Barbell Hip-Thrust Exercise: Test-Retest Reliability and Correlation With Isokinetic Performance

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Abstract

Dello Iacono, A, Padulo, J, Bešlija, T, and Halperin, I. Barbell hip-thrust exercise: Test-retest reliability and correlation with isokinetic performance. *J Strength Cond Res* XX(X): 000–000, 2018—The barbell hip-thrust (BHT) exercise is growing in popularity as evident by the large increase in research outputs investigating its utility as a training intervention and a testing tool. The aim of this study was to examine the test-retest reliability of the BHT and its correlation with isokinetic performance. Test-retest reliability was established by correlating the peak force and power outcomes measured with the BHT force-velocity profile test of 20 handball athletes on 2 separate days. The peak force and power measured with the BHT force-velocity profile test of 49 handball athletes were correlated with peak concentric force of the knee flexors and hip extensors measured with an isokinetic device at 2 different velocities ($60–180^\circ \cdot s^{-1}$). The correlation between the isokinetic testing scores and the BHT force-velocity profile tests were moderate to large (Pearson r ranges: 0.45–0.86, all p values <0.001). Test-retest reliability of the BHT force-velocity profile was very high as shown with intraclass correlations of 0.94 and 0.99 for peak force and 0.97 and 0.99 for peak power measures. The BHT force-velocity profile can serve as a tentative substitute in cases that athletes do not have access to an isokinetic device, given the moderate to large correlations between them. Moreover, the BHT force-velocity profile was shown to be very reliable, thus providing coaches and scientists a range of day-to-day performance variability in this exercise.

Key Words assessment, neuromuscular profile, strength and power training, team sports

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Introduction

The barbell hip thrust (BHT) is a bridging exercise used to target the hip extensor and knee flexors' musculature that is growing in popularity among applied practitioners and exercise scientists (4,6,8,15,29). This is supported by the increasing number of studies investigating the BHT biomechanics (3), electromyography responses (6), and the immediate (15) and longitudinal (4,8,29) effects on athletic performance. For example, a heavy (85% of 1 repetition maximum [1RM] (47)) BHT completed 8–12 minutes before a sprinting activity was found to improve sprinting performance of football and handball athletes (15,16). Longitudinally, incorporating the BHT for a 6–8-week period was found to improve sprinting speeds (8) and 1RM in the BHT and squat (29). Although not all studies observed beneficial effects (4,29), in light of the growing popularity of the BHT, its relative ease of use, and potential athletic benefits, it is a worthwhile endeavor to investigate whether the exercise can also serve as a performance test. Similar to other exercises that are used as both training interventions and performance tests, such as the countermovement jumps (42), bench press exercises, and medicine ball throws (44), the BHT has the potential to be used as both. In view of the emerging research interest in the BHT exercise and potential in serving as a performance test, an important first step is to investigate and establish the reliability of the BHT exercise and investigate whether or not it is correlated with other common type of resistance-type exercises.

Reliability, in its simplest sense, refers to the test-retest results in exercise performance (24,25). Establishing the test-retest reliability of the BHT will allow coaches and exercise scientist to calculate the precision of the assessed test and the associated confidence interval limits, which are necessary to further detect real changes in performances, and to develop an appreciation for day-to-day performance variability in training and testing. The degree to which performance in one test, the one under investigation, correlates with performance of a different test, which commonly serves as a gold standard in the particular field of research, can serve as a useful starting point to investigate the new exercise. Measurements of peak concentric torques of the hip extensors and knee flexors with isokinetic machines are routinely included in athletic testing (1,18,46,48). Both hip extensors and knee flexion peak torques are strongly correlated with athletic performance such as sprinting speeds (20), cycling power (39), and jumping performance (23,46). However, isokinetic machines are very expensive and of limited availability. For financial and logistical reasons, many athletes have limited accessibility to this device, if any at all. Therefore, tests that incorporate similar muscle groups and that correlate with performance of the isokinetic device test could serve as an affordable and accessible substitute. Because the hamstrings (knee flexors) and gluteal muscles (hip extensors) are involved in the BHT exercise as primary hip extensors (5), it is of interest to examine how performance of these 2 muscles groups as measured with the isokinetic machines correlates with performance in the BHT. However, when performing the BHT exercise, the knee is ~90° bent and the hamstrings length shortens leading to active insufficiency (40), which can increase the mechanical demands of the gluteal musculature. Accordingly, although BHT performances is expected to be correlated with the isolated isokinetic test outcomes of both hip extensors and knee flexors, a stronger relationship is expected with the hip extensors.

Traditional strength assessments, such as determining athlete's 1RM, can be used to design the effective load for training purposes aiming to enhancing functional performance. However, this procedure could be very time-consuming when large groups of individuals have to be regularly assessed (31). In settings where it is not practical or desirable to assess 1RM, monitoring change in kinetic and kinematic data at submaximal loads may be advantageous. It has been widely suggested that prediction of 1RM may be determined from the submaximal load-velocity relationship (26,33), simply by measuring the velocity of the moving bar used in resisted exercises with linear positioning transducers (LPTs) using increasing loads. As such, 1RMs' estimation and the load-velocity relationships may be determined. In addition to the maximal load that can be lifted once, the bar velocity measured during the lifting phase under different loads allows for the creation and monitoring of force-velocity-power (F-V-P) curves and the derivative mechanical outputs (22). This provides a detailed picture of the athlete's mechanical abilities and potentially reveals weaknesses requiring training implementation. For example, strength and conditioning practitioners could rely on the F-V-P profiling approach for more individualized and accurate evaluation, monitoring, and training procedures (42,43). Although, to the best of our knowledge, bar velocity during the BHT was not yet examined, this seems to be a worthwhile effort. To allow for an accurate measurement of vertical bar velocity, the BHT had to be completed in a Smith machine device that allows the bar to move only in one axis.

Accordingly, the goals of this study were twofold. The first was to establish the test-retest reliability of a BHT test that examines the peak power and peak force in competitive athletes using LPT technology across 2 separate days. The second goal was to establish the correlation between the BHT peak power and force with the peak torques of the hip extensors and knee flexors across 2 different velocities in an isokinetic machine.

Methods

Experimental Approach to the Problem

This investigation examined the test-retest reliability of the BHT F-V-P profile as well as its correlations with performance in the isokinetic device using a correlation design. The correlation between exercises was assessed over a 2-week period during which athletes randomly completed the tests of the isokinetic knee flexors (IKFs) and isokinetic hip extensors (IHEs), and the BHT F-V-P profile test. The tests were separated by 7–10 days of rest. To assess test-retest reliability, 20 athletes performed the BHT F-V-P profile twice, separated by 3–4 days of rest. All tests were performed in the same training facilities, at the same time of the day (16:00–20:00 hours), and in similar ambient conditions of temperature (22.2 ± 0.5° C) and relative humidity (60 ± 3.5%). Moreover, athletes were instructed to avoid intense training 24 hours before each day of testing, prohibited from consuming any known stimulant or depressant substances for 24 hours before testing, and instructed not to eat for 2–3 hours before each assessment session.

Subjects

Fifty high-level male handball players (age: 24.7 ± 2.9 years; body mass: 91.7 ± 7.4 kg; and height: 191.7 ± 9.5 cm; all measurements are mean ± *SD*) volunteered to participate in this study. The players had at least 7 years of handball practice and trained once a day for around 90 minutes, 5 days per week, undergoing technical, tactical, strength, and speed training. The athletes also had 2 years of experience with both isokinetic and BHT testing procedures. Written informed consent was obtained from the athletes after they received an oral explanation of the purpose, benefits, and potential risks of the study. All procedures were conducted in accordance with the Helsinki Declaration and approved by the Ethics Committee of the Academic College at Wingate, Israel.

Procedures

Isokinetic Testing. Bilateral isokinetic testing assessed maximal knee flexors' and hip extensors' performance using an isokinetic dynamometer (Biodex "3" generation System, New York, NY, USA). Isokinetic tests were assessed after a standardized 10-minute warm-up on a cycloergometer and an adequate familiarization with the dynamometer in the form of further warm-up by performing several repetitions at various angular speeds (60–180°·s^{-1}). The order between the IKF and IHE tests was randomized with at least a 60-second rest period between them. For both tests, the protocol included 5 maximal repetitions in concentric modality at both slow

($60° \cdot s^{-1}$) and fast speeds ($180° \cdot s^{-1}$) with 120 seconds of passive recovery in-between (50). Previous studies have suggested the choice of these speeds to ensure reliable measures of peak torques (14,27,37). The athletes did not receive visual feedback during the test, whereas strong verbal encouragement was provided to ensure maximal and consistent efforts (21). Analysis of the results included the absolute peak torques in Newton meters normalized to body mass ($N \cdot m \cdot kg^{-1}$) that occurred during the second or third repetition of the tests. Testing of the knee flexion followed the protocol of Dello Iacono et al. (14), with the athlete tested in a sitting position with the body stabilized by straps around the thigh, waist, and chest to avoid compensations (12). The range of knee motion was fixed at 95° of flexion from the active maximum extension. The gravitational factor of the dynamometer's lever arm and lower segment ensemble was calculated by the dynamometer, and automatically compensated during measurements. As for the hip extension test, we adopted the protocol proposed by Harrison et al. (23) (Figure 1).

While standing, the athletes were asked to lean over a wedge placed on the chair of the dynamometer adjusted in a flat position. The chair was raised to the level of the anterior superior iliac spine so that the mechanical axis of the dynamometer resulted aligned to the anatomical axis of the hip joint identified in the greater trochanter as established by the International Society of Biomechanics (49). For the testing execution, 2 straps were pulled around the chair and the lumbar spine, and the tested leg was strapped tightly above the patella.

Barbell Hip-Thrust F-V-P Profile. In a separate session, the athletes were assessed for BHT F-V-P. In accordance with Contreras et al. (6), and as recently described by Dello Iacono et al. (15), the BHT exercise was performed by having the participants' upper back rest on a bench of approximately 40-cm height, with the feet slightly wider than the shoulder width and the toes pointed forward (Figure 2). The barbell was padded with a thick bar pad and placed over the subjects' hips. The athletes first performed a 10-minute general warm-up consisting of various dynamic mobilization exercises for the lower-body musculature. Then, 3 specific warm-up sets with progressively heavier barbell loads were performed. The BHT F-V-P profile was assessed through the BHT exercise performed on a Smith machine (Technogym Equipment, Cesena, Italy) using progressive loads. Before each set, a test administrator instructed the participant to maintain constant downward pressure on the barbell throughout the execution, to prevent the bar from moving independently of the body (9). The athletes were instructed to execute 3 propulsive upward repetitions at maximal velocity with each load, starting at 50% of their body mass. A load of 20% of body mass was gradually added in each set until a decrease in BHT peak power was recorded (34). This was observed after 5–6 sets on average, resulting in an overall testing time of about 15 minutes. A 3-minute interval was provided between sets with progressive loads.

To obtain the BHT mechanical measures, an LPT (T-Force, Dynamic Measurement System; Ergotech Consulting S.L., Murcia, Spain) was attached to the bar on the Smith machine, and the double-differentiation method was followed (22,34). Specifically, the LPT allowed to measure the vertical displacement of the barbell. Then, velocity was calculated from displacement and time (velocity = displacement [s]/time [t]), and acceleration was calculated from velocity and time (acceleration = velocity [v]/time [t]). Once the acceleration measures were obtained, the mechanical variables of interest were computed. Force was calculated by multiplying the mass of the lifted loads by the acceleration (force = mass × acceleration), and the power by

Figure 1. Start and end position of the isokinetic hip extension exercise.

Figure 2. Start and end position of the BHT exercise. BHT = barbell hip thrust.

multiplying force-time by velocity-time values (power = force × velocity) (9,16,32). The LPT data were collected for every trial at 1,000 Hz and then filtered with a fourth-order low-pass Butterworth filter with a cutoff frequency of 50 Hz (2).

For the calculation of the mechanical measures, we did not include the body mass as additional resistance besides the Smith machine barbell. It is generally accepted that for lower-body movements, where the whole-body mass must be moved in addition to any additional external load, the resulting velocity, force, and power measures are determined by the athlete's ability to accelerate the total system mass (i.e., the external load + body mass) (10,17). Conversely, for upper-body exercises and others performed with the body partially unloaded because of a no-antigravitational position (e.g., machine exercises such as the leg press and hip-thrust), the inclusion of body mass is not warranted, and the mechanical work applied to the barbell or machine is the variable of interest. The lack of clear guidelines, in detailing the exact percentage of the body mass to be added for an accurate calculation of the mechanical measures, may have led to discrepancies in reported outputs, causing results' misinterpretations and likely limiting the chances to accurately replicate the testing procedures used in our study (22).

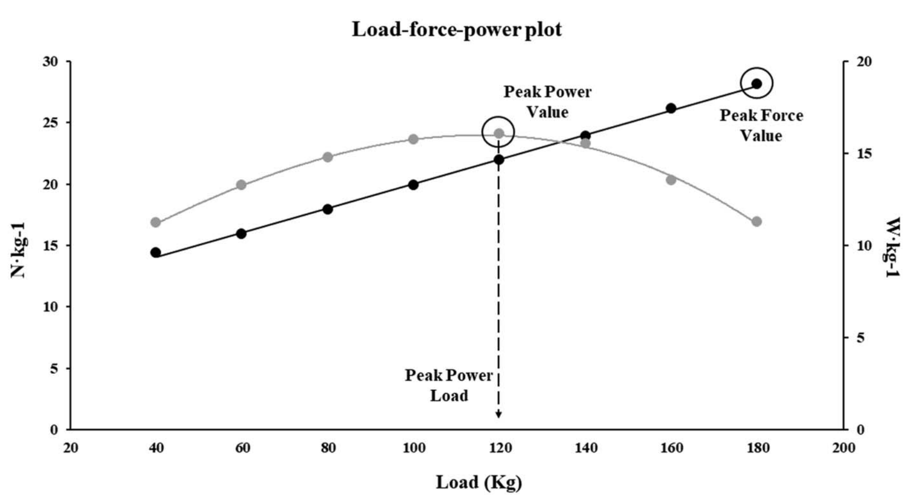

Figure 3. Plot of the load-force-power outcomes of the BHT exercise. The plot refers to a subject with a body mass of 89 kg who performed 8 consecutive trials with incremental loads. The plot highlights: Peak force value equal to 28.1 N·kg^{-1} (black circle), peak power value equal to 2,816 W·kg^{-1} (black circle), and the corresponding optimum load of 120 kg (dashed arrow). BHT = barbell hip thrust.

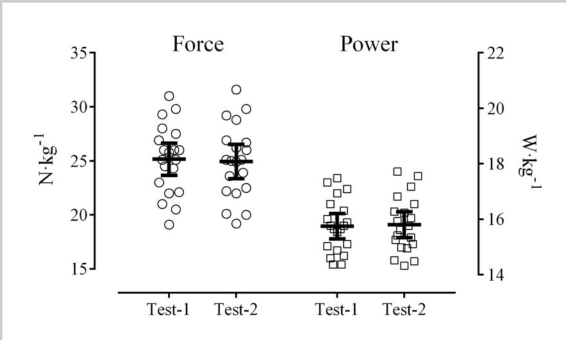

Figure 4. Individual data points of peak force and power as measured with the BHT F-V-P across the 2 testing days. Error bars represent 95% CI and the midline represents the mean. BHT = barbell hip thrust.

Such uncertainty could be questioned in a future study where a full biomechanical analysis could be used for exactly determining the amount of body mass lifted during the BHT performed in a standardized position and precisely factoring its effects on the mechanical responses.

In our study, we considered the BHT peak propulsive force (PFpeak) and power (PPpeak) for data analysis purposes instead of mean values (Figure 3). This choice may have likely limited the influence of individual anthropometry, barbell kinematics (e.g., vertical displacement), and the position of the barbell relative to the trunk, hips, and knee joints (7). To avoid misinterpretation of the mechanical outputs and taking into consideration the influence of body mass on its calculation, we normalized the BHT PFpeak and PPpeak values by dividing the absolute force and power values by the athletes' body mass (BHT relative force = $N \cdot kg^{-1}$; and BHT relative power = $W \cdot kg^{-1}$). After this assessment session, the athletes reported to the training facility on an additional occasion, separated by 3–4 days of rest, to assess the test-retest reliability of the BHT F-V-P test.

Statistical Analyses

All data are presented as mean ± *SD* and confidence interval (95% CI). The Shapiro-Wilk test was used to ensure normal distribution of the results. To reduce the overall numbers of comparisons, the average peak torques of both legs within the same muscle group, tested under the same velocity in the isokinetic device, were averaged to a single value. For example, the left and right peak concentric torques of the knee flexors tested at $180° \cdot s^{-1}$ were averaged for the statistical analysis. The isokinetic intratest outputs' reliability and interday BHT F-V-P profile test-retest reliability were examined using the coefficient of variation (CV%) and intraclass correlation coefficient (ICC) with 95% CI, respectively. Coefficient of variation values ≤10% were considered acceptable (2). Based on the 95% CI of the ICC estimate, values less than 0.5, between 0.5 and 0.75, between 0.75 and 0.9, and greater than 0.90 were indicative of poor, moderate, good, and excellent agreements, respectively. The sensitivity of the mechanical outputs obtained from the BHT F-V-P profiles was assessed by comparing the smallest worthwhile change (SWC) and *SEM* with 95% CI. As a result, variables were considered sensitive if the *SEM* was less than or equal to SWC (38). Linear relationships among the isokinetic test scores and the BHT mechanical outcomes were assessed using Pearson's correlation coefficients. To avoid possible confounders, this procedure was followed only in cases in which the left to right torque ratio was >10% as measured with the isokinetic tests. The 10% cutoff was decided on in view of literature suggesting that musculoskeletal abnormalities occur at the 10% strength asymmetry mark (13) as well as a greater risk of suffering from injuries (45). The qualitative magnitude of associations was reported according to

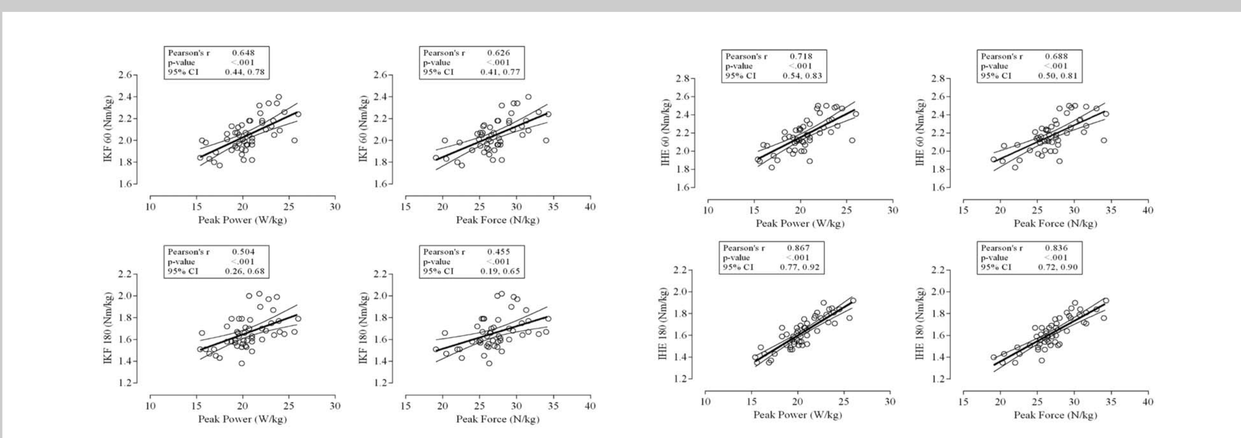

Figure 5. Illustrates the correlation between the isokinetic testing scores and the BHT F-V-P profile mechanical outcomes. Individual data points are presented as well as linear regression line with 95% CI around it for visual illustration purposes rather than inferential ones. Each graph includes the Pearson's *r*, *p* value, and 95% CI. BHT = barbell hip thrust; IKF = isokinetic knee flexor; IHE = isokinetic hip extensor.

Hopkins et al. (25), with thresholds of 0.1, 0.3, 0.5, 0.7, and 0.9 for small, moderate, large, very large, and extremely large correlations, respectively. The level for statistical significance was set at $p < 0.05$. Statistical analysis was performed using Jamovi statistics software (Version 0.8).

Results

Forty-nine athletes completed the study's requirements. One athlete was excluded from the analysis because of a between-leg difference >10% in the isokinetic testing scores. Excellent agreements between the test and retest trials of the BHT F-V-P profile were found with the ICCs ranging between 0.94–0.99, and 0.97–0.99 for the PFpeak and PPpeak measures, respectively (Figure 4). The CVs% of the isokinetic tests, the PFpeak, and PPpeak measures ranged between 3.76 and 4.45%, 1.22–1.99%, and 0.81–1.64%, respectively, indicating high intratest reliability. *SEM* 95% CI of the PFpeak and PPpeak scores, expressed as percentage changes (%), ranged between 0.33 and 0.42 $N \cdot kg^{-1}$ and 0.29–0.38 $W \cdot kg^{-1}$, respectively. Smallest worthwhile change of the PFpeak and PPpeak scores were 0.5 $N \cdot kg^{-1}$ and 0.65 $W \cdot kg^{-1}$, respectively, indicating a good confidence about the sensitivity of these measures. The correlations between the isokinetic testing scores and the BHT F-V-P profile mechanical outcomes computed by Pearson's correlation coefficient showed moderate to large correlations as shown in Figure 5.

Discussion

The goals of this study were to establish the test-rest reliability of a newly developed performance test that quantifies the mechanical outputs of the BHT exercise and to examine whether performance in the BHT exercise correlates with performance measured with the isokinetic device among trained athletes. Very high test-retest correlations were detected between days in both the BHT PFpeak and PPpeak scores (Figure 4). Furthermore, performance in the BHT showed moderate to strong correlations with peak concentric torques of IKF and IHE, respectively (Figure 5). As such, PFpeak and PPpeak scores measured with the BHT can be considered as reliable and associated with performance in commonly used exercise tests.

In view of the growing research and applied interest in the BHT exercise, examining the exercise utility as a performance test by establishing the reliability and correlations with commonly implemented exercises were 2 important initial attainments. Having an appreciation of day-to-day performance variability is of value. It allows scientist and coaches to assess performance outcomes in a more sensitive and accurate manner. The test-retest results in this study are encouraging (Figure 4), also considering that the SWC scores of both PFpeak and PPpeak were consistently greater than the noise or uncertainty as measured by the *SEM.* This reasonably suggests that SWCs of the mechanical measures in BHT performance can be easily detected and potentially reflect a real change rather than random fluctuations. This result may partly be explained by the relative ease of completing the exercise and the reduced degrees of horizontal movement of the barbell. In addition, the athletes' experience with the BHT exercise and testing procedures may have contributed in reducing the error in the test.

The moderate to strong correlations between the BHT and performance in the isokinetic device is also a finding with practical value. In situations where athletes do not have access to an isokinetic device for testing purposes, the BHT F-V-P could serve as a tentative substitute. Moderate to large relationships (*r* range: 0.68–0.86) were found between hip extensors' torques, as measured with the isokinetic device, and BHT performances. This outcome is similar to other studies examining the relationships between IHE torques and jump and sprint performances in professional male handball, soccer, and rugby players (19,20,23,41). Only moderate correlations were observed (*r* range: 0.45–0.64) between IKFs' torques and BHT performance. This finding is not surprising when considering that the knee flexors are at a state of active insufficiency reducing their ability to produce forces (5). Because the knee flexors are at a shortened length and primarily contract through a shorter range (28) as prime movers for hip extension and stabilizers of the knee joint during the BHT, other performance tests that involve concentric and eccentric contractions are better suited to test the knee flexors than the BHT. The force production insufficiency in the knee flexor muscles can assist explaining the weaker correlations between the isokinetic tests and BHT mechanical measures compared with the hip muscles.

The BHT F-V-P is a relatively time-efficient test that can easily assess important physical qualities with only a few test attempts. In this study, the athletes completed the required trials for creating their BHT neuromuscular profiles and the associated F-V-P relationships in less than 15 minutes. Although this period is longer compared with other performance tests that may take a few minutes to complete, such as the isometric midthigh pull and isometric squats, the BHT F-V-P provides a large amount of applied and actionable information concerning the hip extensors' muscle groups. It is thus our view that the BHT F-V-P is a worthwhile performance test, especially among athletes who require powerful hip extensors, such as sprinters. The BHT F-V-P can be used to determine the optimal individual load that can be used for BHT-based training protocols aiming to enhance performance. The importance of using individualized monitoring and training methods according to an individual athlete's neuromuscular profile has received great interest and support in the recent years (32,36). The simple diagnostic procedures and subsequent individualized training interventions make this approach preferable to the common approaches that use percentages of 1RM (36). By considering the F-V-P and targeting optimum training zones (36), it is possible to limit nonfunctional overloading and to pursue optimal training outcomes (32,35,36). Moreover, besides the practical uses for long-term monitoring and training processes, the F-V-P approach can be implemented in injury prevention and rehabilitation processes (35). Immediate or even real-time diagnostic and training information can enhance decision-making processes regarding the training and rehabilitation strategies (35).

There are a number of limitations concerning the generalizability and practicality of this study worthy of discussion. First, our procedures used an "endpoint" approach, where we examined the mechanics of an "endpoint," in this case the Smith machine barbell, to profile the exercise performance without factoring the amount of body mass lifted for the mechanics calculation. Although we recognize that the total system mass model seems to be more appropriate to describe mechanical responses of the BHT exercise, this point was not the central question of the experiment. We recognize the importance of this evidence, but the reason for not including the athletes' body mass in barbell assessments performed with LPT is related to training purposes. By measuring the bar mechanical outputs without including the individual's body mass when working with LPT allows strength coaches and sport scientists to immediately and adequately determine ranges of loads able to target certain mechanical goals (30). Nevertheless, a full biomechanical analysis, performed in a laboratory setting, implementing both measuring kinetic responses associated with the hip-thrust exercise and investigating the multijoint kinematical strategy, may provide complete insights about the mechanical profile of the hip-thrust exercise.

In this regard, we suggest using a beam with internal hinge model for the mechanical analysis of the BHT exercise. The thigh and trunk anatomical segments can be considered as the 2 portions of the beam, and their masses should be considered for determining the total system mass lifted (the external load + thigh mass + trunk mass), and for accurately computing the mechanical calculations. Although the thigh mass could be fully added to the calculation, the lifted trunk mass is only partial and highly variable on the position of the subjects and how he/she lies on the edge of the bench. In this context, it would be necessary to firstly determine the center of trunk mass position by using a time-consuming motion analysis procedure, and then calculate its relative mass to be added to the mechanical calculation. This long procedure is unlikely practical and impossible to be used in field-based scenarios.

Secondly, the results can mainly be generalized to (a) male athletes, (b) who are experienced with the BHT exercise (~2 years), and (c) as completed with a Smith machine. The large correlations observed in this study are likely to be a product of the interaction between the abovementioned facts, and as such, should be interpreted with a degree of caution. Performing the BHT on a Smith machine allows for a more accurate measurement of F-V-P because of the elimination of horizontal movement of the barbell. This could also partly assist explaining the observed high test-retest reliability in this study, which would have likely been lower if a free-weight barbell was used instead. However, from a practical and logistical perspective, Smith machines are relatively expensive and space consuming turning them into a less feasible option for team sports with limited budgets and space. The linear encoder, while is not space consuming, may be a financial hurdle for some, although with emerging technologies' prices are expected to become more and more affordable. In light of these limitations, future research concerning the BHT would benefit from testing other populations (females, and less trained and experienced athletes), comparing the reliability results of the Smith machine with free-weight barbells, and quantifying the relationship of the BHT with other outcome measures, such as jumping and agility tests.

Coaches and exercise scientists now have access to a working range of test-retest scores of BHT F-V-P exercise of trained athletes. These values provide initial guidelines allowing coaches to better understand what variability can be considered a real change in comparison with random performance fluctuations. The moderate to strong correlations between the BHT F-V-P and the isokinetic performance point to the possibility that the BHT F-V-P can be used as a tentative substitute to isokinetic machine as a training intervention and/or as an episodic test, which mainly targets the hip extensors. Thus, the BHT F-V-P can be used as a performance test with emphasis on the hip extensors alongside other useful tests that have been regularly implemented in the S&C profession such as the isometric midthigh pull and countermovement jump. By using a number of different tests emphasizing different muscle groups and movement patterns, a clearer and more detailed picture of the athletes' need will emerge allowing for better and more specific designs of training interventions.

Practical Applications

The BHT F-V-P profile could be implemented by practitioners as a reliable, simple, and accessible method to assess, train, and monitor athletes, especially those who require strong hip extensors such as sprinters. This approach could help creating the neuromuscular profiles and the force-velocity-power relationships of individual athletes, thus detecting eventual strength and weaknesses. This information can then be used to design effective training interventions. The findings of this study are in accordance with the calls (11) for sport science to investigate valuable, simpler, and timesaving methods to bridge the gap between the science and field practice.

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