Original Research

Comparison of Common Methodologies for the Determination of Knee Flexor Muscle Strength

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Background

Knee flexion strength may hold important clinical implications for the determination of injury risk and readiness to return to sport following injury and orthopedic surgery. A wide array of testing methodologies and positioning options are available that require validation prior to clinical integration. The purpose of this study was to 1) investigate the validity and test-retest reliability of isometric knee flexion strength measured by a fixed handheld dynamometer (HHD) apparatus compared to a Biodex Dynamometer (BD), 2) determine the impact of body position (seated versus supine) and foot position (plantar- vs dorsiflexed) on knee flexion peak torque and 3) establish the validity and test-retest reliability of the NordBord Hamstring Dynamometer.

Study Design

Validity and reliability study, test-retest design.

Methods

Forty-four healthy participants (aged 27 ± 4.8 years) were assessed by two raters over two testing sessions separated by three to seven days. Maximal isometric knee flexion in the seated and supine position at 90º knee flexion was measured with both a BD and an externally fixed HHD with the foot held in maximal dorsiflexion or in plantar flexion. The validity and test-retest reliability of eccentric knee flexor strength on the NordBord hamstring dynamometer was assessed and compared with isometric strength on the BD.

Results

Level of agreement between HHD and BD torque demonstrated low bias (bias -0.33 Nm, SD of bias 13.5 Nm; 95% LOA 26.13 Nm, -26.79 Nm). Interrater reliability of the HHD was high, varying slightly with body position (ICC range 0.9-0.97, n=44). Isometric knee flexion torque was higher in the seated versus supine position and with the foot dorsiflexed versus plantarflexed. Eccentric knee flexion torque had a high degree of correlation with isometric knee flexion torque as measured via the BD (r=0.61-0.86). The NordBord had high test-retest reliability (0.993 (95%CI 0.983-0.997, n=19) for eccentric knee flexor strength, with an MDC_{95} of 26.88 N and 28.76 N for the left and right limbs respectively.

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Conclusion

Common measures of maximal isometric knee flexion display high levels of correlation and test-retest reliability. However, values obtained by an externally fixed HHD are not interchangeable with values obtained via the BD. Foot and body position should be considered and controlled during testing.

Level of Evidence

2b

INTRODUCTION

Impairment of muscular strength is linked to functional disability,[1] and measurement in a clinical setting may be useful to identify those at increased risk of injury or readiness to return to sport or work following injury. Clinically, muscular strength can be assessed with different methodologies with manual muscle testing (MMT), hand-held dynamometry (HHD) and isokinetic dynamometry representing more common techniques alongside new technologies such as the NordBord Hamstring Dynamometer.[1] MMT is a subjective measure that evaluates strength of specific muscle groups against resistance provided by the clinician. Strength is graded on a scale from zero (unable to produced measurable muscle activity) to five (strong resistance) based on the clinician's subjective perception of the degree of provided resistance. Unfortunately, this technique lacks the precision that is required in clinical cases such as return to sport assessment, where between-limb differences of 10% may be clinically relevant, yet undetectable through MMT.[2]

Isokinetic dynamometers are considered the gold standard for strength testing as they have been tested for validity and reliability [3–5] and can test multiple muscle actions (isokinetic, isometric, isotonic). However, they are expensive and space consuming, which may limit their use.[6] Given the imprecision of MMT and the expense of an isokinetic dynamometer, testing with HHD is becoming more common due to its ease in testing, reproducibility, and reduced cost.[6,7]

Previous authors have reported good to excellent inter- and intra-rater reliability for clinician-stabilized HHD and a high degree of correlation with isokinetic dynamometry,[8] yet some concerns remain with this technique.[1,7,9] Clinician-stabilized HHD has good agreement with isokinetic dynamometry,[3,9–12] however variations in correlations can be expected given that differing contraction modes are often tested (i.e. isometric HHD against isokinetic concentric/eccentric actions).[8] The inability to maintain a stable isometric contraction during testing on the part of the clinicians or patient can lead to unreliable and imprecise results. Kelln et al[13] suggest that with increasing levels of movement difficulty or strength output, HHD measurements become less reliable. As such, strength of the tester may be a limiting factor for MMT and HHD as well as lack of stabilization of the tester, subject, and device, especially when measuring stronger muscle groups.[14,15] If testers of different sexes perform the same measurements, the inter-tester reliability can be questioned when using HHD, especially when testing larger muscles.[15,16] This may contribute to the wide range of standard error of measurements (SEM) that have been observed across the literature (SEM 3.8-13.5%).[17] Despite these concerns, many authors report moderate to high levels of concurrent validity with isokinetic dynamometers[8] and acceptable inter- and intra-rater reliability when comparing HHD to isokinetic dynamometers.

Anchoring the HHD to an immovable object may address the limitations of clinician-stabilized HHD.[3,5,6,18–21] Various iterations of stabilization have been used, from engineered metallic frames,[22,23] strapping the dynamometer to an immovable object,[9,24,25] or bracing using PVC pipes.[26] By externally 'bracing' the dynamometer, instead of holding it while the subject exerts their maximal force against it, the results are no longer dependent on either the examiner or the subject's strength.[1] Not surprisingly, devices that provide stability to the dynamometer are associated with good to excellent intra-tester and inter-tester reliability; however, the majority of studies have focused on the hip with fewer regarding the knee flexors.[9,12,19,24] Agreement between fixed and instrumented dynamometry is variable depending on contraction mode, device tested and muscles evaluated.[12,24,25] Kim et al[19] found that correlation in knee flexor peak torque was greater when fixed versus clinician stabilized HHD alone when compared with isokinetic dynamometry. Recently Martins et al[25] found fixed HHD to show moderate to high correlation with isokinetic dynamometry, yet absolute values are likely not interchangeable between the devices. Consequently, further validation is required for externally fixed-HHD, considering both the validity and agreement with isokinetic dynamometry.

Strength assessment of the hamstrings is complicated due to the anatomical complexity of the muscle group. Differences in torque have been noted with the highest values occurring in the seated as compared with supine and prone positions[27,28] which may be attributable to alterations in length and utilization of differing components of the hamstrings. Generally, knee flexion torque is greater with increasing hip flexion (seated versus supine and prone) and with lower levels of knee flexion. The most common positioning across the literature had the participant seated with the hip at or near 90º flexion, and the knee between 30º and 90º of flexion.[1,4,5,11,12,29–37] Only a few studies have positioned participants in prone,[3,38,39] or with larger angles of hip flexion to more closely replicate striding position during gait.[40] Knee flexion torque may also be influenced by the position of the ankle in dorsi- or plantarflexion as the gastrocnemius is a bi-articular muscle at both the ankle and the knee. Knee flexion moments of the gastrocnemius decrease with knee flexion and increase with greater degrees of dorsiflexion.[41] The majority of the literature investigates differing angles at a single joint, when it is apparent that concurrent alterations in hip, knee and ankle position may

impact isometric knee flexion torque and potentially, the clinical implications of the test. There is a paucity of research examining the impact of concurrent hip and ankle joint angles on isometric strength testing. Consequently, in addition to considerations of stabilization, clinicians must be aware of the impact of foot and hip position on knee flexion torque.

While HHD appears to be a viable alternative to isokinetic dynamometry, questions remain regarding the validity and reliability of fixed HHD and the NordBord dynamometer and the impact of hip and foot position on isometric knee flexion strength. The purpose of this study was to 1) investigate the validity and test-retest reliability of isometric knee flexion strength measured by a fixed HHD apparatus compared to a BD, 2) determine the impact of body position (seated versus supine) and foot position (plantar- vs dorsiflexed) on knee flexion peak torque and 3) establish the validity and test-retest reliability of the Nord-Bord Hamstring Dynamometer. It was hypothesized that fixed-HHD would provide a level of agreement with BD that would not permit interchange of values between devices and have high inter-rater reliability. Knee flexor strength was hypothesized to be greater in the seated and dorsiflexed position relative to supine testing with the ankle in plantarflexion. Finally, the NordBord was anticipated to have a low to moderate correlation with isometric testing completed on the BD, given the differences in contraction mode assessed, and have excellent test-retest reliability.

METHODS

SUBJECTS

Forty-four healthy participants (22 males, 22 females, age: 27.1 ± 4.8 years, height: 172.2 ± 9.3 cm, weight: 74.8 ± 13.8 kg, Table 1) with no history of neurological conditions, chronic lower extremity injury or lower extremity reconstructive surgeries participated in two experimental sessions separated by three to seven days. Participants were instructed to maintain their regular activities but to avoid intensive lower extremity training the day immediately prior to both testing sessions. This study was approved by the University of Manitoba Health Research Ethics Board and was completed in accordance to the recommendations of the Declaration of Helsinki. Participants were informed of all study procedures and provided written informed consent prior to participation.

PROCEDURES

At the beginning of each testing day, the participant completed a five-minute warm up on a cycle ergometer at a self-selected pace and resistance, followed by lower body stretching as required. Following the five-minute warm up, participants were tested on a HHD, the BD, and a NordBord in each session. The order of the HHD and BD were randomized in the first session, and this order was maintained on the second testing day. The NordBord was completed at the end of the session both days. The HHD (Chatillon DFX2, Ametek, PA, USA) was externally fixed to the wall by a glass suction cup via two S-biners (Nite-Ize, Boulder, CO, USA) each rated to 100 pounds of tension and the suction cup

Table 1: Participant characteristics

	Mean ± SD
Age (yrs)	27.18 ± 4.8
Height (cm)	172.17 ± 9.39
Weight (kg)	74.8 ± 14
L Shank Length (cm)	40.48 ± 2.11
R Shank Length (cm)	40.66 ± 2.51

Figure 1: Equipment set up.

was secured to a metal sheet affixed to the wall. The HHD was outfitted with a hook-shaped clip insert that allowed an inelastic Velcro strap that looped around the participant's lower limb to connect to the HHD via a metal loop (Figure 1).

Testing was also performed on an isokinetic dynamometer (Biodex System3, Biodex Medical Systems, Shirley, NY) and eccentric knee flexion force and torque was measured during the Nordic Hamstring curl with the NordBord Hamstring dynamometer (NordBord; Vald Performance, Newstead, Australia), both operated according to the manufacturer's recommendations.

HHD data were collected by three investigators (two per participant) to assess inter-rater reliability, whereas the Biodex and NordBord data were collected by the same single investigator. Device order (BD, HHD, Nordbord) was standardized across days based on the day one randomization whereas rater order and ankle position (plantar flexion vs dorsiflexion) were randomized between sessions. The Nord-Bord test was completed by the same rater at the end of each testing day, and the seated and supine positions were tested on day one and two respectively. Three attempts were provided on each device and position with a five-second hold for isometric actions, a 10-second break between maximal contractions, a 30-second break between different foot positions, and a five-minute break between devices.

SEATED ISOMETRIC STRENGTH PROTOCOL

Testing with the HHD in the seated position consisted of the participant having both hips and knees in 90° flexion with their popliteal fossae approximately two finger widths away from the edge of the therapy bed to negate any bracing effect. A Velcro strap with a metal loop for attachment to the HHD was secured to the participant's ankle two centimeters proximal to the lateral malleolus, measured from its point of greatest protrusion. The rater adjusted the height of the bed to ensure the line of force from the strap on the HHD was parallel to the floor and perpendicular to the participant's leg. The rater ensured the participant's tested knee remained at 90° of flexion, that the participant's arms were at their sides with hands holding the edges of the bed, and that there was no excessive trunk or hip flexion throughout the isometric contractions through all trials.

Positioning in the BD was similar to that of the HHD with the participant seated with their back against a backrest positioned at 90° above the horizontal, their hips and knees in 90° of flexion, and their arms at their sides with their hands holding the handles of the chair. The axis of rotation of the dynamometer lever arm was positioned coaxial to the lateral femoral epicondyle. The shank was fixed to the lever arm two centimeters proximal to the lateral malleolus again, to keep the active lever arm length consistent between devices. Stabilization straps were secured diagonally across the participant's chest, and across their waist and thigh of the tested leg, to assure accurate, reproducible testing by controlling excessive movement. Once the participant was positioned, they were familiarized with the testing apparatus and performed two practice repetitions (five-second hold) prior to testing.

SUPINE ISOMETRIC STRENGTH PROTOCOL

The participant was positioned in neutral hip alignment (0º hip flexion) and 90º knee flexion, with the other limb positioned in a relaxed position. The rater aligned the subject and HHD in the same manner as outlined for seated testing. For testing with the BD in the supine position, the participant was laying against the backrest oriented at 5° above the horizontal with their hips at approximately 0° flexion and knees at 90° flexion. The rater again aligned the Biodex System3 and participant in the same fashion as outlined for seated testing.

NORDBORD ECCENTRIC STRENGTH PROTOCOL

Eccentric knee flexor strength was assessed on the Nord-Bord Hamstring dynamometer. Participants were positioned kneeling with their ankles in the posterior hook anchors on the device. They were instructed to stay straight through the hips and trunk, keeping their shoulders as in line with their knees as possible through the entire movement. The participant then began to lean forward, extending at the knee, and lowered themselves toward the ground as low and slow as possible, while pushing up into the hooks as hard as they could with their ankles. When they could no longer maintain this task, the participant released their contraction and caught themselves with their hands on the landing mat.

STATISTICAL ANALYSIS

Peak force (N), and torque (Nm) were recorded from each device. Shank length (cm) of each participant was measured in order to convert force measurements attained from the HHD testing into torque values, to facilitate absolute comparisons between the HHD and the BD results. Three attempts were completed in each position and test (BD, HHD, NordBord) and the average torque (BD, HHD) and force (NordBord) from the three attempts was used in subsequent analysis. Bland-Altman limits of agreement (LOA) analysis were calculated from the difference between test and retest values plotted against the average of the trials, with 95% LOA calculated as 1.96 multiplied by the standard deviation of the difference (Prism Graphpad, CA, USA). A factorial ANOVA was conducted to determine the impact of differing foot position (plantar flexed (PF) or dorsiflexed (DF), body position (seated or supine), body side (left and right) and test types (BD, HHD, NordBord) on resultant torque values. Intraclass correlation (ICC) estimates and their 95% confidence intervals were calculated using SPSS (IBM, Armonk, NY, USA). Criterion validity of the HHD and Nordbord were established relative to the BD measures through comparison of Pearson correlation coefficients and ICC. Finally, test-retest reliability of the NordBord was established through consideration of ICCs for the left and right lower extremities (two-way mixed effects, absolute agreement, mean K raters). Statistical significance was considered at $p<0.05$ where appropriate. ICC values were classified as poor (ICC <0.50), moderate (ICC = 0.5-0.75), good (ICC = 0.75-0.90) or excellent (ICC>0.90).[42] Pearson correlation coefficients were classified as high (r >= 0.70), moderate (r = 0.50-0.70), low (r = 0.30-0.50) and weak (r<0.30).

RESULTS

HHD VALIDITY AND INTER-RATER RELIABILITY

Bland-Altman LOA analysis of isometric knee flexion torque between HHD and BD found low bias with wide limits of agreement relative to obtained test scores (Bias -0.33 Nm, standard deviation (SD) of bias 13.5 Nm; 95% LOA 26.13 Nm, -26.79 Nm). Given the potential for heteroscedasticity in the comparison of HHD against BD, alternative analysis was run on logarithmic transformed data, yielding comparable bias with narrowed limits of agreement (Bias -0.0007, SD of Bias 0.1169, 95% LOA: -0.2298, -0.2284). Inter-rater reliability of the fixed HHD was high as all but one ICC exceeded 0.9, with minimal variation between the differing testing conditions (body position, foot position; Table 2).

BODY AND FOOT POSITION ON TORQUE

Main effects were found for body ($F_{(1,43)}$=*584.9, p<0.001)*) and foot *($F_{(1,43)}$=57.6, p<0.001)* position with greater isometric peak torque found in seated, dorsiflexed positions as opposed to supine, plantar flexed positions with data collapsed by side (left and right) and test type (HHD and BD; Figure 2).

Table 2: Inter-rater reliability of the Handheld Dynamometer across body and foot positions

Position	Rater 1 (Nm)	Rater 2 (Nm)	ICC (95%CI)	SEM (Nm)	MDC$_{95}$ (Nm)
Seated, Dorsiflexed, Left	70.47 ± 26.53	68.39 ± 28.42	0.94 (0.89, 0.97)	6.73	18.65
Seated, Plantarflexed, Left	62.26 ± 23.23	60.84 ± 24.49	0.93 (0.87, 0.96)	6.31	17.50
Seated, Dorsiflexed, Right	69.50 ± 26.11	68.32 ± 26.54	0.97 (0.95, 0.99)	4.56	12.64
Seated, Plantarflexed, Right	62.66 ± 24.87	57.67 ± 22.07	0.93 (0.87, 0.96)	6.21	17.21
Supine Dorsiflexed, Left	41.72 ± 14.21	40.82 ± 13.90	0.92 (0.85, 0.96)	3.98	11.02
Supine Plantarflexed, Left	31.97 ± 10.54	30.95 ± 11.41	0.92 (0.85, 0.95)	3.1	8.60
Supine, Dorsiflexed, Right	40.33 ± 13.65	39.79 ± 15.50	0.94 (0.89, 0.97)	3.57	9.89
Supine, Plantarflexed, Right	32.49 ± 11.88	30.14 ± 11.25	0.90 (0.81, 0.94)	3.66	10.14

ICC=intraclass correlation coefficient, *CI*=confidence interval, *SEM*=Standard Error of the Measurement, *MDC$_{95}$*=Minimum Detectable Change, *Nm*=Newton-Meter

Table 3: Correlations between Biodex Dynamometer measured isometric knee flexion torque and maximal eccentric knee flexor torque during the Nordic Hamstring Curl exercise

| Body and Foot Position	Biodex Isometric Torque (Nm)	Nordic Eccentric Torque (Nm)	Pearson Correlation (Sig)
Seated, Dorsiflexed, Left	71.4 ± 25.80	110.35 ± 47.03	0.665 (p=0.001392)
Seated, Plantarflexed, Left	61.92 ± 23.15	110.35 ± 47.03	0.608 (p=0.004482)
Seated, Dorsiflexed, Right	72.01 ± 25.10	107.20 ± 43.41	0.791 (p=0.000033)
Seated, Plantarflexed, Right	64.24 ± 23.39	107.20 ± 43.41	0.714 (p=0.000407)
Supine Dorsiflexed, Left	43.86 ± 17.31	110.35 ± 47.03	0.861 (p=0.000001)
Supine Plantarflexed, Left	32.37 ± 13.85	110.35 ± 47.03	0.743 (p=0.000172)
Supine, Dorsiflexed, Right	45.02 ± 16.36	107.20 ± 43.41	0.791 (p=0.000033)
Supine, Plantarflexed, Right	33.93 ± 14.40	107.20 ± 43.41	0.702 (p=0.001)
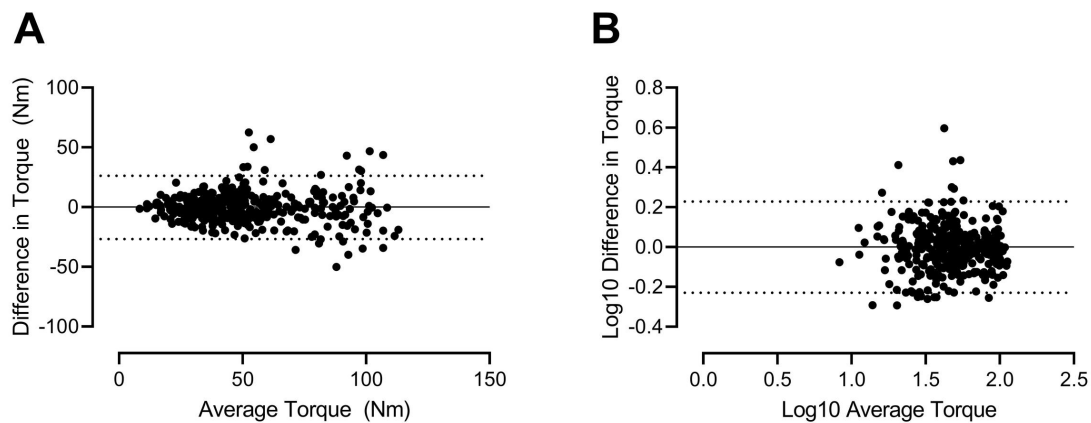
Figure 2: Difference in torque and Log10 difference in torque by foot position

NORDBORD VALIDITY AND TEST-RETEST RELIABILITY

Moderate to high correlations were found between eccentric Nordbord hamstring torque and BD isometric torque, ranging from r=0.61-0.86, varying slightly with body and foot position for the BD (Table 3). Peak eccentric hamstring force during the NordBord Hamstring Curl displayed high test-retest reliability (left leg: 0.993 (95%CI 0.983 – 0.997); right Leg: 0.992 (95%CI 0.979-0.997). MDC$_{95}$ values for the left and right limb were 26.88 N and 28.76 N respectively (Table 4).

Table 4: Test-retest reliability and MDC$_{95}$ of the NordBord hamstring dynamometer force measurements

	Test 1 (N)	Test 2 (N)	ICC	SEM (N)	MDC$_{95}$ (N)
Left	276.98 ± 119.68	274.49 ± 115.42	0.993 (0.98, 0.997)	19.31	26.88
Right	269.32 ± 112.10	271.93 ± 116.63	0.992 (0.97, 0.997)	13.66	28.76

ICC=intraclass correlation coefficient, CI=confidence interval, SEM=Standard Error of the Measurement, MDC$_{95}$=Minimum Detectable Change, Nm=Newton-Meter

DISCUSSION

The purpose of this study was to: 1) investigate the validity and reliability of isometric knee flexion strength measured with an externally fixed HHD compared to a BD, 2) determine the impact of hip and ankle position on isometric knee flexion strength and 3) assess the validity and test-retest reliability of the NordBord Hamstring Dynamometer.

VALIDITY AND RELIABILITY OF FIXED-HHD

With respect to the validity of fixed-HHD, a moderate to high degree of correlation with the BD was found, consistent with previous studies across various muscle groups.[3,5,10–12,19,25,43] The magnitude of correlation did not differ substantially between the seated and supine position or with plantar or dorsiflexion. Despite the degree of correlation between the two devices, the limits of agreement spanned more than 50 Nm for the knee flexors. This is consistent with previous data from Lesnak et al[10] who compared isometric knee extension peak torque between fixed-HHD, finding limits of agreement of 19.4 ± 53.2 Nm, and larger when evaluating rate of torque development. Martins et al[25] demonstrated comparable correlations between the two machines, with similarly wide limits of agreement for the knee flexors. Katoh et al[44] found higher forces with isokinetic dynamometers (tested isometrically) than with a belt stabilized HHD. As the design lacked a clinician-stabilized condition, it cannot be concluded that stabilization of the dynamometer improved agreement between BD and HHD. Data from Kim et al[19] found correlation between the two devices were improved with fixation. Others have suggested that belt fixation is associated with greater force generation than clinician-stabilized conditions, and that HHD may underestimate strength relative to BD.[19–21,24,25,44,45] Conversely, Lesnak et al[10] found HHD to overestimate peak torque production yet underestimate the rate of torque development. Nevertheless, these results indicate that while instrumented assessment on isokinetic dynamometers and fixed HHD are correlated, values should not be interchanged between devices.

Inter-rater reliability of the fixed HHD was generally high and consistent with previous literature using fixed HHD for assessment of knee extensors[12,19] and flexors.[12,18,19,43,46] Romero-Franco et al[43] tested a comparable seated knee flexion setup, anchoring the dynamometer to solid wall bars finding an ICC of 0.979 when retesting over a one week period. Differing from the present setup, both Wollin et al[45] and Thorborg et al[18] used a strap to anchor the dynamometer to the ground, with the patient near 0º-30º knee flexion

in the prone position. While differences in knee flexion strength across the studies may represent differing contributions of components of the hamstring and gastrocnemius, inter-rater reliability was acceptable but lower than the present study (ICC 0.8 (95%CI 0.65-0.93) and ICC 0.87 (95%CI 0.75-0.93)). Kim et al[19] found fixation of the dynamometer to marginally improve inter-rater reliability against clinician-stabilized for the knee extensors (ICC 0.952 to 0.984 and 0.940 to 0.963 respectively); However, van der Made et al[46] found fixation did not improve inter-tester reliability for isometric knee flexion in a cohort of rugby players of increased lower extremity strength, although all ICC values were 0.8 or higher. Nevertheless, this methodology displays excellent inter-rater reliability on-par with prior methodologies for fixed-HHD and indicates that HHD is acceptable for clinical use.

EFFECT OF HIP AND ANKLE POSITION ON KNEE FLEXOR ISOMETRIC STRENGTH

Given the biarticular structure of semitendinosus, long head biceps femoris, semimembranosus and gastrocnemius, hip, knee and ankle position must be considered when determining isometric knee flexion strength. Across the literature, assessment of knee flexion strength has been completed in the seated, prone and supine positions, although few, if any, direct comparisons of all three positions exist. Additional differences in the assessed contraction modes (i.e. isokinetic, isometric) further confound the comparison of knee flexion strength across studies by body position. In the present comparison of torque by position, collapsed for device (HHD and BD) knee flexion torque was greatest in the seated position with the foot dorsiflexed, and lowest in the supine position with the foot plantarflexed. Prior data evaluating concentric isokinetic strength generally agrees, finding increased torque with increased hip flexion in the seated as compared to the semi-reclined, supine and prone positions that is attributed to optimal positioning on the hamstring length-tension relationship with hip flexion beyond 90º.[27,47–50] Consistent with these findings, Miller et al[51] found an approximate 12% reduction in isokinetic knee flexion torque with the ankle in plantarflexion against dorsiflexion. Marchetti et al[52] demonstrated a 22% difference in isometric knee flexion favoring the dorsiflexed versus plantar flexed position at 90º knee flexion, although the magnitude of difference was reduced at 0º knee flexion. Due to the biarticular nature of the gastrocnemius, plantar flexion of the ankle produces active insufficiency, and thus, reduced knee flexion torque. The values in the present study are lower than those previously observed.[18,45] This may

be attributed to differences between the sampled groups, prone versus supine positioning, and that testing at 90º of knee flexion may result in reduced active contribution from the gastrocnemius, and reliance of differing components of the hamstring complex compared to those testing within lesser degrees of knee flexion.[47,52–54] It is apparent that knee flexion torque varies with position of the hip, knee and ankle, and future studies should report and control these parameters.

VALIDITY AND RELIABILITY OF THE NORDBORD HAMSTRING DYNAMOMETER

Few studies have evaluated the NordBord Hamstring dynamometer against other methodologies of strength assessment like the isokinetic dynamometer or isometric HHD. These data indicate a strong correlation between isometric knee flexion and eccentric knee flexion torque during the Nordic Hamstring curl. The relationship between torque during the Nordic hamstring curl and isokinetic dynamometry is equivocal. Van Dyk et al[55] found a poor degree of correlation between seated concentric and eccentric isokinetic knee flexion at 60º/s and 300º/s and eccentric Nordic hamstring curl torque. The authors attributed this to the characteristics of the tasks, whereby the hip is in a relatively neutral position during the Nordic hamstring curl opposed to seated knee flexion, and the bilateral nature of the Nordic hamstring curl as compared to unilateral isokinetic measures. Conversely, Lodge et al [56] assessed a comparable Nordic dynamometer (Hamstring Solo Elite) and found an inter-device correlation of 0.823 and 0.840 between the left and right limbs with isokinetic eccentric knee flexion torque at 30º/s. Our data may partially support this assertion, as the range and degree of correlations were slightly higher in the supine, hip neutral position as compared to the seated position. Inter-rater reliability of the NordBord exceeded the previously published values and is comparable to those observed by Lodge et al[56] for the Hamstring Solo dynamometer. Consequently, the NordBord shows high test-retest reliability and a moderate correlation with isometric knee flexion assessed with the BD. Further work is required to clarify the relationship between differing test methodologies by body position and contraction mode.

LIMITATIONS

Although foot position was controlled for during the BD and HHD trials, it was not rigidly monitored during completion of the Nordic Hamstring Curl on the NordBord. Participants were given standardized instructions for positioning on the device that started with the foot in a neutral position; however, foot position was not specifically controlled during completion of the repetition. While foot position has been shown to be inconsequential for EMG amplitude in biceps femoris and the medial gastrocnemius,[57] data on force production is lacking. A further limitation is that as we counterbalanced body position across testing days, our design did not allow for the determination of test-retest reliability for the externally fixed HHD.

CONCLUSION

The results of the present study serve to establish the validity of externally fixed HHD for the assessment of knee flexion strength against the BD. Wide limits of agreement despite low bias suggest that these values should not be interchanged between devices. As expected, inter-rater reliability of externally fixed HHD was also high. The position of the hip, knee and ankle must be considered as this may influence torque developed by the knee flexors. Future research is required to conclusively determine whether selective activation or utilization of the knee flexors may contribute to the differential in torque production, beyond changes in muscle length alone. The NordBord displayed moderate correlation with the BD despite testing differing contraction modes, and excellent test-retest reliability. Ultimately, clinicians have various options available to them for the measurement of knee flexion strength, but must determine whether variation in testing device, contraction mode, and body position are relevant to the clinical issue at hand. Nevertheless, fixed HHD is valid and reliable for the assessment of knee flexor strength and is therefore a useful tool for clinicians who do not have access to other assessment methodologies such as isokinetic dynamometry.

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