COMPARISON OF THE BILATERAL AND UNILATERAL BARBELL HIP THRUST

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The purpose of this study was to quantify the kinetics and kinematics of the unilateral (UL) barbell hip thrust and compare UL biomechanics with the bilateral (BL) barbell hip thrust. Ten resistance trained males performed three sets of three repetitions UL and BL at 10 repetition maximum intensity. The biomechanics of each lift were analysed using 3D motion capture and force plates that were floor mounted and instrumented in to a bespoke rig. Joint kinetics and kinematics were calculated in the sagittal, frontal and transverse planes. The UL condition produced significantly ($p<0.05$) greater mean moment in the sagittal plane. It was concluded that UL loaded the hip joint to a greater extent than the BL across all three planes. The current study offers novel insight to the biomechanical demand of the unilateral hip thrust and has implications for exercise selection within the physical preparation of athletes.

KEY WORDS: kinetics, gluteus maximus, weight training, hip extensor.

INTRODUCTION: The barbell hip thrust has risen in popularity in recent years amongst athletes and individuals aiming to develop their hip extensor musculature. Current literature indicates that the barbell hip thrust is an effective exercise for loading the hip extensor musculature (Contreras et al., 2015, Contreras et al., 2016, Bezodis et al., 2017). The objective of the exercise is to displace the barbell vertically through a forceful extension of the hip joint and the individual should control the lift throughout the raising and lowering phases (Contreras et al., 2011). The barbell hip thrust can be categorised under the bridging group of exercises (Stevens et al., 2006). Peak EMG activity has been shown to be higher in unilateral bridging exercises compared to their bilateral counterparts, with some muscles eliciting five times more activation in the unilateral variation (Stevens et al., 2006). An alternative to the bilateral barbell hip thrust is the unilateral barbell hip thrust. The distinguishing feature in the unilateral variation being that the individual raises the barbell with a single lifting leg in contact with the floor and holds the non-lifting leg parallel to the ground. Research on the barbell hip thrust, as with the majority of literature studying lower body strength training exercises, has focused on bilateral variations. Therefore the aim of this study is to quantify the hip joint kinetics and kinematics of the unilateral barbell hip thrust, and perform a biomechanical comparison with the bilateral barbell hip thrust at the same relative external load. The purpose of this study is to help inform exercise selection for developing the hip extensor musculature.

METHODS: Ten healthy, resistance trained males (24 ± 4 years, 79.4 ± 9.7 kg, 1.78 ± 0.08 m, bilateral barbell hip thrust 10 RM = 149.00 ± 48.00 kg, unilateral barbell hip thrust 10 RM = 44.00 ± 14.30 kg) attended were recruited and provided written informed consent to participate in accordance with the University's ethics board. All participants had a minimum of three months training with the barbell hip thrust. Following a standardised warm-up, participants performed bilateral (BL) and unilateral (UL) hip thrusts for three sets of three repetitions at a 10 repetition max intensity, with full recovery between sets. Values for 10RMs for the BL and UL conditions were collected using the method outlined by Reynolds et al., (2006) a minimum of five days prior to kinetic and kinematic data collection. For the bilateral variation a total of nine repetitions were performed. For the unilateral variation a total of 18 repetitions were performed (nine per leg).

Kinematic data were captured using a lower-limb and trunk marker set, in order to create an eight segment model (thorax, pelvis, and bilateral thighs, shanks and feet). Three individual markers were also attached to the barbell. Marker trajectories were recorded using a 15 camera Vicon Vantage system (Vicon, Oxford, UK), capturing at 250 Hz. Kinetic data were captured with three Kistler 9287CA (Kistler, Winterhur, Switzerland) force plates (1000 Hz). Two force plates were mounted in standard in-ground dwellings, for each foot. The third force plate was mounted to a bespoke rig, 25 cm above the ground and angled at 20^o to the horizontal to measure the external force between the thorax and the bench. Tracked trials were exported to Visual 3D (v6, C-Motion Inc, Germantown, USA) for further processing. Marker trajectories and force data were low-pass filtered (4th order Butterworth) with cut-off frequencies of 6 and 80 Hz respectively. Data from the rig mounted force plate were rotated and resolved in the global coordinate system. Each segment's local coordinate system was defined using a static calibration trial, with the x-axis pointing right, y-axis forward and z-axis upwards in the standing anatomical position.

For sagittal plane analysis, x-axis data was used with extension defined as positive. Frontal plane analysis was performed with data from the y-axis with abduction defined as positive, for the transverse plane the z-axis data was used with external rotation defined as positive (Robertson et al., 2014). The start of each repetition was defined as the onset of hip extension (the point at which hip angular velocity increased and remained above 0 $^{\circ}s^{-1}$). The end of each repetition was defined as the end of the lowering phase (the point at which the barbell vertical acceleration reached and remained at 0 $^{\circ}s^{-1}$). Waveform data were time-normalised to 100% of the repetition period using a cubic spline. For angular velocity calculations the repetition was divided into the raising and lowering phases, with the maximum vertical displacement used as the end of raising and the start of the lowering phases. Mean and peak angle, angular velocity, moment, work and power values were exported from Visual 3D. Group means and standard deviations (SD) were calculated for the BL hip thrust and UL hip thrust. In the bilateral condition these data were averaged over the two limbs. In the unilateral condition, data were averaged as the lifting or non-lifting leg. All joint kinetic data were normalised to body mass. Data were not normally distributed and therefore a Mann-Whitney U test was used to compare joint kinematic and kinetic data between BL and UL conditions, statistical significance was accepted at a level of $p<0.05$. All mean data (text, figures and tables) are presented as mean ± standard deviation (SD).

RESULTS: No significant differences ($p>0.05$) were found for sagittal plane kinematics as seen in table 1 and figure 1(a). Analysis of the angle-time curve (Figure 1a) suggests that the hip joint remained in a more extended position throughout the repetition in the BL condition, supported by a peak extension angle of 162 ± 9° in the BL compared with 159 ± 9° for UL. Peak flexion was greater in the UL condition with values of 85 ± 6° and 87 ± 5° for the UL and BL, respectively.

Table 1 Mean (± SD) values for hip joint angles in the sagittal, frontal and transverse planes for the double and single leg barbell hip thrusts.

Joint angle (°)	Condition		
	BL	UL	
Peak Extension	162 ± 9	159 ± 9	
Peak Flexion	87 ± 5	85 ± 6	
Peak Abduction	4 ± 3	6 ± 4	*
Peak Adduction	-2 ± 3	-3 ± 4	
Peak External Rotation	-1 ± 4	11 ± 6	*
Peak Internal Rotation	-7 ± 4	-16 ± 5	*

*** denotes statistically significant difference (p < 0.05) between the double and single leg barbell hip thrust**

For both conditions, mean and peak angular velocities were greater in the raising phase than the lowering phase. Peak raising angular velocity was substantially greater in the BL condition (163 ± 188 $°s^{-1}$) compared to the UL condition (123 ± 95 $°s^{-1}$) in the sagittal plane, however no statistical significance ($p>0.05$) was observed for these differences. Peak abduction was significantly ($p<0.05$) greater in the UL condition with a value of 6 ± 4° compared to 4 ± 3° for BL but this difference is almost negligible. Peak adduction angles were comparable with values of -2 ± 3° and -3 ± 4° for BL and UL respectively. Peak external rotation was significantly greater ($p<0.05$) in the UL condition with 11 ± 6° compared to -1 ± 4° in the BL condition. The UL condition also produced significantly ($p<0.05$) greater peak internal rotation than the BL condition of -16 ± 5° and -7 ± 4° respectively.

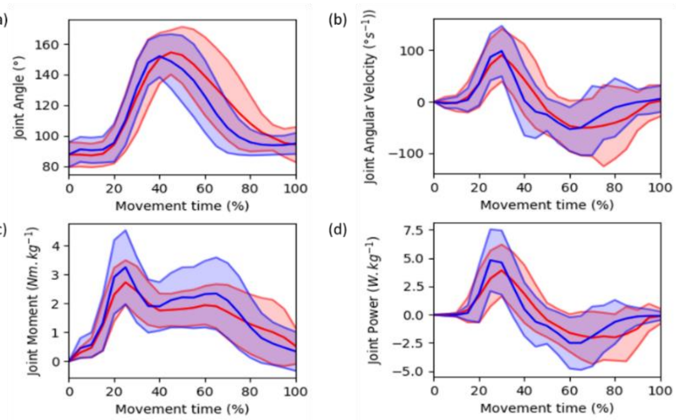

Figure 1. Sagittal plane hip joint kinetics and kinematics plotted against percentage time for BL (red) and UL (blue): (a) joint angle, (b) joint angular velocity, (c) joint moment, (d) joint power.

Table 2. Group mean (± SD) hip joint kinetics and angular velocities in the sagittal, frontal and transverse planes for the BL and UL barbell hip thrust.

Variable	Condition	Anatomical Plane					
		Sagittal		Frontal		Transverse	
Mean Moment (Nm.kg-1)	BL	1.47 ± 0.26		0.04 ± 0.02		0.04 ± 0.04	
	UL	1.87 ± 0.26	*	0 ± 0.09		0.09 ± 0.04	*
Peak Moment ($Nm.kg^{-1}$)	BL	4.59 ± 1.01		0.79 ± 0.54		1.21 ± 0.8	
	UL	6.69 ± 4.36		1.21 ± 1.18		1.66 ± 1.56	
Peak Power ($W.kg^{-1}$)	BL	14.32 ± 8.17		3.39 ± 3.73		0.95 ± 0.78	
	UL	15.96 ± 10.70		3.37 ± 5.06		7.68 ± 14.8	
Positive Work Done ($J.kg^{-1}$)	BL	2.73 ± 1.11		0.16 ± 0.22	*	0.06 ± 0.17	
	UL	3.11 ± 0.60	*	0.05 ± 0.03		0.04 ± 0.07	
Mean angular velocity raising ($°.s^{-1}$)	BL	46.00 ± 29.40		10 ± 6		6 ± 4	
	UL	44.00 ± 25.00		12 ± 7		3 ± 3	
Peak angular velocity raising ($°.s^{-1}$)	BL	163.86 ± 188.55		46.98 ± 60.84		53.61 ± 63.86	
	UL	123.49 ± 95.78		43.37 ± 68.07		37.24 ± 87.35	
Mean angular velocity lowering ($°.s^{-1}$)	BL	28.86 ± 14.08		7.00 ± 4.00		4.00 ± 2.00	
	UL	22.10 ± 10.10		6.58 ± 2.72		2.21 ± 1.37	
Peak angular velocity lowering ($°.s^{-1}$)	BL	125.30 ± 122.29		57.83 ± 57.23		46.98 ± 63.25	
	UL	119.27 ± 113.25		49.39 ± 81.32		48.79 ± 93.37	

*** denotes statistically significant difference (p < 0.05) between the double and single leg barbell hip thrust**

In the sagittal plane mean moment was significantly ($p<0.05$) greater in the UL condition, peak moment was greater but not significantly ($p>0.05$) so as seen in Table 2. The moment-time curve (Figure 1c) shows that peak moment was achieved earlier and maintained to a greater extent throughout the repetition in the UL condition. Table 2 shows that in the sagittal plane UL produced significantly ($p<0.05$) greater positive work of 3.11 ± 0.60 ($J.kg^{-1}$) compared to 2.73 ± 1.11 ($J.kg^{-1}$). Greater extensor power was generated in UL (Table 2). Thus the hip extensors exerted more energy at a greater rate in the UL. Frontal plane peak moment was again greater in the UL condition (1.21 ± 1.18 $Nm.kg^{-1}$) and notably greater than the BL condition (0.79 ± 0.54 $Nm.kg^{-1}$).

DISCUSSION: The purpose of this study was to quantify the hip joint kinetics and kinematics of the unilateral barbell hip thrust, and compare those values with the values for the bilateral barbell hip thrust at the same relative external load.

A 10° difference was observed for peak external rotation with the UL condition demonstrating a peak external rotation angle of 11 ± 6° compared to -1 ± 4°. UL peak internal rotation exhibited a two fold increase for the compared to the BL condition (Table 2). The reduced base of support associated with unilateral exercise increases the demand for control about the frontal and transverse planes (McCurdy, 2017). The single base of support also created greater peak moments in all three anatomical planes as well as increased mean moments in the sagittal and transverse planes (Table 2). As participants were instructed to complete the exercises as they normally would during their habitual exercise routine the rate of flexion and extension was not controlled. It's hypothesised that the lower angular velocity in the sagittal plane may have occurred due to the increased requirement for stabilisation about the hip joint during the raising an lowering of the barbell in the UL condition. In order to maintain a level pelvis in a unilateral stance, the results indicate that an increased recruitment of both the hip extensors and hip rotators is required. This finding aligns with the findings of (Stevens et al., 2006) that unilateral exercises elicit greater activation levels than their bilateral counterparts.

Interestingly the greater joint moments in the UL were achieved with a load that was approximately 30% of that used in BL. Therefore, results indicated that UL may offer coaches a variation of the hip thrust that elicits increased musculoskeletal demand at the hip extensors, and highlights the potential to further explore the effect of manipulating external load on the joint kinetics and kinematics of the UL and BL.

CONCLUSION: This study quantified the joint kinetic and kinematic demands of the UL barbell hip thrust. The results for joint moment showed that the UL variation of the barbell hip thrust offers greater multi-planar mechanical loading at the hip joint compared with BL. The kinetic results as well as the results for angular velocity suggest that the UL requires increased stabilisation about the hip joint. The findings of this study will help to inform coaches and rehabilitation practitioners when prescribing barbell loaded bridging exercises.

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