Biomechanical differences between hip thrust and glute bridge for hip extensors

Efecto de las diferencias biomecánicas del hip thrust y el glute bridge para los extensores de cadera

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Short title:
Hip thrust and glute bridge biomechanics

How to cite this article:
Zabaleta-Korta, A., & Fernández-Peña, E. (2024). Biomechanical differences between hip thrust and glute bridge for hip extensors**.** *Cultura, Ciencia y Deporte, 19*(59), 81-88. https://doi.org/10.12800/ccd.v19i59.2084

Received: 14 July 2023 / **Accepted**: 24 January 2024

Abstract

The aim of this study was to compare the biomechanical characteristics of two similar exercises used to strengthen hip extensors: the Hip Thrust and the Glute Bridge. Ten resistance-trained participants were recruited and performed three repetitions of each exercise in a randomized order at 80% of their one repetition maximum of the Hip Thrust. Kinematic and kinetic variables were assessed. Significant differences were found between the Hip Thrust and Glute Bridge for the concentric phase in time (0.8 ± 0.14 s vs. 0.58 ± 0.07 s; p < .002), vertical displacement (35.65 ± 3.4 cm vs. 15.45 ± 4.82 cm; p < .002), total displacement (39.36 ± 4.03 cm vs. 19.22 ± 5.63 cm; p<.002), displacement vector magnitude (36.68 ± 3.51 cm vs. 17.84 ± 5.42 cm; p < .002), displacement vector angle (102.18 ± 6.32 deg vs. 61.79 ± 11.08 deg; p < .002), vertical positive impulse (1315.28 ± 300.34 Ns vs. 940.65 ± 93.59 Ns; p < .002), and total impulse (1422.11 ± 321.59 Ns vs. 1024.02 ± 105.48 Ns; p < .002). All effect sizes ranged between 1.59 and 4.64. These results suggest that the Hip Thrust is better suited for sports that require the application of strength from smaller hip angles or higher ranges of motion, and the Glute Bridge allows a higher force application close to the hip lockout. However, due to the training experience of our sample, these results should only be extrapolated to resistance trained males.

Keywords: Displacement vector index, impulse, gluteus maximus, kinematics, force.

Resumen

El objetivo de este estudio es comparar las características de dos ejercicios similares que se usan para desarrollar la fuerza de los extensores de cadera: el Hip Thrust y el Glute Bridge. Diez sujetos experimentados en el entrenamiento de fuerza realizaron tres repeticiones de cada ejercicio usando el 80% de su repetición máxima en el Hip Thrust. Se evaluaron variables cinéticas y cinemáticas. Se hallaron diferencias significativas entre el Hip Thrust y el Glute Bridge en la duración de la fase concéntrica (0.8 ± 0.14 s vs. 0.58 ± 0.07 s; p <.002), desplazamiento vertical (35.65 ± 3.4 cm vs. 15.45 ± 4.82 cm; p <.002), desplazamiento total (39.36 ± 4.03 cm vs. 19.22 ± 5.63 cm; p <.002), magnitud del vector de desplazamiento (36.68 ± 3.51 cm vs. 17.84 ± 5.42 cm; p <.002), ángulo del vector de desplazamiento (102.18 ± 6.32 deg vs. 61.79 ± 11.08; deg; p <.002), impulso vertical positivo (1315.28 ± 300.34 Ns vs. 940.65 ± 93.59 Ns; p < .002), e impulso total (1422.11 ± 321.59 Ns vs. 1024.02 ± 105.48 Ns; < .002). Todos los tamaños del efecto estuvieron entre 1.59 y 4.64.

Palabras clave: Displacement vector index, impulse, gluteus maximus, kinematics, force.

Introduction

There is an emerging body of evidence that shows the importance of hip extensors for sports performance (Cahalan et al., 1989). Hip extensors are the muscles that produce the greatest torque at the hip joint, and these muscles are of paramount importance in daily living, such as walking (Lieberman et al., 2006). The role of hip extensors in sports performance is critical to accelerate the body, especially when starting from a deep hip flexion, e.g., in cycling (Martin & Brown, 2009), sprint accelerations, rising from a deep squat or climbing very steep hills (Neumann, 2010a). Roberts and Belliveau (2005) found that the contribution of knee and ankle work during uphill running remained relatively equal as the slope increased, and the increase in total work came from the hip joint. These authors suggested that this distribution may be due to the increased moment arm on the hip (Roberts & Belliveau, 2005).

A higher ground reaction force produces faster running speeds (Weyand et al., 2000). Horizontal forces are relatively larger as running intensity increases compared to vertical forces, which are primarily produced to overcome the force of gravity and remain nearly constant (Brughelli et al., 2011). Horizontal forces are 11% of the vertical forces while running at 40% of the maximum speed, but these magnitudes increase to 18% when the subjects run at maximum speed (Brughelli et al., 2011). The hip extensor group is essential for the application of backwards force to push the body forward while sprinting 4. There is enough evidence to state that the role of the hip joint is paramount for sports performance (Comfort et al., 2012; Lieberman et al., 2006; Neumann, 2010a; Randell et al., 2011; Roberts & Belliveau, 2005), especially as the mechanical power requirements increase (Martin & Brown, 2009; Roberts & Belliveau, 2005).

Traditional exercises, such as squats and leg curls have been used to strengthen hip extensors. Seitz et al. (2014) found that squats help improve sprint times, but these authors did not analyze other training exercises that might have produced better results. However, Contreras et al. (2011) found that typical standing free-weight exercises are not optimal to strengthen the muscles involved in movements with antero-posterior force vectors, primarily because these exercises apply force vertically (Contreras et al., 2011). For example, barbell back squats may involve a powerful hip extension at the beginning of the movement, but its contribution rapidly decreases as the hip approaches full extension. This movement may be a major drawback for athletes who need the hip joint to apply high levels of force when it is fully extended, e.g., running-related sports.

The barbell Hip Thrust (HT) was first described in the scientific literature by Contreras et al. (2011). The HT is a free-weight exercise that consists of performing a hip extension with a loaded barbell placed in the hip while lying supine with the upper back on a bench and the knees in a 90° flexion. The concentric part of the movement starts with the plates in contact with the ground and finishes when the hip reaches full extension. The barbell displacement must be as perpendicular to the ground (or vertical) as possible, so that gravitational forces make the hip undergo a large torque during the entire movement (Bezodis et al., 2017). However, the scientific evidence on the value of the HT is not clear for all sports because some researchers found an improvement in sprint performance (Contreras et al., 2017) while others found no benefits (Jarvis et al., 2019). Nonetheless, there is clear evidence that the HT plays a major role in training the gluteus maximus because it activates this muscle to a greater degree than the back squat (Contreras et al., 2016).

The recently increased popularity of the HT among movement science professionals has led to the creation of many new variations, such as the "loaded Glute Bridge" (GB). This exercise is technically almost identical to the HT, with the only difference consisting of the placing of the upper back on the ground instead of on a bench. This difference led many practitioners to believe that the HT and GB are interchangeable. However, to the best of our knowledge, no study has analyzed these exercises from a biomechanical standpoint. Therefore, the aim of the present research is to study the biomechanical differences between the HT and GB exercises when the same external load is lifted. We also introduce a new concept, the displacement vector index. This index is used to numerically express the relationship between the vertical and horizontal components of the barbell displacement relative to the ground.

Methods

Participants

Eleven healthy men (age 23.5 ± 3.63 years, body mass 78.6 ± 13.7 kg, height 1.78 ± 0.08 m) volunteered to participate in this study. Participants had resistance training experience of at least 3 years, and they had performed the HT in their training sessions twice weekly for at least one year. The participants showed various training backgrounds, but most were athletes that used resistance training as a way to enhance their physical capacities (n = 3). Other participants had resistance training as their sport, in the case of weightlifters (n = 2), powerlifters (n = 4), and crossfitters (n = 2). The participants' one repetition maximum (1RM) in the HT exercise was 211.6 ± 27.27 kg. One participant could not complete the experimental protocol for reasons that were not related to the study. The anthropometric data of the 10 participants who completed the study is displayed in Table 1.

The study was approved by the Ethics Committee of the local University. All the participants were informed about the benefits and risks of participation in the current study and signed informed consent prior to participation. The study was developed according to the declaration of Helsinki.

Table 1. Descriptive statistics of the subjects

	Age (y)	Body mass (kg)	Height (m)	Hip Thrust 1RM* (kg)	80% 1RM (kg)
Subject 01	22	82	1.75	235	188
Subject 02	33	78	1.8	229	183.2
Subject 03	25	80	1.92	205	164
Subject 04	20	64	1.61	192	153.6
Subject 05	23	114	1.8	245	196
Subject 06	22	75	1.76	235.5	188.4
Subject 07	22	75	1.82	224.6	179.68
Subject 08	21	79	1.82	210	168
Subject 09	24	73	1.77	164.5	131.6
Subject 10	23	66	1.71	175	140
Average	23.5	78.6	1.8	211.6	169.2
SD	3.6	13.7	0.1	27.3	21.8

*1RM = One repetition máximum
*y = Years
*m = Meters
*kg = Kilograms
**SD* = Standard Deviation

Procedure

Participants attended the laboratory on two separate days, with at least one week between visits. Participants underwent a familiarization session during the first visit, in which investigators provided the participants with instruction about how to correctly perform the HT and GB. Specifically, we emphasized the importance of a linear movement pattern and a symmetrical barbell movement. One hour was sufficient for all of the participants to become accustomed to the exercise requirements. Each participant's 1RM was estimated for the HT after a 10-minute rest using the Powerlift app. The Powerlift app is a valid and reliable mobile phone app that allows the user to estimate the 1RM of a participant in certain exercises based on the velocity of the barbell (Balsalobre-Fernández et al., 2018). This app helped avoid any kind of potential risk involved in the lifting of higher loads.

During the second visit, the participants performed a standard warm up involving the HT and GB exercises of increasing loads (20%, 40%, 60% and 80% of 1RM). A dense pad was placed between the barbell and the participants' crease of the hips to protect the abdominal and pubis areas, as described by Contreras et al. (2011). An active LED marker was placed at the end of the barbell on the side to be filmed, and participants performed two sets of three consecutive repetitions of the HT or GB exercises in a randomized order using 80% of the 1RM of the HT exercise that was estimated in the previous session. Half of the subjects performed the HT first, and the other half performed the GB first. To ensure equal conditions between HT and GB assessments, the same load was also used for the GB. Even if this meant that subjects were not lifting the same relative intensity in both exercises, we considered this could help us avoid the fatigue accumulation that another 1RM calculation can carry. Recovery time between both sets was at least three minutes. An experienced coach supervised the exercises, which were deemed valid if performed according to the following criteria: the hips reached full extension, the barbell was pulled symmetrically and parallel to the ground, and the movement was as vertical as possible.

Instruments

A Casio Exilim EX-F1 digital camera with a sampling rate of 300 Hz was used to film the HT and GB exercises. To reduce the perspective error, the camera was placed at ten meters with the zoom as close as possible to ensure that the whole motion was captured (Payton, 2008). The videos were digitalized using the Kinovea 8.15 video analysis software to track the bar's endpoint two-dimensional position. The raw data were filtered using a fourth-order zero-lag Butterworth low-pass filter at a cut-off frequency of 10 Hz. The ensemble averages were created by reducing each individual exercise to 100 points using linear interpolation. Data were analyzed using a Microsoft Excel 2016 spreadsheet (Microsoft, Redmond, WA, USA) to calculate the bar's position, velocity and acceleration.

All the variables were assessed during the concentric phase of the movement, which was defined from the initial vertical barbell displacement to its maximum vertical height for each repetition. The following variables were assessed: time in seconds; horizontal displacement in centimeters, which was the sum of all the forward and backward barbell displacements that occurred in the horizontal axis; vertical displacement in centimeters, which was the sum of all the upward barbell displacement that occurred in the vertical axis; total displacement in centimeters, which was the sum of instantaneous linear barbell displacements in the two-dimensional space; displacement vector magnitude in centimeters, which was the linear distance between the initial and final barbell positions; displacement vector angle in degrees, which was the angle formed between the initial and final barbell positions with respect to the horizontal axis; and displacement vector index, which is an adimensional ratio between displacement vector magnitude and total displacement that assesses the linearity of the barbell displacement. A linear path for the HT and GB is supposed to more specifically target the hip extensor muscle group. The displacement vector index ranges from 0 to 1, with 1 indicating a perfect linear motion of the barbell and lower values meaning a more circular motion, and it is calculated as follows: displacement vector index = displacement vector magnitude / total displacement. The vertical positive impulse, measured in Newtons per second, is the positive area under the vertical force / time curve, and it is calculated using the trapezoidal rule. The instantaneous vertical force was calculated using the mass of the external load (barbell plus plates) and the calculated vertical acceleration plus the resistance of gravity. The horizontal total impulse, measured in Newtons per second, is the total area under the horizontal force / time curve, and calculated using the trapezoidal rule. The instantaneous horizontal force was calculated using the mass of the external load and the measured horizontal acceleration. The total impulse, measured in Newtons per second, was the vectorial sum of instantaneous linear impulses in the two-dimensional space.

Statistical analyses

Descriptive data is represented as means and Standard Deviations. Data were evaluated for normality using Shapiro-Wilks tests and for homoscedasticity using Levene's test. The variables that passed both criteria were assessed using a paired Student's t-test, and the other variables were compared using Wilcoxon's test. All data were analyzed using SPSS 23.0 (IBM, Armonk, NY, United States of America) statistical software. Statistical significance was set at $p < .05$. Because of the small sample size, Hedge's g was calculated to measure effect sizes instead of Cohen's d and considered small (*ES* ≤ .2), medium (*ES* ≤ .5), large (*ES* ≤ .8) or extremely large (*ES* > 1.0).

Results

All the variables were distributed normally, and all the variables were homoscedastic, except the vertical positive impulse and total impulse. Table 2 summarizes the average differences and ranges of all of the variables between the HT and GB. There were no significant differences between the HT and GB in horizontal displacement, total horizontal impulse or displacement vector index. The rest of the analyzed variables showed significantly larger values for the HT compared to the GB, with effect sizes that ranged from 1.59 to 4.64 and *p* values lower than .002. See Table 2 for full details.

Table 2. Results for the concentric phase of the HT and GB exercises

	HT (Avg ± *SD*)			HT Range (min - max)			GB (Avg ± *SD*)			GB Range (min - max)			Effect Size (Hedge's *g*)
Time (s)	0.8	±	0.14 †	0.53	-	0.98	0.58	±	0.07	0.46	-	0.65	1.91
DisplHor (cm)	11.47	±	3.74	7.64	-	20.38	9.19	±	3.35	4.68	-	15.38	0.61
DisplVert (cm)	35.65	±	3.4 ‡	29.92	-	40.26	15.45	±	4.82	7.06	-	23.49	4.64
DisplTot (cm)	39.36	±	4.03 ‡	33.02	-	46.3	19.22	±	5.63	9.42	-	29.83	3.94
DisplVectMag (cm)	36.68	±	3.51 ‡	30.91	-	41.42	17.84	±	5.42	8.02	-	28.08	3.95
DisplVectAng (deg)	102.18	±	6.32 ‡	87.72	-	109.32	61.79	±	11.08	48.25	-	79.47	4.29
DisplVectIndex	0.93	±	0.05	0.84	-	0.99	0.92	±	0.04	0.85	-	0.99	0.19
ImpPosVert (Ns)	1315.28	±	300.34 †	880.53	-	1773.63	940.65	±	93.59	796.84	-	1112.19	1.61
ImpTotHor (Ns)	107.04	±	28.84	70.56	-	158.56	83.37	±	26.53	46.22	-	124.76	0.82
ImpTot (Ns)	1422.11	±	321.59 †	958.95	-	1932.2	1024.02	±	105.48	856.1	-	1236.67	1.59

Results (Average ± SD and Range) of the concentric phase for the Hip Thrust (HT) and Glute Bridge (GB) exercises. DipslHor = horizontal displacement of the barbell; DisplVert= vertical displacement of the barbell; DisplTot = total displacement of the barbell; DisplVectMag = displacement vector magnitude; DisplVectAng = displacement vector angle; DisplVectIndex = displacement vector index; ImpPosVert = positive vertical impulse; ImpTotHor = total horizontal impulse; ImpTot = total impulse.

† Significantly different from GB ($p < .05$)
‡ Significantly different from GB ($p < .001$)

There was a high variability in barbell displacement in the HT and GB. Some participants showed a linear barbell displacement, while others showed a clear arched pattern in both exercises. This pattern is reflected in the displacement vector index, which ranged from 0.84 to 0.99 for the HT and 0.85 to 0.99 for the GB. Figure 1 shows the two-dimensional barbell displacements of four participants while performing the HT and GB.

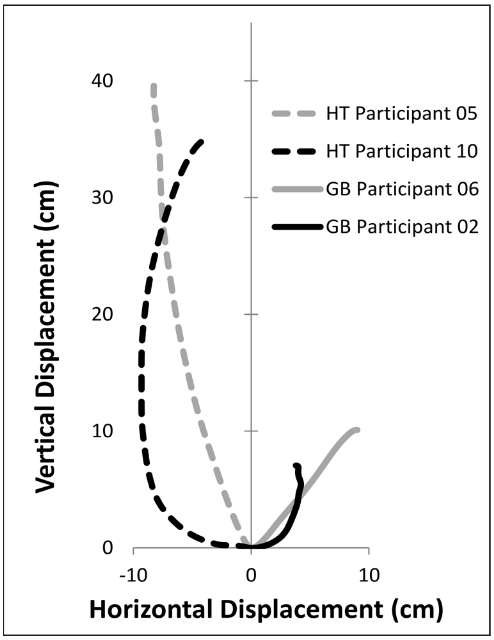

Figure 1. 2-dimensional barbell displacement for the HT and GB in participants with higher and smaller displacement vector indexes

Note: Gray dashed line: HT barbell displacement for participant 05 (displacement vector index = 0.99). Black dashed line: HT barbell displacement for participant 10 (displacement vector index = 0.84). Gray solid line: GB barbell displacement for participant 06 (displacement vector index = 0.99). Black solid line: GB barbell displacement for participant 02 (displacement vector index = 0.85). Patterns are normalized to show the (0.0) coordinate as the initial point of motion.

Figure 2 shows the average barbell displacement patterns with corresponding displacement vectors. Average displacement vector magnitude and angle were 36.68 ± 3.51 cm and 102.18 ± 6.32 degrees (*p* < .002), respectively, for the HT and were 17.84 ± 5.42 cm 61.79 ± 11.08 degrees, respectively, for the GB (*p* < .002).

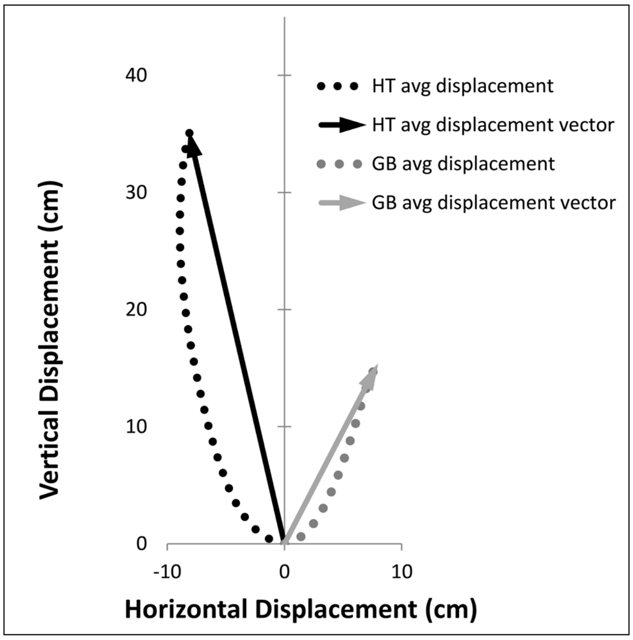

Figure 2. 2-dimensional barbell displacement and corresponding displacement vectors for average HT and GB patterns

Note: Black dotted line: HT average barbell displacement. Black arrow: HT average displacement vector. Gray dotted line: GB average barbell displacement. Gray arrow: GB average displacement vector. Refer to Table 2 for the magnitude and angle of average displacement vectors.

Discussion

The main objective of the present study was to compare a series of biomechanical variables between the HT and GB performed with the same load. All of the statistically significant differences found in this study were larger for the HT and had extremely large effect sizes, which reveals that both exercises have very different biomechanical characteristics. Overall, the HT elicited larger vertical and total displacements and impulses than the GB, with horizontal variables remaining equal.

It is known that the largest extensor moment on the hip during the hip thrust exercise happens when the hip is near full extension (Bezodis et al., 2017; Brazil et al., 2021). Near full extension, gluteus maximus muscle is strongest when compared to other regions of the hip extension Range of Motion (Németh & Ohlsén, 1985; Neumann, 2010b). For that reason, we consider that the GB may be a better suited exercise to develop gluteal muscles, as a lower degree of hip flexion implies less contribution from other hip extensors. However, this may not be true if we consider that according to recent findings, muscle elongation during a resistance exercise may increase the growth potential of muscles (Pedrosa et al., 2023). Whether a more pronounced degree of muscle elongation can beat a greater moment arm as a relevant factor for muscle growth is a question that remains to be answered.

The biggest findings of this study were that the HT vector magnitude was twice as large as the GB vector magnitude, and its displacement angle was much more vertical. The larger displacement vector magnitude of the HT likely allows a greater hip extension range of movement, which could be more beneficial for sports that require large hip extension ranges, even if this may not be as positive as it seems, as recent evidence suggests that the greatest extensor moment happens when the hip is near full extension (Brazil et al., 2021). The athlete is supposed to lift the barbell completely vertical during the HT to create the highest possible gravitational resistance for hip extensors. Surprisingly, the angle of the HT displacement vector was not completely vertical, which raises concerns about its supposed verticality. This absence of a completely vertical angle is very likely due to the lack of movement restriction during the free-weight HT, which implies that movement also occurs in the horizontal axis and reduces the effectiveness of the exercise.

The GB displacement vector angle was less vertical (Figure 2). This result was expected because the lifting trajectory is not totally opposed to the force of gravity (at least it is less opposed than in the HT). This trajectory creates a higher horizontal displacement and a lower gravitational resistance for the hip extensors, which means that lower force is likely needed to move a given weight in the GB. Consequently, one may expect to observe a higher 1RM in the GB compared to the HT, allowing athletes to lift higher absolute loads with the same relative intensity.

Therefore, the assessment of the horizontal displacement is a key parameter of the technique. However, we found no differences in the horizontal displacement or the horizontal impulse between the HT and GB when both exercises were performed with the same load. This result may be explained by the particular technique of some lifters during the performance of both exercises. Some lifters showed a clear trend towards performing a horizontal forward movement at the very beginning of the concentric phase and a backwards horizontal movement at the end of the HT (Figure 1), but no forward movement was observed in the GB. We hypothesize that these horizontal movements are an unconscious strategy of the lifters to lift the weight more easily by taking advantage of the horizontal inertia that this movement creates. The start of the repetition was considered as soon as a movement was recorded in the vertical axis from a totally stopped position, and it was considered finished when the movement in the vertical axis ended. Most of the two-dimensional trajectories analyzed showed a clear "arch" pattern in this frame during both exercises, even if there were interparticipant differences when lifting (Figure 1). This particularity reveals new aspects of this exercise that must be considered by coaches when choosing the HT or the GB for their training sessions.

The present study is the first time the displacement vector index was used in the scientific literature. This index is a novel kinematic indicator that assesses the way that the total displacement occurs compared to the displacement vector. This index ranges from 0 to 1, and it numerically expresses the extent to which the actual movement reflects the desired linear pattern. A scale for this index must be developed, but its initial classification is quite simple: the closer the displacement vector index value is to the number one, the higher the adjustment of the bar displacement is to its theoretical linear displacement and the lesser the movement pattern is arch-shaped. Notably, this index was equal for the HT and GB, and the effect size was small. These results may be due to the similarities in the mechanics of the HT and GB, e.g., both exercises use free weights to perform a hip extension that starts while lying supine on the floor with the bar in the pubis area. The displacement vector index ranged from 0.84 to 0.99 in the HT and 0.85 to 0.99 in the GB in our tests, which means that some participants correctly followed the exercise instructions for a linear movement pattern, and other participants took advantage of the horizontal movement. Figure 1 shows different movement patterns for participants with higher and lower displacement vector index values. Therefore, the displacement vector index precisely reflects the movement linearity and may be used to assess it.

The primary aim of this research was to analyze the biomechanical differences between the HT and GB. Therefore, the study used equal loads to evaluate the exercises under equal conditions. However, this decision was proven as a limitation because the GB likely allows higher absolute loads to be lifted. Additionally, the low number of subjects and the fact that only two dimensions could be measured can be considered limitations. Therefore, future research should focus on assessing biomechanical differences between the HT and GB when proportional percentages of the 1RM loads are lifted.

Conclusions

The larger vertical and total displacements of the HT render this exercise more relevant to sports that require the application of strength from smaller hip angles or higher ranges of motion. Notably, the HT exhibits larger vertical positive and total impulses, which suggests that it has superior properties for sports in which large amounts of force per unit time must be applied, e.g., weightlifting. We suggest to maintain the barbell trajectory as vertical as possible during this exercise to produce a displacement vector index of close to 1.

The GB is an interesting exercise for practitioners looking for a high amount of force application close to hip lockout because its range of motion is very small and very near to full hip extension where the gluteus maximus is very strong. This movement is similar to the powerful hip extension seen in many resistance training-related sports exercises, e.g., snatch. The GB may also be used by athletes looking for a new stimulus for the gluteus maximus to avoid a stalemate in muscle hypertrophy.

We consider that these conclusions only apply to trained subjects, as our sample is mainly compound by trained subjects.

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