HIP JOINT KINETICS DURING THE BARBELL HIP THRUST

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The barbell hip thrust is thought to overload the hip extensors near full extension. The aim of this study was to quantify the hip joint kinetics of a full repetition of the barbell hip thrust. Seven participants performed 3x3x70% 1RM barbell hip thrusts, during which external force (1000 Hz) and full body kinematics (250 Hz) were captured. Inverse dynamic analysis revealed a double peak in the hip extensor moment through the repetition, with maximum hip extensor moment (3.13 ± 0.48 Nm/kg) occurring early in the movement, when the hip joint was close to 90° flexion. Despite the changes in magnitude of hip extensor moment during the repetition, the moment remained extensor dominant throughout, which provided some support for the force vector theory and the previous suggestion that the hip thrust effectively overloads the hip extensors near full extension.

KEY WORDS: hip extensors, inverse dynamics, joint moment, strength training

INTRODUCTION: The barbell hip thrust is a relatively newly developed exercise that is designed to develop the hip extensor muscles (gluteals and hamstrings, Contreras et al., 2011). It is specifically thought to increase the tension in the hip musculature as the hip joint reaches full extension, when compared to traditional standing barbell strength exercises such as the back squat and deadlift. This is thought to be the case due to the horizontal (antero-posterior) orientation of the force vector in the hip thrust, compared to the vertical (downwards) orientation of the force vector in traditional standing barbell strength exercises, and is known as the force vector theory (Contreras et al., 2011). The barbell hip thrust is a popular exercise for sprint acceleration training, since it is thought to overload the hip extensors near full extension with a horizontal force application (Contreras et al., in press).
To the authors' knowledge studies have been conducted of electromyographic activity in the barbell hip thrust (Contreras et al 2015; 2016), but there are no existing studies of the kinematics or kinetics of the exercise. It has been suggested that the barbell hip thrust requires a consistent hip extension moment throughout the exercise (Contreras et al., in press), yet this has not been empirically investigated. Joint moments have previously been calculated in standing barbell exercises such as the back squat (Southwell et al., 2016; Legg et al., 2017) and deadlift (Swinton et al., 2011). The primary aim of this study was to quantify the hip joint kinetics during the barbell hip thrust, with the secondary aim of investigating the hip joint moment throughout the movement.

METHODS: Data Collection: Seven resistance trained males (20.7 ± 1.3 years, 73.3 ± 4.9 kg, 1.734 ± 0.091 m, barbell hip thrust 1RM = 164 ± 48 kg) gave written informed consent to participate after institutional ethical approval. Participants were free from injury at the time of data collection and regularly used the barbell hip thrust as a part of their training routine.
Kinematic data were captured at 250 Hz with a 15 camera Vicon Vantage system. A full-body marker set comprising 32 individual markers and eight four-marker clusters were attached to each participant to facilitate the creation of a fifteen segment model (bilateral feet, shanks, thighs, hands, forearms and upper arms, and pelvis, thorax and head). Three markers and one cluster were attached to the barbell to track its trajectory. Synchronised kinetic data were captured using three Kistler 9287 force plates (1000 Hz). Two were located in standard in-ground dwellings, and were used to measure forces separately at each foot. The third was mounted to a custom built rig, raised above the ground and angled at 20° to the horizontal, to facilitate accurate measurement of external force between the thorax and bench. A 15 mm medium density foam mat was secured to the top of the raised force plate to reduce participant discomfort. The rig was positioned such that the participant could comfortably perform the movement with their feet located near the centre of the in-ground plates.

Participants performed a self-selected warm-up, and were given verbal instructions on performing the movement as outlined by Contreras et al. (2011). Data collection comprised three sets of three repetitions of the barbell hip thrust at 70% 1RM, with self-selected rest permitted between sets.

Data Processing: After labelling and gap-filling of marker trajectories (Nexus, v2.0, Vicon, Oxford Metrics, UK), data processing was performed using Visual 3D software (v6, C-Motion Inc, Germantown, USA). Raw marker coordinates and force traces were low-pass filtered (4th order Butterworth) with cut-off frequencies of 3 and 30 Hz, respectively. Data from the raised force plate were rotated and resolved into the global coordinate system. Each segment's local coordinate system (SCS) was defined using a static trial, with the x-axis pointing right, y-axis forward and z-axis upwards. Joint angular velocity was the rate of change of the distal relative to the proximal SCS, described by an XYZ Cardan sequence. Newton-Euler inverse dynamic procedures (Selbie et al., 2014) were used to calculate resultant joint moments resolved in the proximal SCS at the ankle, knee, hip and trunk. Due to the sagittal plane nature of the movement, x-axis data only are reported, with extension defined as positive. Joint power was calculated as the product of joint moment and angular velocity. Joint work was calculated for each power phase by integrating the power-time curve using the trapezium rule. All joint kinetic data were normalised to body mass. Joint kinematic and kinetic time-histories were normalised to 100% of the full repetition using a cubic spline. The start of the rep was defined by the onset of hip extension (when hip extensor angular velocity increased and remained above zero). The end of the rep was defined by the termination of hip flexion (when hip flexor angular velocity decreased and remained below -1°/s). The end of the raising phase of the rep was defined by the maximum vertical displacement of the barbell. Group means and standard deviations were calculated for all variables using each participant's mean data from nine reps.

RESULTS: The hip extended throughout the raising phase, and flexed throughout the lowering phase (Figure 1). Peak hip angular velocities occurred approximately midway through the respective phases. The hip extensor moment peaked (3.13 ± 0.48 Nm/kg, table 1) early in the raising phase (11.0 ± 3.9 % repetition duration), when the hip joint was in flexion (99 ± 6°), and reached a second peak late in the lowering phase of the repetition.

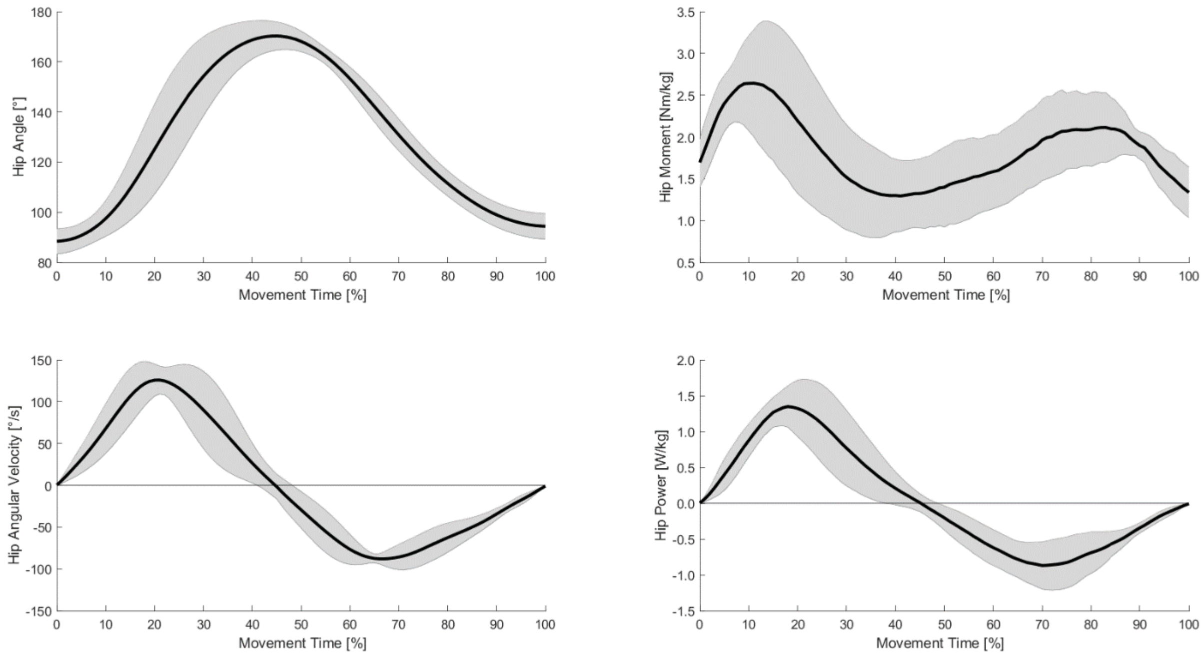

Figure 1: Mean ± standard deviation of hip angle, angular velocity, moment and power throughout the movement duration.

Table 1: Mean ± standard deviation of discrete kinematic and kinetic variables.

Variable	Mean	SD
Duration of raising phase [s]	1.011	0.139
Duration of lowering phase [s]	1.484	0.421
Total repetition duration [s]	2.495	0.464
Time of peak bar displacement [% rep]	41.2	6.3
Hip extension range of motion [°]	84	5
Peak hip extensor moment [Nm/kg]	3.13	0.48
Time of peak hip extensor moment [% rep]	11.0	3.9
Hip angle at peak extensor moment [°]	99	6
Mean hip extensor moment [Nm/kg]	1.83	0.41
Hip extensor impulse [Nms/kg]	4.48	0.98
Peak hip extensor power [W/kg]	5.52	1.21
Minimum hip extensor power [W/kg]	-3.70	1.34
Positive work done [J/kg]	2.54	0.55
Negative work done [J/kg]	-2.30	0.45

The double peaked hip extensor moment was combined with a hip extensor angular velocity during the raising phase and hip flexor angular velocity during the lowering phase. This led to the hip extensor muscles generating peak positive power of 5.52 ± 1.21 W/kg, and peak negative power of -3.70 ± 1.34 W/kg in the raising and lowering phases, respectively. The hip extensors generated 2.54 ± 0.55 J/kg positive work in the raising phase of the rep, and -2.30 ± 0.45 J/kg negative work in the lowering phase.

DISCUSSION: The aim of this study was to quantify the hip joint kinetics during the barbell hip thrust. To the authors' knowledge, this is the first study to successfully achieve that aim. The secondary aim of this study was to investigate the hip joint moment throughout a barbell hip thrust repetition. The hip joint moment-time profile was extensor throughout the repetition and clearly double-peaked in nature. The peak extensor moment at the hip (3.13 ± 0.48 Nm/kg) occurred at only 11.0 ± 3.9% of the repetition duration, when the hip angle was close to 90° flexion. This was followed by a second peak towards the end of the lowering phase, as the hip came back towards 90° flexion. The peak extensor moments measured in this study at the hip are similar in magnitude to those previously measured in traditional standing barbell strength exercises, using similar measurement and analysis techniques. In the barbell back squat, Southwell et al. (2016) found a peak hip extensor moment of approximately 3 Nm/kg at 80% 1RM, whilst Legg et al. (2017) reported the peak hip extensor moment to be approximately 1.6 Nm/kg at 75% 1RM. Similarly, Swinton et al. (2011) reported a peak hip extensor moment of approximately 3.1 Nm/kg in the barbell deadlift at 80% 1RM. Taken together, these results suggest that the barbell hip thrust may elicit a larger hip extensor moment than the back squat and deadlift at equivalent external loads. Further investigation is clearly required, testing the exercises within the same sample to confirm this suggestion.

The current study is the first time that the hip joint moment has been empirically quantified throughout a barbell hip thrust repetition using detailed motion capture techniques. It has previously been suggested, based on a theoretical analysis, that the hip extensor moment is consistent throughout a barbell hip thrust (Contreras et al., in press). Based on the evidence presented here, that does not appear to be the case, with a peak in the hip extensor moment shown early in the raising phase. However, whilst the net hip moment was not consistent, it clearly remained extensor-dominant throughout the whole of the hip thrust repetition, with the lowest hip extensor moment during the raising phase being approximately 1.3 Nm/kg (Figure 1), occurring just before the hip reached peak extension. This is in marked contrast to previous research in the barbell back squat, which has shown that the hip extensor moment returns to zero as the hip joint comes towards full extension at the end of a repetition (Southwell et al., 2016). Contreras et al. (in press) conducted a six-week training study, investigating the effects of both the hip thrust and front squat on sprint acceleration performance, amongst other things. That study found potentially beneficial effects of the hip thrust over the front squat for 10 & 20 m sprint times (i.e. times were reduced in the hip thrust training group). The hip extensor-dominant moment shown in this study near full

extension, and the considerable difference to the negligible hip extensor moment at a similar position in the back squat exercise may provide a mechanistic explanation for the differences seen by Contreras et al. (in press), providing support for the force vector hypothesis. Further investigation of the joint kinetics of the two exercises in the same sample is required to support this finding.
Limitations of the current study included the relatively large range of 1RM values for the participants. Additionally, the durations of the whole repetition and the raising and lowering sub-phases were not controlled, leading to variation between participants. Future research in this area should seek to provide a comprehensive description of the joint kinetics across all active joints in the barbell hip thrust, in order to quantify the relative contribution of the hip extensor muscles. Furthermore, a comparison of the joint kinetics of the hip thrust with those of the barbell back squat and deadlift across a range of external loads will be valuable in understanding the differing characteristics of the three exercises. This will provide additional information to the practitioner when targeting training programmes towards specific applications, such as sprinting.

CONCLUSION: To the authors' knowledge this is the first study to empirically quantify hip joint kinetics in the barbell hip thrust. The hip moment was extensor dominant for the duration of the repetition, but was double peaked rather than consistent throughout. The peak hip extensor moment occurred early in the raising phase, but maintained a considerable load throughout the repetition, potentially supporting the force vector hypothesis.

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