels of excitation of the muscles associated with the joints of the knee and hips. Beyond this, BHT causes a significant acute transfer for high-speed activities and horizontal displacement. On the other hand, there is still controversy about the effects of chronic training of BHT on long-term sports performance. It is not surprising that BHT has provoked greater EMG activity in the gluteus maximus muscle compared to the other exercises

(Andersen et al., 2018; Contreras et al., 2015; Williams et al., 2018). Worrell et al. (2001) showed that when testing the maximum isometric torque of hip extension in a dynamometer, the gluteus maximus EMG activity was higher with the hip at 0° extension (exactly the end of the concentric phase of the BHT). In addition, knee flexion (about 90º angle) during the hip-raising phase induces a hamstrings insufficiency (lower force production), requiring a greater effort of the gluteus maximus muscle to generate sufficient torque for hip extension (Know and Lee, 2013). According to Collazo Garcia et al. (2018), lowering the flexion angle of the knees by placing the feet forward would increase the neuromuscular demands of the hamstrings without changing gluteus maximus excitation. Regardless of, it seems that the shorter the muscle length (as the top concentric phase of BHT), the greater the potential levels of EMG activity of the gluteus maximus (Robertson et al., 2008). This fact can be explained by the anatomical nature of the gluteus maximus muscle architecture, associated with the angle of the position in which the volunteers remain for the maximum voluntary isometric contraction test used for normalization of the EMG signal. Thus, the greater the levels of hip extension, the closer the Z-lines of the sarcomeres would be, increasing the levels of force production, and reaching the highest levels of EMG measured along the movement tested. In addition, the concept of the specificity principle applies directly in this case, whose association between the EMG test normalization test and the BHT exercise amplitude reaches its closest values. Collazo Garcia et al. (2018) also demonstrated that the greater the distance between the feet during BHT, the greater the activity of the gluteus maximus muscle, suggesting that the production of force tending to the frontal plane causes a greater excitation of this muscle.

Table 2. Description of data regarding neuromuscular activity in each article included, in relation to exercise type and normalized EMG activity (values expressed as mean and/or peak %MVIC) of upper and lower portions of gluteus maximus, gluteus medius, semitendinosus, biceps femoris, rectus femoris, vastus lateralis, vastus medialis and erector spinae muscles.

Reference	Exercise	Upper Gluteus Maximus	Lower Gluteus Maximus	Gluteus Medius	Semitendinosus	Biceps Femoris	Rectus Femoris	Vastus Lateralis	Vastus Medialis	Erector Spinae
Contreras et al. (2015)	Back Squat	29% mean 85% peak	45% mean 130% peak	n/a	n/a	15% mean 37% peak	n/a	110% mean 244% peak	n/a	n/a
	Barbell Hip Thrust	69% mean 172% peak	87% mean 216% peak	n/a	n/a	41% mean 87% peak	n/a	99% mean 216% peak	n/a	n/a
Contreras et al. (2016)	Barbell Hip Thrust	69% mean 172% peak	87% mean 216% peak	n/a	n/a	41% mean 87% peak	n/a	99% mean 216% peak	n/a	n/a
	American Hip Thrust	57% mean 157% peak	90% mean 200% peak	n/a	n/a	44% mean 99% peak	n/a	87% mean 177% peak	n/a	n/a
	Band Hip Thrust	49% mean 120% peak	79% mean 185% peak	n/a	n/a	37% mean 89% peak	n/a	93% mean 185% peak	n/a	n/a
Andersen et al. (2018)	Barbell Hip Thrust	108% mean	98% mean	n/a	n/a	Upper 110% mean Lower 68% mean	n/a	n/a	n/a	Upper 93% mean Lower 83% mean
	Barbell Deadlift	95% mean	95% mean	n/a	n/a	Upper 115% mean Lower 100% mean	n/a	n/a	n/a	Upper 88% mean Lower 90% mean
	Hex bar Deadlift	85% mean	90% mean	n/a	n/a	Upper 80% mean Lower 85% mean	n/a	n/a	n/a	Upper 83% mean Lower 85% mean
Williams et al. (2018)	Back Squat	69% mean and 100% peak		n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Split Squat	69% mean and 100% peak		n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Barbell Hip thrust	105% mean and 130% peak		n/a	n/a	n/a	n/a	n/a	n/a	n/a
Collazo Garcia et al. (2018)	Original Barbell Hip thrust	55% mean		47% mean	32% mean	41% mean	6% mean	27% mean	35% mean	n/a
	Pull Hip Thrust	66% mean		60% mean	50% mean	61% mean	5% mean	24% mean	21% mean	n/a
	Rotation Hip Thrust	86% mean		65% mean	33% mean	43% mean	5% mean	29% mean	29% mean	n/a
	Feet away Hip Thrust	51% mean		48% mean	70% mean	72% mean	3% mean	11% mean	11% mean	n/a

Table 3. Description of data extracted from each article regarding functional transference, in relation to subtopics: type of intervention, sample, gender, age, experience time, type of study, outcomes, main results and PEDro scale score (0-8).

Reference	Intervention	Sample (n)	Gender	Age (years)	Experience (years)	Type of study	Outcomes	Main findings	PEDro
Contreras et al. (2017)	Barbell hip thrust (HT) versus front squat (FS)	24	Male	HT:15.49±1.16 FS:15.48±0.74	Adolescent rugby and rowing athletes with a minimum of 1 year experience	Chronic (6 weeks)	Sprints of 10 and 20 meters; Vertical and horizontal jumps; Isometric mid-thigh test	Hip thrust presented better ES for sprints of 10 and 20 meters and isometric half-thigh test	8
Dello Iacono et al. (2018)	Barbell hip thrust 50%RM versus 85%RM	18	Male	19.8±0.3	Elite handball players with 2.6 ± 0.8 years of experience	Acute	10 and 15 meters sprint time	Both strategies statistically reduce the time in the measured distances	7
Bishop et al. (2017)	Barbell hip thrust versus control	21	Male and female	Intervention group: 27.36±3.17 Control group: 27.2±3.36	University athletes with at least 1 year of experience	Chronic (8 weeks)	40 meters sprint time	The hip thrust did not shorten the time on the benchmark test	7
Zweifel et al. (2017)	Barbell hip thrust versus back squat e deadlift	26	Male and female	22.15±2.2	Not quoted	Chronic (6 weeks)	10 and 40-yard sprint	Hip thrust reduced the time of the 40-yard sprint	6
Lin et al. (2017)	Barbell hip thrust versus control	20	Male	Hip thrust: 19.9±0.8 Control: 20.4±2.1	College baseball players with at least 1 year of experience	Chronic (8 weeks)	Horizontal jump; Sprint 30 meters	No significant difference reported	7
Loturco et al. (2018)	Barbell hip thrust versus vertical exercises	16	Male and female	21.8±3.0	World-class athletes	Acute	Vertical jump; Sprints of 10, 20, 40, 60, 100 and 150 meters	Performance in the hip thrust was associated with the Maximum acceleration phase	7
Dello Iacono e Seitz (2018)	Barbell hip thrusts 85%RM versus optimal power loads	18	Male	19.3±0.2	Professional soccer players with 2.1 ± 0.3 years of experience	Acute	5, 10 e 20 meters sprints	Both loads tested improved the test time, with the maximum power development load being even more efficient.	7
Williams et al. (2018)	Barbell hip thrust versus back squat and split squat	12	Male	25.0±4.0	4.0±1.0	Acute	Maximum sprints on the non-motorized treadmill; A horizontal and vertical force	Sprint peak velocity correlated with horizontal force and peak ground reaction force only in hip thrust exercise	7

Similarly, it was evidenced that the EMG activity of the biceps femoris muscle was significantly higher in the BHT compared to squatting (Contreras et al., 2015). A number of studies have shown that squatting and its variations exhibits lower hamstring demands compared to measurements made on the quadriceps femoris (Escamilla et al., 2001; McCaw et al., 1999; Marchetti et al., 2018). It is possible to relate the bi-articular nature of the hamstring muscles to this lower EMG activity (Contreras et al., 2015). While squats involve the extension of the hip during concentric phase, for which the hamstrings are a primary motor, it also involves the extension of the knee, to which the hamstrings are antagonists. Thus, the hamstring EMG activity is lower when the combined hip and knee extension is performed in comparison to the isolated hip extension (Yamashita, 1988). Such a situation occurs because the hamstrings change length in the BHT compared to performing simultaneous hip and knee extension that occurs in the various types of squats. This same effect (lower hamstring activity compared to other recruited muscles) is evidenced for other multi-joint exercises, such as lunges and leg press (Escamilla et al., 1998; Machado et al., 2017; Marchetti et al., 2018). According to Know and Lee (2013), the greater the angle of knee flexion, the lower the myoelectric activity of the hamstring would be. This action occurs during all multi-articular exercises, thus explaining the different and lower levels of hamstring excitation found in these types of exercises. On the other hand, in the BHT exercise, there is virtually no knee extension movement, keeping the muscle tension levels of the hamstring associated only with hip extension. Collazo Garcia et al. (2018) present a strategy to further increase the levels of neuromuscular excitation of the hamstring muscles (biceps femoris and semitendinosus), by positioning the feet further, enabling a greater level of stretching and increased muscle tension.

The fact that the traditional deadlift presented greater activation of the biceps femoris than BHT was due to the mechanical difference between the two (Andersen et al., 2018). At the beginning of the concentric phase of the traditional deadlift, the lever arm of the hip joint, in relation to the load, is longer, creating greater stress in the extensor muscles of the hip (Andersen et al., 2018). Thus, as the deadlift exercise reaches greater ranges of motion compared to BHT, there is a greater demand for work from these muscle groups. For this, the greater the distance traveled (greater work), the greater the myoelectric activity measured. On the other hand, in the BHT, the mechanical demand for the gluteus maximus and hamstring muscles is higher at the end of the movement than at the beginning (Contreras et al., 2015; 2017). Another possible explanation could be the initial muscle length, wherein the traditional deadlift, the knees are more extended at the beginning of the movement compared to the BHT, increasing the muscles' ability to generate force. Know and Lee (2013) demonstrated that the excitation of the hamstrings is greater in 0º of knee flexion, decreasing progressively until 110º. If you take into account that the knee flexion angles in the deadlift are smaller than in the BHT, it is easy to understand the higher EMG values found in the deadlift. According to the authors, two factors explain this: first, when the connective tissue is previously extended by the greater muscular stretching, this causes an increase of the passive tension, increasing the active tension for the muscular contraction; and second, the tension-length relationship of the sarcomeres, creates an ideal interaction for the generation of force by the actin and myosin bridges (Know and Lee, 2013).

In contrast, the vastus lateralis muscle exhibited similar EMG activity between the squat and BHT (Contreras et al., 2015). However, we could hypothesize that the BHT exercise would present less myoelectric activity of the vastus lateralis muscle in comparison to the squatting. Squatting is well known for causing high levels of quadriceps femoris EMG activity compared to other lower limb exercises (Schwanbeck et al., 2009; Wilk et al., 1996). Contreras et al. (2015) justify their findings through a concern with the statistical methods used, indicating a probable risk of type I error during the post hoc test used by using the Holm-Bonferroni correction instead of the more conservative Bonferroni correction. However, it is also possible that the different muscles that form the quadriceps femoris may present different levels of EMG activity during BHT (Collazo Garcia et al., 2018). Nevertheless, the different loads used by the studies included in this study make it difficult to compare the variations of BHT and other studies (Collazo Garcia et al., 2018; Contreras et al., 2015; 2017). Even so, the heavier loads used in the BHT, compared to squat types, could also have led to the significant differences found in the vastus lateralis muscle, whose function would be to stabilize (isometrically) the knee during the execution of BHT. Further, Collazo Garcia et al. (2018) presented that the muscle excitation sequence during the BHT exercise is the gluteus maximus, gluteus medius, biceps femoris, semitendinosus, vastus lateralis, vastus medialis, and rectus femoris. Therefore, according to them, the hamstrings: quadriceps coactivation ratio increases when variations are performed (Collazo Garcia et al., 2018).

Andersen et al. (2018) demonstrate similar EMG of erector spinae muscles between BHT and traditional and hex bar deadlift exercises. The results obtained here were expected since several other studies have already presented similar results analyzing other exercises (Camara et al., 2016; Gullett et al., 2009; Yavuz et al., 2015).

The maximum velocity required in activities such as sprinting seems to be dependent on horizontal and vertical force production (Brughelli and Cronin, 2011; Kuitunen et al., 2002; Loturco et al., 2018; Nummela et al., 2007; Williams et al., 2018). Williams et al. (2018) demonstrated high neuromuscular activity of the gluteus maximus muscle, along with a positive correlation between peak sprint speed and anteroposterior horizontal force with peak ground reaction force only in the BHT compared to two types of the barbell squat. Testing the effects of post-activation potentiation of different training loads on the BHT, Dello Iacono et al. (2018) and Dello Iacono and Seitz (2018) demonstrated improved speed in both professional handball and soccer athletes. Additionally, Loturco et al. (2018) indicate that the post-activation potentiation of the BHT is more associated with the acceleration phase (0 to 10 m) than with maximum velocity phases (distances greater than 40 m). These results suggest that the high recruitment of the hip extensor muscles can potentiate the acceleration for horizontal displacements in short duration tests such as sprinting. In this sense, Loturco et al. (2018) indicate that the near-perfect associations found between different loads of BHT and all velocities evaluated in the acceleration phase (up to 60 m) represent an important input for the development of optimal sprint training interventions.

According to the review done here, it is clear that the results of the chronic studies are divided as to the efficiency of this exercise beyond the acute phase, demonstrating both improvement (Contreras et al., 2017; Zweifel et al., 2017) as "no effect "(Bishop et al., 2017; Lin et al., 2017) over 6 and 8 weeks of training. The pilot study by Zweifel et al. (2017) demonstrated greater effect sizes for BHT after 6 weeks of training with varying loads (30-100% RM). Corroborating, Contreras et al. (2017) showed better results in the 10 and 20 m tests with BHT training compared to the front squat. In contrast, Lin et al. (2017) and Bishop et al. (2017) failed to transfer strength gains into more practical results. This variability of results may be associated with the different training loads used in each study. Zweifel et al. (2017) and Contreras et al. (2017) used load variation over the training time (30-100% RM), while Lin et al. (2017) and Bishop et al. (2017) used higher loads (6-12RMs). It is known that sub-maximal loads demonstrate greater transference to sports activities that depend on higher power output. Thus, lighter and submaximal loads may be ideal for this outcome. In addition, the included chronic studies used samples of athletes composed of different sports specialties, and this may also have directly affected the results of the study, since the sprint technique may have varied among the different samples.

Finally, future studies should investigate whether the high levels of muscle activation of the hip extensor muscles seen in the BHT, transfer into results of muscle hypertrophy, and the optimal relationship of the BHT training load and its transfer to sprint performance. Outcomes such as these are still cause for much debate.

Conclusion

Through the studies included in this systematic review, we reached the following conclusions: a) the mechanics of the BHT favors the greater activation of the extensor muscles of the hip compared to more conventional exercises, b) regardless of the variation of BHT used, the muscle excitation sequence is gluteus maximus, erector spinae, hamstrings, and quadriceps femoris; c) the post-activation potentiation (acute effects) of the BHT is significant, improving short sprint time, and d) although training with submaximal BHT loads can improve sprint times, further investigations are needed.

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References

Andersen, V., Fimland, M. S., Mo, D. A., Iversen, V.M., Vederhus, T., Rockland Hellebø, L.R., Nordaune, K.I. and Saeterbakken, A.H. (2018) Electromyographic Comparison of Barbell Deadlift, Hex Bar Deadlift, and Hip Thrust Exercises: A Cross-Over Study. *Journal of Strength and Conditioning Research* **32(3),** 587-593.

Bishop, C., Cassone, N., Jarvis, P., Turner, A., Chavda, S., and Edwards, M. (2017) Heavy Barbell Hip Thrusts Do Not Effect Sprint Performance: An 8-Week Randomized-Controlled Study. *Journal of Strength and Conditioning Research.* Epub ahead of print.

Brughelli, M., and Cronin, J. (2011). Effects of running velocity on running kinetics and kinematics. *Journal of Strength and Conditioning Research* **25,** 933-939.

Camara, K.D., Coburn, J.W., Dunnick, D.D., Brown, L.E., Galpin, A.J., and Costa, P.B. (2016) An Examination of Muscle Activation and Power Characteristics While Performing the Deadlift Exercise With Straight and Hexagonal Barbells. *Journal of Strength and Conditioning Research* **30,** 1183-1188.

Collazo García, C.L, Rueda, J., Suárez Luginick, B., Navarro, E. (2018) Differences in the electromyographic activity of lower-body muscles in hip thrust variations. *Journal of Strength and Conditioning Research.* Epub ahead of print.

Contreras, B., Cronin, J., and Schoenfeld, B. (2011) Barbell hip thrust. *Strength and Conditioning Journal* **33(5),** 58-61.

Contreras, B., Vigotsky, A.D., Schoenfeld, B.J., Beardsley, C., and Cronin, J. (2015) A comparison of gluteus maximus, biceps femoris, and vastus lateralis EMG amplitude in the back squat and barbell hip thrust exercises. *Journal of Applied Biomechanics* **31,** 452-458.

Contreras, B., Vigotsky, A.D., Schoenfeld, B.J., Beardsley, C., McMaster, D.T., Reyneke, J. and Cronin, J.B. (2017) Effect of a six week hip thrust versus front squat resistance training program on performance in adolescent males: A randomized control trial. *Journal of Strength and Conditioning Research* **31,** 999-1008.

Dello Iacono, A., Padulo, J., and Seitz, L.D. (2018) Loaded hip thrust-based PAP protocol effects on acceleration and sprint performance of handball players. *Journal of Sports Science* **36(11),** 1269-1276.

Dello Iacono, A., and Seitz, L.B. (2018) Hip thrust-based PAP effects on sprint performance of soccer players: heavy-loaded versus optimum-power development protocols. *Journal of Sports Science* **36(20),** 2375-2382.

Eckert, R.M. and Snarr, R.L. (2014) Barbell hip thrust. *Journal of Sports and Human Performance* **2(2),** 1-9.

Escamilla, R.F., Fleisig, G.S., Zheng, N., Barrentine, S.W., Wilk, K.E., and Andrews, J.R. (1998). Biomechanics of the knee during closed kinetic chain and open kinetic chain exercises. Medicine and Science of Sports and Exercise;30(4):556-69.

Escamilla, R.F., Fleisig, G.S., Zheng, N., Lander, J.E., Barrentine, S.W., Andrews, J.R., Bergemann, B.W., and Moorman, C.T 3rd. (2001) Effects of technique variations on knee biomechanics during the squat and leg press. *Medicine and Science of Sports and Exercise* **33(9),** 1552-1566.

Freitas, T.T., Calleja-González, J., Carlos-Vivas, J., Marín-Cascales, E., and Alcaraz, P.E. (2018) Short-term optimal load training vs a modified complex training in semi-professional basketball players. *Journal of Sports Science* **1,** 1-9.

Gonzalo-Skok, O., Tous-Fajardo, J., Valero-Campo, C., Berzosa, C., Bataller, A. V., Arjol-Serrano, J. L., and Mendez-Villanueva, A. (2016) Eccentric Overload Training in Team-Sports Functional Performance: Constant Bilateral Vertical vs. Variable Unilateral Multidirectional Movements. *International Journal of Sports Physiology and Performance*, 1-23.

Gullett, J.C., Tillman, M.D., Gutierrez, G.M., and Chow, J.W. (2009) A biomechanical comparison of back and front squats in healthy trained individuals. *Journal of Strength and Conditioning Research* **23,** 284-292.

Hales, M.E., Johnson, B.F., and Johnson, J.T. (2009) Kinematic analysis of the powerlifting style squat and the conventional deadlift during competition: is there a cross-over effect between lifts? *Journal of Strength and Conditioning Research* **23(9),** 2574-80.

Kuitunen, S., Komi, P.V., and Kyro¨ la¨inen, H. (2002) Knee and ankle joint stiffness in sprint running. *Medicine and Science of Sports and Exercise* **34,** 166-173.

Kwon, Y.J., and Lee, H.O. (2013) How different knee flexion angles influence the hip extensor in the prone position. *Journal of Physical Therapy and Science* **25,** 1295-1297.

Lin, K., Wu, C., Huang, Y., and Cai, Z. (2017) Effects of hip thrust training on the strength and power performance in collegiate baseball players. *Journal of Sports Science* **5,** 178-184.

Loturco, I., Contreras, B., Kobal, R., Fernandes, V., Moura, N., Siqueira, F., Winckler, C., Suchomel, T. and Pereira, L.A. (2018) Vertically and horizontally directed muscle power exercises: Relationships with top-level sprint performance. *PLoS ONE* **13(7),** e0201475.

Machado, W., Paz, G., Mendes, L., Maia, M., Winchester, J.B., Lima, V., Willardson, J.M. and Miranda, H. (2017) Myoelectric Activity of the Quadriceps During Leg Press Exercise Performed With Differing Techniques. *Journal of Strength and Conditioning Research* **31(2),** 422-429.

Marchetti, P.H., Guiselini, M.A., da Silva, J.J., Tucker, R., Behm, D.G., and Brown, L.E. (2018) Balance and Lower Limb Muscle Activation between In-Line and Traditional Lunge Exercises. *Journal of Human Kinematics* **13(62),** 15-22.

McCaw, S.T., and Melrose, D.R. (1999) Stance width and bar load effects on leg muscle activity during the parallel squat. *Medicine and Science of Sports and Exercise* **31(3),** 428-436.

Moher, D., Liberati, A., Tetzlaff, J., and Altman, D. G. (2009) Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Journal of Clinical Epidemiology* **62,** 1006-1012.

Nummela, A., Kera¨nen, T., and Mikkelsson, L.O. (2007) Factors related to top running speed and economy. *International Journal of Sports Medicine* **28,** 655-661.

Paoli, A., Marcolin, G., and Petrone, N. (2009) The effect of stance width on the electromyographical activity of eight superficial thigh muscles during back squat with different bar loads. *Journal of Strength and Conditioning Research* **23(1),** 246-250.

Robertson, D.G., Wilson, J.M., and St Pierre, T.A. (2008) Lower extremity muscle functions during full squats. *Journal of Applied Biomechanics* 24(4), 333-339.

Schwanbeck, S., Chilibeck, P.D., and Binsted, G. (2009) A comparison of free weight squat to Smith machine squat using electromyography. *Journal of Strength and Conditioning Research* **23(9),** 2588-2591.

Vigotsky, A.D., Halperin, I., Lehman, G.J., Trajano, G.S., and Vieira, T.M. (2018) Interpreting Signal Amplitudes in Surface Electromyography Studies in Sport and Rehabilitation Sciences. *Frontiers in Physiology* **4;8**, 985.

Vinstrup, J., Calatayud, J., Jakobsen, M.D., Sundstrup, E., Jay, K., Brandt, M., Zeeman, P., Jørgensen, J.R., and Andersen, L.L. (2017) Electromyographic comparison of conventional machine strength training versus bodyweight exercises in patients with chronic stroke. *Top Stroke Rehabilitation* **24(4),** 242-249.

Wilk, K.E., Escamilla, R.F., Fleisig, G.S., Barrentine, S.W., Andrews, J.R., and Boyd, M.L. (1996). A comparison of tibiofemoral joint forces and electromyographic activity during open and closed kinetic chain exercises. *American Journal of Sports Medicine* **24(4),** 518-527.

Williams, M.J., Gibson, N., Sorbie, G.G., Ugbolue, U.C., Brouner, J., and Easton, C. (2018) Activation of the gluteus maximus during performance of the back squat, split squat, and barbell hip thrust and the relationship with maximal sprinting. *Journal of Strength and Conditioning Research*, Epub ahead of print.

Worrell, T.W., Karst, G., Adamczyk, D., Moore, R., Stanley, C., Steimel, B., and Steimel, S. (2001) Influence of joint position on electromyographic and torque generation during maximal voluntary isometric contractions of the hamstrings and gluteus maximus muscles. *Journal of Orthopedics Sports and Physical Therapy* **31(12),** 730-740.

Yamashita, N. (1988) EMG activities in mono- and bi-articular thigh muscles in combined hip and knee extension. *European Journal of Applied Physiology and Occupational Physiology* **58(3),** 274-277.

Yavuz, H.U., Erdag, D., Amca, A.M., and Aritan, S. (2015) Kinematic and EMG activities during front and back squat variations in maximum loads. *Journal of Sports Science* **33,** 1058-1066.

Zweifel, M.B., Vigotsky, A.D., Contreras, B., and Simiyu, W.W.N. (2017) Effects of 6-week squat, deadlift, or hip thrust training program on speed, power, agility, and strength in experience lifters: a pilot study. *Journal of Trainability* **6,** 13-17.

Key points

- Barbell hip thrust exercise presents greater activation of the hip extensor muscles compared to more conventional exercises.
- Post-activation potentiation of the barbell hip thrust is significant, improving short sprint time.
- Barbell hip thrust training with sub-maximal loads can improve sprint times.

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