

# The ballistic hip thrust test: a potential tool to monitor neuromuscular performance

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**ABSTRACT:** To investigate the reliability of the ballistic hip thrust (BHT) test performed on force plates as a diagnostic tool to monitor posterior chain neuromuscular status and compare its usefulness with the counter movement jump (CMJ). Twenty-two male football players from an elite Under-19 French Ligue 1 football club ( $16.4 \pm 0.6$  years) performed two assessments; Assessment 1: Two testing sessions separated by one week were performed to assess the reliability of the test. Participants performed a 3-set workout of 4 repetitions of the BHTs each session. Intra-day (between set) and inter-day (between testing day) reliability of concentric mean force, takeoff peak force and peak power were assessed. Assessment 2: Participants performed a 1-set workout of 3 repetitions of the CMJ and 4 repetitions of the BHT tests pre- and post-training to compare the usefulness of both tests. Concentric mean force and takeoff peak force showed small-to-moderate standardised typical errors (TE: 0.2–0.7) for inter- and intra-day reliability. Inter-day concentric mean force showed a coefficient of variation (CV) of 7.2%. Intra-day concentric mean force and take-off peak force showed a CV of 4.2% and 5.5%. BHT and CMJ showed similar moderate levels of usefulness. The BHT test showed moderate levels of reliability and usefulness. This test could be a useful addition to a testing battery to monitor posterior chain neuromuscular status.

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## INTRODUCTION

Over the past decade, team-sport practitioners have increased their interest in load monitoring and players responses to that load, to better manage athlete fatigue [1]. To avoid training/playing in a fatigued-state and potentially mitigate injury risk, practitioners often use monitoring of neuromuscular status as a means to manage player's load [2]. The counter movement jump (CMJ) is the most commonly used test in team-sports due to its high reliability (CV = 2.8%) for measuring neuromuscular fatigue when compared to other jump tests such as the squat jump (CV = 3.3%) [3]. However, CMJ is mostly a quadriceps-dominant exercise [4] with the hamstrings only activated during the breaking phase, thus, little-to-no information is available on the posterior chain neuromuscular status when using CMJ.

Hamstrings have the highest injury occurrence rate in soccer [5, 6] with up to 67% of thigh injuries in the English Premier League affecting hamstring muscles [6]. The stress placed on this muscle group during games will unlikely decrease as the trends favour an improvement in high-speed running and sprinting [6]. It is therefore essential for practitioners to monitor the neuromuscular status of this muscle group. As hamstrings injuries and contractions mainly occur

during sprinting at high angular velocity (700–1000°/s) [7], it seems relevant to test posterior chain neuromuscular status in relatively similar kinetics and kinematics conditions. However, posterior-chain testing is mainly done on isolated, single joint (isokinetic testing) or no-to-low velocity, non-sprint specific velocities (nordic hamstring, isometric hamstring bridge) [7, 8, 9]. This provided the rationale to develop a more specific test to monitor posterior chain neuromuscular status based on a high-velocity hip-extension movement.

The hip thrust is an exercise that is designed to improve hip flexor, gluteus maximus and hamstring strength [10]. The addition of a ballistic aspect (jump at the end of the concentric phase) forces the athlete to maximise this phase to generate the highest achievable power required to maximally jump from this position. Despite the potential advantages of the ballistic hip thrust (BHT) exercise to monitor posterior-chain neuromuscular status, there is to our knowledge no available data on its reliability or usefulness. The purpose of this study was to investigate the intra-day and inter-day reliability of force and power outputs during the BHT test and compare its usefulness with CMJ.

## MATERIALS AND METHODS

### Subjects

22 male football players from an elite Under-19 French Ligue 1 football club (Age;  $16.4 \pm 0.6$  years; Height;  $177.5 \pm 4.5$ cm; Body Mass;  $66.3 \pm 6.8$ kg) participated in this study. Athletes performed on average 10 hours of on-field training and 2 hours of resistance training per week. Players were free from injury and illness for at least 4-weeks before testing. Data collection was part of the club's monitoring procedures and conformed to the Declaration of Helsinki [11].

### Procedures

Prior to testing, athletes participated in 2 BHT familiarisation sessions. Two different assessments were performed. Assessment 1 was designed to measure the intra-day (between workout sets 2 and 3) and inter-day (between testing day) reliability of the BHT. Assessment 2 was designed to compare the usefulness of the BHT with that of the CMJ.

**Assessment 1:** Two testing sessions were separated by one week with each player testing on the same day of each week (D+3). Each session consisted of a standardised warm-up (5-min on a WattBike, 10 body-weight squats, 10 body-weight squats with jumps, 10 explosive hip thrusts, 10 submaximal BHTs) followed by a 3-set workout of 4 repetitions of BHTs on force plates (Force Decks—Vald Performance®, Australia). The second and third sets were used for data analysis.

**Assessment 2:** Participants performed a 1-set workout of 3 repetitions of the CMJ and 4 repetitions of the BHT tests pre/post a non-fatiguing training session to compare the usefulness [12] of the tests. The training consisted of a technical warm-up, a possession drill and small-sided-games and was performed 2 days after the game thus, was not designed to elicit fatigue.

### Methodology

#### BHT

The BHT test consisted of three consecutive phases (Figure 1.): 1) Test Starting Position (hip Flexion): A pair of force plates were placed next to each other roughly 1-m from a gym bench. Feet were placed flat on the Force Decks (one foot per plate) and shins were aligned vertically. The body was supported on the gym bench by the upper back (rhomboids, trapezius' and upper Latissimus Dorsi). Arms were crossed over the body with hands on the front of the shoulders. The head was facing forwards with chin tucked into the body throughout the exercise. Glutes were lowered to the floor. Before jumping, the player paused in the start position for 3 -s. 2) Pre-jump explosive phase (hip extension): To start, the player explosively extended the hips upwards with contraction of the glutes and hamstrings. 3) Jump Phase: As maximal hip extension was achieved the force generated was used to raise the feet off the force plates and into the air while the body was supported by the upper back on the gym bench. The player then landed back

onto the force plates into the starting position. The player paused again before repeating for the next repetitions. The chin remained tucked into the chest throughout the exercise.

#### CMJ

From a standing position, the feet were placed on separate force plates with hands placed on hips. Participants were instructed to



**FIG. 1.** BHT Setup: Picture A: Test Starting Position (hip Flexion). Picture B: Pre-jump explosive phase (hip extension). Picture C: Jump Phase.

perform the eccentric and concentric phases of the jump in one continual movement with no pause between them (self-selected eccentric phase depth) [13]. Participants had to land onto the force plates and stabilise in this position before repeating the jump.

The metrics assessed in the study were: Concentric mean force, Takeoff peak force, and Peak Power.

*Statistical Analysis*

Data are presented as means ± 90% confidence Limits (CL). All data were first log-transformed to avoid bias arising from non-uniformity error. Reliability analyses were performed using Hopkins specifically designed spreadsheet [14] to identify the mean ± standard deviation, standardised typical error (TE), coefficient of variation (CV), smallest worthwhile change (SWC), intraclass correlation coefficient (ICC).

The SWC was calculated by multiplying the between groups standard deviation (SD) by 0.2. Standardised TE were used to determine

the magnitude of reliability between tests using Hopkins scale: 0.2 (Small), 0.6 (Moderate), 1.2 (Large), 2.0 (Very Large). The magnitude of the ICC was assessed using the following thresholds: > 0.99, extremely high; 0.99–0.90, very high; 0.90–0.75, high; 0.75–0.50, moderate; 0.50–0.20, low; < 0.20, very low [14].

The usefulness of the tests were assessed by comparing the signal (SWC) to the noise (TE) for each test (BHT and CMJ) and metric [14]. Tests are usually considered as good when the noise (TE) is smaller than the SWC, where the higher signal to noise ratio, the better usefulness [12].

**RESULTS**

The results for the inter- and intra-day reliability of each metric can be found in Table 1. Overall, intra-day and inter-day standardised TEs were small for concentric mean force (CV: 5.5 ± 2.7 and 7.2 ± 3.8% respectively), small-to-moderate for takeoff peak force

**TABLE 1.** Mean ± standard deviation, standardised typical error (TE) ± 90% confidence limits (CL), coefficient of variance (CV) ± 90% CL, smallest worthwhile change (SWC), intraclass correlation coefficient (ICC) and usefulness (SWC/TE) of the 3 -metrics for inter- and intra-day testing (Testing day 1 (D1) and day 2 (D2)) for the Ballistic Hip Thrust (BHT).

Inter Day	Mean ± Standard Deviation							
	D1	D2	D1–D2	TE ± 90% CL	CV ± 90% CL	SWC (%)	ICC	SWC/TE
Conc Mean Force (N)	456 ± 80	477 ± 91	-19 ± -11	0.4 ± 0.2	7.2 ± 3.8	4.16	0.88	0.58
Takeoff Peak Force (N)	761 ± 132	745 ± 140	16 ± -8	0.7 ± 0.4	12.7 ± 6.1	4.68	0.7	0.37
Peak Power (W)	794 ± 339	817 ± 305	-23 ± 34	2.9 ± 1.5	57.8 ± 24.3	12.38	0.11	0.21
Intra Day	Mean ± Standard Deviation							
	Set 2	Set 3	S2–S3	TE ± 90% CL	CV ± 90% CL	SWC (%)	ICC	SWC/TE
Conc Mean Force (N)	484.7 ± 92.5	469.4 ± 90.2	15.3 ± 2.3	0.3 ± 0.2	5.5 ± 2.7	4.24	0.93	0.77
Takeoff Peak Force (N)	748.4 ± 144.7	741.6 ± 135.8	6.8 ± 8.9	0.2 ± 0.1	4.2 ± 2.1	4.44	0.96	1.06
Peak Power (W)	754.1 ± 274.6	880.0 ± 333.3	-125.9 ± -58.7	1.6 ± 0.8	39.8 ± 20.4	9.78	0.3	0.21

**TABLE 2.** Mean ± standard deviation, typical error expressed as a coefficient of variation (TE as a CV) ± 90% confidence limits (CL), smallest worthwhile change (SWC), for Pre- and Post-training data as well as usefulness (SWC/TE) analysis for comparison between the Ballistic hip thrust (BHT) and Counter movement jump (CMJ) tests.

		Pre	Post	TE as a CV ± 90% CL	SWC (%)	SWC / TE
Conc. Mean Force (N)	CMJ	1268 ± 180	1277 ± 170	5.9 ± 2.5	2.8%	0.47
	BHT	478 ± 75	489 ± 65	5.1 ± 2.1	3.1%	0.61
Peak Power (W)	CMJ	3328 ± 876	3647 ± 988	21.8 ± 9.9	5.3%	0.24
	BHT	1384 ± 448	1295 ± 259	18.8 ± 8.4	6.5%	0.35
Take-off Peak Force (N)	CMJ	1639 ± 205	1687 ± 228	3.9 ± 1.6	2.5%	0.64
	BHT	844 ± 116	820 ± 109	5.5 ± 2.3	2.7%	0.49

( $4.2 \pm 2.1$  and  $12.7 \pm 6.1\%$ ) and large-to-very large for peak power ( $39.8 \pm 20.4 - 57.8 \pm 24.3\%$ ). There were high between-days and between-sets ICC for concentric mean force (0.88–0.93) and takeoff peak force (0.70–0.96) and very low ICC for peak power (0.11–0.30).

Usefulness data for the comparison of the CMJ and BHT tests can be found in Table 2.

The CMJ and BHT show similar SWC and SWC/TE for concentric mean force and takeoff peak force.

## DISCUSSION

The purpose of this study was to investigate the reliability of force and power outputs during the BHT and compare its usefulness with the CMJ. The main findings of this study were the following: (1) the BHT showed moderate levels of intra- and inter-day reliability for force-related metrics (mean force; takeoff peak force) (2) the BHT showed similar moderate levels of usefulness in comparison with the CMJ. The BHT test could therefore provide relevant information regarding posterior-chain neuromuscular status and be used in classic players monitoring testing batteries.

The BHT is a posterior-chain neuromuscular status assessment that is easily implementable for weekly-to-bi-weekly monitoring. It presents the advantage to be likely less stressful than Nordics and more specific than CMJs (force orientation [4], hip extension angular velocity) and in turn, better suited for decision making regarding the implementation of high-speed running training.

Concentric mean force and take-off peak force showed moderate standardised TE ( $< 0.7$ ) and high ICC ( $> 0.7$ ) for inter- and intra-day testing. Other studies reported high-to-moderate reliability (ICC: 0.83–0.90, CV: 5.8–8.5%) of the Nordic hamstring exercise and high reliability of the isometric posterior lower limb test muscle test (ICC: 0.95, CV: 4.3%) [15]. Previous research has shown that intra-day CMJ CV for mean force ( $2.2 \pm 1.1\%$ ) and peak force ( $2.8 \pm 1.6\%$ ) [16] was slightly lower than the CV of the BHT examined in the present study (concentric mean force =  $5.5 \pm 2.7\%$ , takeoff peak force =  $4.2 \pm 2.1\%$ ). However, the BHT is a more specific test to measure posterior chain neuromuscular status in the horizontal plane in comparison to the vertical, quadricep-dominated CMJ [4] and no-to-low velocity, non-sprint specific exercises (Nordics, isometric hamstring bridge) [7, 8]. Currently the CMJ is a vastly

popular test and is technically simpler to perform than the BHT which highlights the importance of greater familiarisation to the BHT prior to using it to measure neuromuscular status.

The CMJ, done on force plates, is perceived as the gold standard on-field test to measure neuromuscular status [4]. This study has shown the reliability and usefulness of the BHT to be similar to the CMJ. As TE decreases by a factor of  $\sqrt{n}$ , and the test is easily implementable and not stressful for players, pooling more trials would increase the signal-to-noise-ratio and in turn, the usefulness of this test. The BHT is then suitable to complement a classic testing battery [17].

An important limitation to the study is due to the complexity of the BHT exercise, a prolonged familiarisation period would have been beneficial to improve the participants technique, potentially improving the reliability of the test. In addition to inter/intra-day reliability and usefulness, it would have been beneficial to assess the sensitivity to neuromuscular fatigue of this test with pre- and post-match testing for example (to ensure significant fatigue is endured).

Commonly, hamstring injury occurs in the late swing phase of sprinting, suggesting potential greater risk of distal hamstring injury [18]. As the BHT is a hip dominant test, another limitation may be that the test does not activate this portion of the hamstring as much as knee dominant tests (Nordics).

This study showed that concentric mean force and take-off peak force were moderately reliable (intra- and inter-day reliability) and presented similar moderate level of usefulness compared with the CMJ. This suggests that the BHT could be a useful addition to a testing battery particularly in running based team sports to monitor posterior chain neuromuscular status. Furthermore, the BHT sensitivity needs to be established to identify its benefits to assess both weekly and post-match monitoring of neuromuscular status/fatigue.

## Practical applications

- This test provides reliable information regarding posterior chain neuromuscular status and its ease of implementation could allow for regular monitoring.
- The BHT could be used to complement a player monitoring testing battery.

## Conflict of Interest Declaration

The authors reported no conflict of interest.

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