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Original Research

Reliability of Hand-Held Dynamometer in Measuring Gluteal Muscle Rate of Torque Development and Peak Torque: Push and Pull Configurations

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Background

Belt-stabilized handheld dynamometers (HHD) assess hip rate of torque development (RTD) and strength in research and clinical practice. However, the reliability of HHD with push and pull configurations to measure hip muscles RTD and peak torque is unclear.

Purpose/Hypothesis

To determine the intra- and inter-reliability of HHD utilizing push and pull configurations to measure hip abduction and extension early (0-100ms) and late (100-200ms) phases RTD and peak torque. We hypothesized HHD with both configurations would be reliable for measuring hip extension and abduction RTD and peak torque.

Study Design

Cross-sectional study.

Methods

Twenty healthy adults (10 females) performed three consecutive maximal isometric contraction trials of hip abduction and extension, utilizing an HHD with push and pull configurations by two raters. Each rater's average early and late phases RTD and peak torque of hip abduction and extension were utilized for analysis.

Results

Intra-rater reliability of hip abduction with push and pull configurations ranged moderate-to-good for early and late RTD phases (push: $ICC_{2,1}$=0.61-0.88; pull: $ICC_{2,1}$=0.59-0.75). Peak hip abduction torque showed good reliability in both configurations ($ICC_{2,1} \geq 0.79$). Hip extension ranged moderate-to-good reliability for early and late RTD phases in push configuration ($ICC_{2,1}$=0.72-0.87), with good-to-excellent reliability in pull ($ICC_{2,1}$=0.77-0.91). Peak hip extension torque showed moderate-to-excellent reliability for push configuration ($ICC_{2,1}$=0.73-0.92) and excellent reliability for pull ($ICC_{2,1} \geq 0.91$). Inter-rater reliability for hip abduction showed moderate in push ($ICC_{3,k} \geq 0.72$) and good in pull ($ICC_{3,k} \geq 0.78$) configurations for both RTD phases, while hip extension showed good reliability in push ($ICC_{3,k} \geq 0.82$) and excellent reliability in pull ($ICC_{3,k} \geq 0.95$) configurations. Peak torque showed good

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reliability for hip abduction (ICC3,k⩾0.83) and excellent reliability for extension (ICC3,k⩾0.94) in both configurations.

Conclusions

HHD with push and pull configurations is a reliable and cost-effective method for assessing RTD and strength of hip abductors and extensors in healthy adults.

Level of Evidence

Level 3.

INTRODUCTION

Functional activities require efficient neuromuscular contributions to support the body.[1] During functional tasks, including sports-specific activities, hip musculature significantly contributes to pelvic control and stabilization to maintain the alignment of the pelvis.[2-4] Weakness of the hip abductors and extensors can lead to excessive hip adduction and internal rotation, which disrupts the efficiency of movement patterns and increases the risk of lower extremity injury.[4-9] Therefore, strength of the hip abductors and extensors is fundamental to functional movement quality and minimizing the risk of injuries.[10,11]

Multiple studies have suggested that isometric maximal muscle strength may not fully represent the neuromuscular requirements of daily activities or athletic tasks.[12-14] Maximum muscle force is usually attained during a maximal voluntary contraction (MVC) of sufficient duration, but many sports and daily activities require rapid development of force that occurs in a submaximal strength paradigm.[15-17] The ability to quickly produce force also has important injury implications, as many lower extremity injuries occur during the early phase of landing after initial foot contact with the ground.[12,18] For instance, non-contact anterior cruciate ligament injuries occur within 100 milliseconds (ms) after initial foot contact.[16,18] Hence, as an alternative measure to MVC strength, rate of torque development (RTD) defined as the change in torque relative to time during MVC, has increasingly been utilized to assess the efficiency of muscle force production in athletes and patients with musculoskeletal injuries.[12] The RTD obtained in the early phase (<100 ms) provides an overview of the central mechanisms of the muscle's physiological function (motor unit recruitment and firing rate), while RTD in the late time interval (>200 ms) is related to peripheral mechanisms such as muscle size, architecture properties, muscle fiber type proportion, and muscle-tendon stiffness.[15,19]

Previous researchers have utilized laboratory-based isokinetic dynamometers (IKD), a gold standard method for evaluating muscle function, to examine isometric RTD characteristics.[20,21] However, the IKD lacks clinical applicability due to cost and space requirements. Portable handheld dynamometers (HHD) have been shown to be valid and reliable when assessing isometric RTD and peak torque of the quadriceps.[16,20,22] Previous studies have also demonstrated moderate to excellent intra-rater reliability of HHD in assessing peak torque of hip abductor and extensor muscle groups.[23,24] Reliability measurements may be influenced by the HHD configuration (push versus pull) due to patient discomfort or stability of the HHD during testing. The pull configuration allows the patient to pull the HHD into a stabilized surface (i.e., treatment table), while the push configuration consists of the patient having to push directly against the HHD.[25]

Currently, HHD with push and pull configurations has been shown to be valid for evaluating hip RTD and peak torque.[26] However, the reliability of HHD with these configurations is unclear. Therefore, the purpose of this study was to determine the intra- and inter-rater reliability of HHD utilizing the push and pull configurations to measure hip extension and abduction RTD (early and late phases) and peak torque. A secondary purpose was to quantify the participant's level of discomfort during the testing using the push and pull configurations. It was hypothesized that the HHD with push and pull configurations would be reliable for measuring hip extension and abduction RTD and peak torque. Additionally, it was hypothesized that there would be no difference in discomfort during the testing configurations.

METHODS

PARTICIPANTS

The sample size was calculated using an anticipated ICC of 0.90 and a minimum ICC of 0.60.[27] With an alpha level of 0.05 and a beta of 0.20, a minimum sample size of 14 participants was determined for this study. Inclusion criteria were healthy adult participants who were: 1) within the ages of 18-35 years old, and 2) physically active (moderate-to-vigorous physical exercise > 30 minutes 3 times per week). Moderate-moderate (e.g., brisk walking) or vigorous (e.g., running) physical activity were defined based on the guidelines of the American College of Sports Medicine and the American Heart Association.[28] Exclusion criteria included: 1) previous history of musculoskeletal pain or injury of the lower extremity or low back within the prior six months, 2) previous history of low back or lower extremity surgery, and 3) any neurological or cognitive impairment. The Institutional Review Board at the University of Connecticut approved the study (H23-0761). This study followed the recommendations from the Guidelines for Reporting Reliability and Agreement Studies.[29]

PROCEDURES

Before testing, all participants provided signed informed consent and completed a standardized health history form and a physical activity level questionnaire (Tegner Activity Scale). A calibrated HHD (microFET2, Hoggan Scientific, LLC; West Jordan, UT) was utilized with gait belts to measure hip extension and abduction RTD measures and peak torque in both configurations. The HHD wirelessly transmits force signal data with a fixed sampling frequency of 100 Hz to a laptop computer via a USB receiver supplied by the manufacturer. Measures were obtained from the only dominant limb, defined as a leg when kicking a ball by two investigators with pull and push configurations. Thigh length was determined and recorded by measuring the distance between the greater trochanter and an identified point positioned 5 cm above the midpoint of the knee joint line.[3,30] Testing orders for hip extension and abduction, investigators, and configuration methods were randomized by a coin toss.

Prior to assessing hip abduction measures, participants were placed in a side-lying position with the test limb placed in approximately 20° of hip abduction and legs in neutral alignment with the trunk.[31] A gait belt was placed proximal to the iliac crest and secured to the table to stabilize the trunk. For the push configuration, the HHD was placed 5 cm proximal to the lateral knee joint line using the flat attachment.[31] Another gait belt attached to the table was utilized to stabilize the HHD during testing (Figure 1A). For the pull configuration, the HHD was positioned against a wood plank that stabilized on the opposite surface of the table in a straight line to the lateral knee joint line using a flat attachment. The gait belt was looped around the participant's leg, and the HHD was secured against the opposite surface of the wood plank (Figure 1B). When the participant performed hip abduction, the HHD was compressed against the opposite surface of the wood plank, and force was measured. Participants were instructed to exert maximal strength as quickly and hard as possible in the direction of hip abduction during the entire test, maintaining the knee in extension.

Before measuring hip extension RTDs and peak torque, participants were asked to lean forward from the prone position on a treatment table and to put the non-test leg in a comfortable and stable position on a step box with a cushion.[30,32,33] During the test, the participants' trunks were supported by the table, and their pelvis was stabilized by a gait belt to minimize compensation movements. Test legs were positioned at 90° of hip flexion and knee flexion.[32,33] For the push configuration, the HHD was placed approximately 5 cm above the midpoint of the knee joint line at the posterior thigh using a flat attachment, and another gait belt attached to the table leg was used to stabilize the HHD during testing, which demonstrates validity compared to IKD (Figure 1C).[3,26] For the pull configuration, the HHD was positioned against the opposite surface of the table leg using the flat attachment, and the gait belt was looped to secure the HHD against the opposite surface of the table leg (Figure 1D). Force was assessed when the participant performed hip extension by compressing the HHD against the opposite surface of the table leg. Participants were instructed to exert maximal strength as quickly and hard as possible in the direction of hip extension while keeping the knee flexion at 90° during the entire test.

For both tasks, participants performed three trials of maximal isometric contraction in each push and pull configuration following a warm-up consisting of up to three trials of isometric contractions. Two raters who had more than four years (Rater 1) and less than one year (Rater 2) of experience assessing RTD and strength conducted the assessments. Each rater set the participant up for testing, including participant positioning, setting the stabilization belts, placing and stabilizing the HHD, and providing verbal encouragement. Each muscle contraction was performed for five seconds, and participants were provided one-minute rest between the trials and five minutes rest between push versus pull tests. Verbal encouragement was accompanied to ensure maximum effort during each contraction. Following each test, participants were asked to rate their level of discomfort during testing by marking a transverse line on a 10 cm VAS labeled 'No discomfort' and 'Worst discomfort imaginable' on each side.

DATA ANALYSIS

Isometric force (N) data were collected during each trial. To calculate torque (N•m), the moment arm, which is the thigh length, was multiplied by the amount of force (N). RTD (N·m/s) was calculated by identifying the slope of the torque-time curve (Δtorque/Δtime) at the 0-100 and 100-200 millisecond periods of time interval utilizing a MATLAB code. Peak torques from each trial for each HHD configuration were also extracted. All RTD and peak torque measures were normalized to the participant's body mass (Nm/s/kg or Nm/kg). The level of discomfort was quantified using the visual analog scale (VAS). The independent variables were push and pull testing configurations. The average peak torque and RTD at 0-100 and 100-200 millisecond periods of time interval from three trials of hip extension and abduction and reported discomfort during the tasks measured by two raters were used as dependent variables for analysis.

STATISTICAL ANALYSIS

Statistical analyses were performed using the SPSS software (version 29.0, SPSS, INC., Chicago, IL, USA). The normality of data was examined using Shapiro-Wilk tests. The difference in discomfort (VAS) between configurations was determined utilizing Wilcoxon signed-rank tests. Within-session intra-rater reliability was evaluated using the intraclass correlation coefficient ($ICC_{2,1}$) with a two-way random-effects model and absolute agreement type and associated confidence intervals (95% CI).[34,35] To identify differences in measurement values between trials, a one-way repeated analysis of variance (ANOVA) was utilized. When data were not normally distributed, Friedman tests were conducted for nonparametric analyses. To provide a better interpretation of reliability estimates, the standard error of measurement (SEM) ($SEM = SD \times \sqrt{1\text{-}ICC}$) and minimal detectable change (MDC) ($MDC = SEM \times 1.96 \times \sqrt{2}$) were also calculated.[34] Inter-rater reliability was determined using

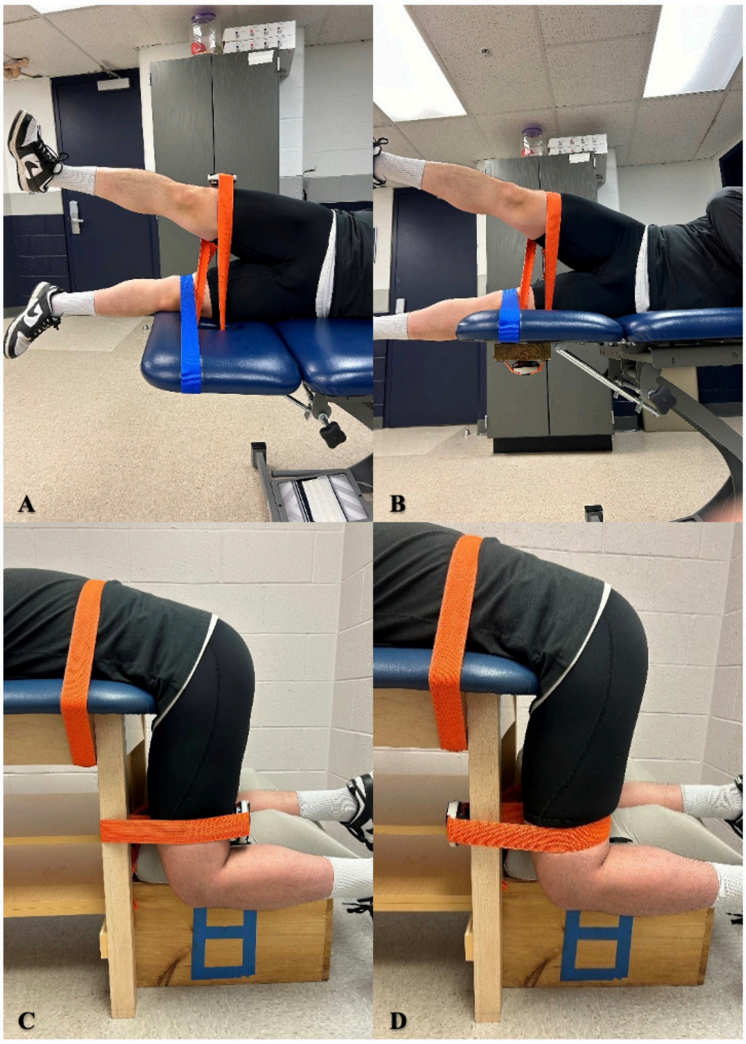

Figure 1. Testing positions with push and pull configurations.

A) Hip abduction push configuration B) Hip abduction pull configuration C) Hip extension push configuration D) Hip extension pull configuration.

the intraclass correlation coefficient ($ICC_{3,k}$) with a two-way mixed-effects model and absolute agreement type and associated confidence intervals (95% CI).[34,35] The pooled standard deviation was utilized to calculate SEM.[36] Reliability was classified as poor (<0.50), moderate (0.50-0.749), good (0.75-0.90), and excellent (>0.90)[35] and statistical significance was set a priori at $p < 0.05$.

RESULTS

Twenty healthy, physically active adults were included in this cross-sectional study (Table 1).

Table 1. Participant characteristics.

	Participants (n=20)
Sex (n)	M = 10, F = 10
Age (years)	28.1 ± 2.6
Height (cm)	169.2 ± 8.0
Weight (kg)	65.9 ± 12.5
Moment Arm (cm)	28.7 ± 4.8
TAS (level)	4.8 ± 0.8
Dominant Leg	Right = 19, Left = 1

TAS: Tegner activity scale. Values of age, height, weight, moment arm, and TAS reported as mean (SD).

INTRA-RATER RELIABILITY

There were no significant differences between trials of RTDs and peak torque measures in hip abduction and extension with both configurations (p⩾0.07) for both raters. Intra-rater reliability results for hip abduction and extension RTD and peak torque measurements by each rater are shown along with the SEM and MDC calculations in Table 2 and Table 3. Intra-rater reliability of hip abduction with the push configuration indicated moderate to good for both early and late phases RTD ($ICC_{2,1}$=0.61-0.88). For the pull configuration, intra-rater reliability was moderate for early phase RTD ($ICC_{2,1}$⩾0.59) and moderate to good for late phase RTD ($ICC_{2,1}$=0.63-0.75). Intra-rater reliability results for the peak torque of hip abduction indicated good for both push and pull configurations ($ICC_{2,1}$=0.79–0.90). In-

Table 2. Intra-reliability for hip abduction RTD and peak torque measures with push and pull configurations.

Intra-reliability		Trial 1 (Mean±SD)	Trial 2 (Mean±SD)	Trial 3 (Mean±SD)	ICC (2,1) (95% CI)	*P* value	SEM	MDC
Abduction	***Push***							
RTD 0-100 ms (Nm/s/kg)	Rater 1	5.35±2.04	5.10±1.80	4.94±1.71	0.87 (0.75-0.94)	0.16	0.20	0.55
	Rater 2	3.66±1.46	3.99±2.13	4.30±2.52	0.65 (0.42-0.83)	0.09	0.60	1.66
RTD 100-200 ms (Nm/s/kg)	Rater 1	4.72±2.28	4.36±2.23	4.44±1.90	0.88 (0.78-0.95)	0.26	0.19	0.52
	Rater 2	2.85±1.55	3.37±2.14	3.48±2.16	0.61 (0.36-0.80)	0.55	0.72	2.00
Peak Torque (Nm/kg)	Rater 1	1.05±0.27	1.01±0.28	0.99±0.24	0.87 (0.75-0.94)	0.13	0.03	0.08
	Rater 2	0.91±0.22	0.94±0.31	0.94±0.33	0.86 (0.74-0.94)	0.59	0.03	0.09
Abduction	***Pull***							
RTD 0-100 ms (Nm/s/kg)	Rater 1	3.38±1.17	3.33±0.98	3.44±1.10	0.74 (0.54-0.88)	0.81	0.24	0.67
	Rater 2	3.55±1.18	3.23±1.24	3.07±1.12	0.59 (0.34-0.79)	0.14	0.41	1.14
RTD 100-200 ms (Nm/s/kg)	Rater 1	3.18±1.21	3.22±1.7	3.25±1.12	0.75 (0.56-0.88)	0.93	0.24	0.68
	Rater 2	3.07±1.31	2.89±1.54	2.59±1.40	0.63 (0.39-0.81)	0.21	0.46	1.28
Peak Torque (Nm/kg)	Rater 1	0.81±0.23	0.80±0.22	0.80±0.25	0.90 (0.80-0.95)	0.80	0.02	0.06
	Rater 2	0.84±0.21	0.83±0.24	0.82±0.22	0.79 (0.61-0.90)	0.84	0.04	0.12

SD, standard deviation; ICC, intraclass correlation coefficient; CI, confidence interval; SEM, standard error of measurement; MDC, minimal detectable change.

tra-rater reliability of hip extension with the push configuration was moderate to good for early phase RTD ($ICC_{2,1}$=0.72-0.85) and good for late phases RTD ($ICC_{2,1}$=0.81-0.87). For the pull configuration, intra-rater reliability was good to excellent for both phases of RTD ($ICC_{2,1}$=0.77-0.91). For the peak torque of hip extension, intra-rater reliability was moderate to excellent for the push configuration ($ICC_{2,1}$=0.73-0.92) and excellent for the pull configuration ($ICC_{2,1}$⩾0.91).

INTER-RATER RELIABILITY

Inter-rater reliability results, SEM, and MDC for the RTDs and peak torque measures of hip abduction and extension with both configurations are displayed in Table 4. Inter-rater reliability of hip abduction was moderate with the push configuration ($ICC_{3,k}$=0.72-0.74) and good with the pull configuration ($ICC_{3,k}$=0.78-0.79) for both early and late phases of RTD. Inter-rater reliability for the peak torque of hip abduction was good for both push and pull configurations ($ICC_{3,k}$=0.83-0.89). Inter-rater reliability of hip extension was good with the push configuration ($ICC_{3,k}$=0.82-0.86) and excellent with the pull configuration ($ICC_{3,k}$⩾0.95) for both early and late phases of RTD. For hip extension peak torque, inter-rater reliability was excellent for both configurations ($ICC_{3,k}$⩾0.94).

DISCOMFORT

There was no significant difference in discomfort between push and pull configurations for both hip abduction and extension for both raters (Rater 1: abduction p=0.28, extension p=0.82; Rater 2: abduction p=0.13, extension p=0.45) (Table 5).

DISCUSSION

The primary purpose of this study was to evaluate the reliability of HHD utilizing the push and pull configurations in measuring RTD and peak torque of hip abductors and extensors. The secondary purpose of this study was to quantify the level of discomfort of push and pull configurations during testing. Consistent with the hypotheses, this study demonstrated that HHD with both the push and pull configurations is a reliable method for measuring early and late phases RTD and peak torque of hip abductor and extensor muscle groups without impacting discomfort levels.

Table 3. Intra-reliability for hip extension RTD and peak torque measures with push and pull configurations.

Intra-reliability		Trial 1 (Mean±SD)	Trial 2 (Mean±SD)	Trial 3 (Mean±SD)	ICC (2,1) (95% CI)	*P* value	SEM	MDC
Extension	***Push***							
RTD 0-100 ms (Nm/s/kg)	Rater 1	6.86±2.08	6.29±2.35	6.46±2.44	0.85 (0.71-0.93)	0.12	0.32	0.89
	Rater 2	5.59±2.45	6.24±2.38	6.03±2.51	0.72 (0.51-0.86)	0.28	0.48	1.32
RTD 100-200 ms (Nm/s/kg)	Rater 1	5.72±1.56	5.31±1.59	5.38±1.79	0.81 (0.65-0.91)	0.16	0.29	0.82
	Rater 2	5.12±1.82	5.51±1.97	5.09±1.90	0.87 (0.74-0.94)	0.10	0.23	0.64
Peak Torque (Nm/kg)	Rater 1	1.62±0.41	1.57±0.38	1.53±0.35	0.73 (0.52-0.87)	0.34	0.07	0.20
	Rater 2	1.57±0.41	1.60±0.40	1.61±0.38	0.92 (0.85-0.97)	0.61	0.03	0.08
Extension	***Pull***							
RTD 0-100 ms (Nm/s/kg)	Rater 1	11.57±4.97	11.79±4.39	11.73±4.71	0.91 (0.83-0.96)	0.87	0.36	1.00
	Rater 2	10.57±3.93	11.17±5.31	11.99±5.79	0.78 (0.60-0.90)	0.17	0.93	2.57
RTD 100-200 ms (Nm/s/kg)	Rater 1	9.67±3.57	10.48±3.56	10.00±3.42	0.91 (0.81-0.96)	0.07	0.29	0.81
	Rater 2	8.93±3.00	9.40±4.53	9.56±4.03	0.77 (0.58-0.89)	0.51	0.77	2.13
Peak Torque (Nm/kg)	Rater 1	2.94±0.78	2.98±0.95	3.04±1.03	0.91 (0.83-0.96)	0.50	0.06	0.17
	Rater 2	2.90±0.80	2.91±0.80	2.88±0.84	0.93 (0.87-0.97)	0.71	0.02	0.07

SD, standard deviation; ICC, intraclass correlation coefficient; CI, confidence interval; SEM, standard error of measurement; MDC, minimal detectable change.

Both push and pull configurations for RTDs and peak torque measures of hip abductors displayed moderate to good intra- and inter-rater reliability. The SEM ranged between 0.19 to 1.0 Nm/s/kg for RTDs and 0.02 to 0.09 Nm/kg for peak torque, while the MDC ranged between 0.55 to 2.78 Nm/s/kg for RTDs and 0.06 to 0.25 Nm/kg for peak torque. These results are consistent with outcomes of previous studies that identified moderate to excellent intra- and inter-rater reliability of side-lying hip abduction strength utilizing HHD with push configuration. (ICC ⩾ 0.62).[24,37-39] Additionally, a previous study reported moderate reliability of the hip abduction RTD when using an IKD (ICC = 0.69).[40] The ICC values in the present study using an HHD are comparable to those from utilizing the IKD.

The results of this study suggest that both configurations can be utilized to assess the ability of hip abductors to produce force rapidly in early time periods and peak torque. However, Rater 2, who had less experience assessing RTD and peak torque, had lower early and late phases RTD values and lower intra-rater reliability for RTDs and peak torque measures in both configurations compared to Rater 1. Although both raters had moderate to good reliability across the measures, it is possible that the raters' proficiency during participant placement, strapping, or securing the HHD to the participant's body parts or external fixation could influence the reliability of HHD for measuring RTDs and peak torque of hip abductors.[38] Clinicians need to recognize the importance of sufficient training and experience in using HHD that could enhance measurement consistency in clinical practice.

The push and pull configurations showed moderate to excellent intra- and inter-rater reliability in measuring RTD and peak torque of hip extensors. The SEM ranged from 0.23 to 0.97 Nm/s/kg for RTDs and 0.02 to 0.19 Nm/kg for peak torque and MDC ranged from 0.64 to 2.69 Nm/s/kg for RTDs and 0.07 to 0.52 Nm/kg for peak torque. The results of this study are consistent with the previous literature on this topic that has identified moderate to good intra-rater reliability (ICC=0.50-0.89) and good inter-rater reliability (ICC=0.86) of RTDs and good to excellent intra-rater reliability (ICC⩾0.85) and excellent inter-rater reliability (ICC=0.95) of peak torque of hip extensors using the push configuration, with excellent (ICC⩾0.99) intra- and inter-reliability of hip extension peak torque using the pull configuration in supine and prone positions.[24,25,39,41-43] Bazett-Jones et al. demonstrated that hip extension torque is greater when tested in a supine position with the hip flexed.[24] However, a prone position with the hip flexed can

Table 4. Inter-rater reliability for hip abduction and extension RTD and peak torque measures with push and pull configurations.

Inter-rater Reliability			Rater 1 (Mean±SD)	Rater 2 (Mean±SD)	ICC $_{(3,k)}$ (95% CI)	SEM	MDC
Abduction	***Push***	RTD 0-100 ms (Nm/s/kg)	5.13±1.78	3.98±1.82	0.74 (0.15-0.91)	0.91	2.52
		RTD 100-200 ms (Nm/s/kg)	4.51±2.06	3.23±1.70	0.72 (0.09-0.90)	1.00	2.78
		Peak Torque (Nm/kg)	1.02±0.25	0.93±0.27	0.89 (0.67-0.96)	0.09	0.24
	Pull	RTD 0-100 ms (Nm/s/kg)	3.38±0.99	3.29±1.01	0.78 (0.44-0.91)	0.47	1.31
		RTD 100-200 ms (Nm/s/kg)	3.22±1.06	2.85±1.24	0.79 (0.47-0.91)	0.53	1.48
		Peak Torque (Nm/kg)	0.80±0.23	0.83±0.21	0.83 (0.56-0.93)	0.09	0.25
Extension	***Push***	RTD 0-100 ms (Nm/s/kg)	6.54±2.18	5.96±2.21	0.82 (0.56-0.93)	0.93	2.57
		RTD 100-200 ms (Nm/s/kg)	5.47±1.54	5.24±1.81	0.86 (0.65-0.94)	0.63	1.76
		Peak Torque (Nm/kg)	1.58±0.35	1.59±0.38	0.94 (0.85-0.98)	0.09	0.25
	Pull	RTD 0-100 ms (Nm/s/kg)	11.70±4.55	11.24±4.69	0.96 (0.89-0.98)	0.97	2.69
		RTD 100-200 ms (Nm/s/kg)	10.05±3.42	9.30±3.59	0.95 (0.85-0.98)	0.81	2.24
		Peak Torque (Nm/kg)	2.99±0.90	2.90±0.79	0.95 (0.88-0.98)	0.19	0.52

SD, standard deviation; ICC, intraclass correlation coefficient; CI, confidence interval; SEM, standard error of measurement; MDC, minimal detectable change.

Table 5. Discomfort using a Visual Analog Scale (VAS).

VAS (cm)	***Abduction*** ***Push***	***Pull***	*p*-value	***Extension*** ***Push***	***Pull***	*p*-value
Rater 1 (Mean±SD)	1.8±2.1	1.2±1.3	0.28	1.7±1.5	1.8±2.4	0.82
Rater 2 (Mean±SD)	2.1±1.7	1.2±1.4	0.13	1.7±1.9	1.9±2.2	0.45

SD, standard deviation.

better target the gluteus maximus muscle.[44] The present study positioned participants in the prone position, leaning forward on the treatment table, to use the table as an external fixation while maintaining the participant's hip flexed. The position utilized in this study also resulted in moderate to excellent reliability of HHD with both configurations for RTDs and peak torque of hip extensors; however, it is unknown if testing hip extension in different positions would influence the results. At a minimum, the use of external fixation should be considered in hip extension testing, as it contributes to enhancing reliability across different testing positions.

The results of the present study indicate that the pull configuration had relatively higher intra- and inter-reliability for measuring RTDs and peak torque of hip extensors with greater RTDs and peak torque values than the push configuration. One of the potential factors resulting in the higher reliability of the pull configuration than the push method might be the rigidity of the surface against which the HHD was placed.[21,45] In the present study, the HHD for the pull configuration was stabilized on the plane of the treatment table legs by a sturdy, nonelastic belt, while the HHD for the push configuration was anchored directly to the participant's thigh by the belt. Therefore, due to the differences in stiffness between the table leg and the participant's test limb, tissue attenuation plays a significant role in the findings of this study. The stabilization of HHD on the firm and flat surface could contribute to maximizing the stability of the HHD and yielding more constant and higher RTDs and peak torque measurements compared to the fixation on the uneven body part.[21,25,41,45] The results of this study suggest that both push and pull configurations can be reliably utilized in clinical practice for evaluating the ability of hip extensor muscles to activate the muscle rapidly and exert maximal strength, with the pull configuration demonstrating higher reliability.[15,46] Due to the difference in RTDs and peak torque values between the configurations, clinicians are also recommended to avoid using both HHD configurations interchangeably.

There was no difference in discomfort between push and pull configurations during testing, which is inconsistent with previous research.[22] Hansen et al. demonstrated that the push configuration resulted in more discomfort than the pull configuration when assessing quadriceps peak torque.[22] In the pull configuration, a foam pad was placed across the anterior aspect of the tibia, and a gait belt was looped through the pad and the HHD against the table leg.[22] While previous authors have used padding to reduce discomfort during testing, the present study did not use a pad for the pull configuration, and participant discomfort did not exceed 2/10 on the VAS.

A limitation of this study is that all participants were relatively young, healthy, and physically active individuals with no history of neurological impairment or orthopedic surgery. Therefore, the results cannot be extrapolated to individuals with lower extremity pathology or those beyond our outlined age range. Thus, future studies should further examine other population groups, such as those with hip pathologies or post-operative conditions. Due to the low discomfort level experienced in both testing positions, clinicians may wish to consider patient-specific limitations when selecting their testing procedures. Another limitation is systemic differences seen in hip extension RTDs and peak torque values between the configurations, which could stem from the soft tissue attenuation and stability of the surface the HHD was positioned against. Therefore, both configurations should not be used interchangeably in clinical practice. Finally, this study utilized a specific treatment table that had a face hole to evaluate hip abduction measures, allowing for the strapping to be fed through the face hole and allowing a direct perpendicular force of the HHD and test limb. The use of a specific treatment table was determined during pilot testing, as strapping around the entire table resulted in reduced force output, likely due to the larger surface area reducing the perpendicular line of pull during the hip abduction assessment. Treatment tables without a face hole could limit the clinical application of the HHD for clinicians, which could impact the generalization of using an HHD to measure hip abduction RTD and peak torque measures. To extend usefulness of the proposed method with the HHD, further studies need to also utilize various treatment tables to measure RTDs and peak torque with push and pull configurations.

CONCLUSION

HHD with push and pull configurations demonstrate moderate to good inter- and intra-rater reliability for evaluating the peak torque and early and late RTD measures of hip abductor muscle groups and moderate to excellent reliability for hip extensor muscle groups without difference in discomfort in healthy, young adult population. HHD with pull configuration was more reliable for measures of early and late phases RTD and peak torque of hip extensors compared to push configuration. The findings of this study provide clinicians with beneficial information, considering the cost-effectiveness of HHD and the feasibility of reproducing the tests in the clinical setting as an alternative to laboratory-based dynamometry.

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