RELIABILITY OF LOWER-EXTREMITY DYNAMOMETRY TESTING OF THE ANKLE, KNEE AND HIP

Katrina A. McQuoid*, Jennifer B. Edmonds**, Catherine M. MacPhail*, Chris A. McGibbon**
*University of New Brunswick, *Department of Mechanical Engineering and ** Faculty of Kinesiology, Fredericton, NB, Canada*

INTRODUCTION

Isokinetic dynamometry systems are commonly used to acquire clinical measures of peak muscle torque in healthy and physically impaired individuals; however, there is limited data available regarding the test-retest reliability of ID torque measures for the ankle, knee and hip. Many studies use isokinetic and isometric measures of the lower extremity for different research and clinical applications, such as monitoring muscle function in persons with neuromuscular or musculoskeletal degeneration due to age or disease (1 2 3). Although reliability of muscle strength testing is well documented for hand-held and stationary dynamometry for bilateral measures of the lower extremity joints (5 6), reliability testing of ID has mostly been confined to individual joints (4). The goal of this study was to develop a bilateral lower extremity muscle strength testing protocol and measure the test-retest reliability of peak isokinetic and isometric torque measures. The protocol development is specifically aimed at older adults with mobility impairments and thus all tests were designed to minimize fatigue, risk, difficulty and overall testing time. This abstract reports the test-retest reliability of the protocol *alpha* version, including isokinetic and isometric measurements of the hip (*flexion, extension, abduction, and adduction*), knee (*flexion, extension*), and ankle (*plantar flexion*, *dorsiflexion*) bilaterally in young healthy persons using the Cybex Norm Isokinetic Dynamometer (HUMAC, CSMI, Norwood MA).

METHOD

Six healthy adults (mean age: 23 ± 6 yrs, 4 female) were recruited for the study. Testing always began on the dominant side which was determined by asking the participant a series of questions such as which leg they would normally kick a ball with (7,8). The joint was first tested for passive and active range of motion to determine the range of motion followed by torque tests.

The isokinetic protocols consisted of 5 isokinetic repetitions as this has been found to measure the greatest peak torque (9,10). Isometric tetsing followed after a rest period of 30 seconds. The isometric measurements were held for 5 seconds which has been shown to be an adequate amount of time for participants to reach their maximum force (5, 6, 7). The participant performed a flexion trial followed by a 15 second rest and then performed an extension trial followed by another 15 second rest. The isometric trials were repeated 3 times. Participants had a 30 second rest period between flexion/extension trial to prevent fatigue and muscle soreness/cramping.

Hip strength testing utilized the hip supine protocols outlined in the Cybex Norm Testing and Rehabilitation System manual. The position is shown in Figure 1. Stabilization straps were placed around the subject's iliac crests and distal thigh of the untested limb. The subject was supine with their arms folded across their chest to prevent them from holding onto and pushing up on the handles. The subject's knee joint was kept in anatomical neutral position to prevent the generation of extra torque by the bending of the knee. The axis of rotation of the dynamometer was aligned with the greater trochanter. The dynamometer arm was placed anteriorly on the distal thigh (*superior to the knee joint*). Isokinetic testing occurred at 60 degrees per second. The isokinetic testing ranged between 0 and 70 degrees of flexion and the isometric angles tested were at 15 degrees and 30 degrees of flexion.

Figure 1: Hip Flexion/Extension testing position

Hip abduction and adduction utilized the side-lying protocols outlined in the Cybex Norm Testing and Rehabilitation System manual. The subject was stabilized by two belts at the iliac crest, one on the distal thigh of untested limb, and one around their shoulders. Undesired movement and rotation of the hip was minimized by adding another stabilization strap at the hip. One strap was wrapped around the hips while another held the subject onto the testing platform which is displayed in Figure 2. The subject was instructed to lay as straight as possible while an assistant held the hip in place to prevent any extra hip movement. The dynamometer arm was placed proximal and lateral to the knee joint and the axis of rotation was aligned medial to the greater trochanter. The strength of the abductors and adductors were tested through a range of 5 degrees adduction to 25 degrees abduction at a speed of 60 degrees per second. The isometric angle used was 0 degrees.

Figure 2: Hip Abduction/Adduction testing position

The knee strength tests utilized the prone protocol provided by the Cybex Norm Testing and Rehabilitation System manual shown in Figure 3. The stabilization straps were wrapped around the distal thigh of the tested limb and around the iliac crests to prevent any additional movement of the body. The dynamometer arm was placed on the anterior, distal shank, superior to the malleoli of the ankle. The hip angle was kept at 180 degrees and the knee was tested through the ranges of 0 to 70 degrees of flexion. The axis of rotation of the dynamometer was aligned with the lateral epicondyle of the knee (11).The knee was tested at 60 degrees per second and the isometric angles chosen were 15 and 60 degrees of flexion.

Figure 3: Knee Flexion/ Extension testing position

The ankle strength tests utilized the supine protocols outlined in the Cybex Norm Testing and Rehabilitation System manual shown in Figure 4. In order to eliminate the additional degrees of freedom, two more straps were used to further secure the toe and ankle to the platform. Two other stabilization straps provided by Cybex were used around the distal thigh of the tested limb and around the iliac crests to prevent any undesired movement of the subject during testing. The axis of rotation of the dynamometer was aligned with the lateral malleolus of the ankle (11). The ankle was tested at 30 degrees per second through a range of 20 degrees of plantar flexion to 20 degrees of dorsiflexion. Isometric tests were performed at 15 degrees of plantar flexion and 15 degrees of dorsiflexion. In order to determine the anatomical zero position universal goniometer was used.

Figure 4: Ankle dorsi/plantarflexion testing position

Data analysis was performed by determining the subjects absolute peak torque produced across all trials and normalizing the result based on body weight. An Inter-Class correlation coefficient, model 3, was used to assess the repeatability of the data, using SPSS (v11.5, SPSS Inc. Chicago IL). (13).

RESULTS

The dominant limb displayed, overall, better repeatability than the non-dominant limb. The isokinetic results were considered reliable (ICC>.7) for all joints on the dominant leg, with the exception of the hip abductors. Reliability testing of the non-dominant limb was notably worse, especially for the hip and knee flexors. All ICC results are summarized in Tables 1 and 2 for isokinetic and isometric results, respectively. The isometric tests found similar reliabilities for the hip flexor and extensors as well as the knee. The ankle showed decreased reliability for the isometric trials. However, the hip adductors and abductors were much more reliable when tested isometrically. The hip extensors had excellent reliability for all trials and were always more reliable than the flexors. The knee extensors were, overall, more reliable than knee flexors, and the plantar and dorsiflexors had similar reliability for all trials.

Table 1: Isokinetic ICC results for all tests

Tested Muscle Group	Isokinetic Test Results (ICC)	
	Dominant Limb	***Non-Dominant Limb***
Hip Flexors	0.874	0.309
Hip Extensors	0.879	0.897
Hip Abductors	0.116	-0.125
Hip Adductors	0.920	0.889
Knee Flexors	0.758	0.134
Knee Extensors	0.973	0.896
Ankle Dorsiflexors	0.882	0.936
Ankle Plantarflexors	0.912	0.694

Table 2: Isometric results for all tests

Tested Muscle Group	Isometric Test Results (ICC)	
	Dominant Limb	***Non-Dominant Limb***
Hip Flexors 15º	0.738	0.587
Hip Extensors 15º	0.886	0.891
Hip Flexors 30º	0.524	0.852
Hip Extensors 30º	0.863	0.920
Hip Abductors 0º	0.666	0.706
Hip Adductors 0º	0.748	0.750
Knee Flexors 15º	0.837	0.692
Knee Extensors 15º	0.735	0.794
Knee Flexors 60º	0.930	0.747
Knee Extensors 60º	0.825	0.819
Ankle PF 15ºD	0.759	0.450
Ankle DF 15ºD	0.549	0.448
Ankle PF 15ºP	0.607	0.670
Ankle DF 15ºP	0.967	0.684

DISCUSSION

The bilateral lower extremity muscle strength protocol was found be, for the most part, repeatable. Most importantly, all joints tested were found to have reliable results with at least one of the testing methods. Furthermore, the full protocol (isometric, isokinetic and ROM tests) could be completed within 1.5 hours.

Several factors may explain the differing repeatability among the joints. All isokinetic tests with the exception of the ankle were performed at 60 degrees per second because as it has been well documented that it produces reliable results without causing delayed onset of muscle soreness (8, 14, 15, 16). The ankle was tested at 30 degrees per second as 60 was uncomfortable for some pilot subjects and others have shown more reliable results can be drawn from testing the ankle at this slower speed (17, 18).

The tests did not encompass a patient's entire active range of motion as peak torques occur through the middle of the ROM and there was no need to further stress the subject or impede on more of their time or put them at unnecessary risk for injury (11). The testing ranges and positions were chosen to gather data in positions similar to the stances of gait and functional measurements such as chair rise time.

For the hip, the range of motion in hip during gait is between 20 degrees extension and 30 degrees flexion for normal, healthy elders, and disabled elders (19). Therefore, the isometric angles tested during the extension/flexion trials were at 15 degrees and 30 degrees as they fall within this range and did not require the patient to change position during the test.

The ab-adductors were more difficult to test as it was hard to prevent rotation of the upper body while testing. This led to customizing the strap positioning in order to better secure the patient. The isometric angle used was 0 degrees as there were complaints of muscle soreness when performed at higher angles by pilot subjects. It would have been ideal to use 10 degrees (20) but the system only provides a choice between 0 and 15 degrees and it was decided that 0 degrees would be more comfortable. Nevertheless, the hip abductors could not be tested reliably using the isokinetic protocol. Reliable measurement of hip abductor strength is very important, as studies have shown increased hip abductor moment may slow the progression of medial knee OA (21). The ability to monitor this protective compensatory strategy in patients would depend considerably on acquiring reliable strength measures.

The knee strength tests utilized the prone protocol provided by the Cybex Norm Testing and Rehabilitation System manual. Prone was preferred to the potentially more comfortable supine position because it allowed the limb to better replicate the swing stance of gait. The knee was tested through the ranges of 0 to 70 degrees of flexion due to the relevance to gait (17, 19, 20, 21). The isometric angles chosen for testing were 15 and 60 degrees of flexion, as they fall within the range of motion of gait and other activities such as chair rise and stair climbing, similarly for the angles used in the isometric tests.

The ankle produced more reliable isokinetic results than isometric results. The isometric results were fair however the reliability may have been decreased by easily made small movements of knee which might affects the amount of force the joint can elicit from the rest of the limb. The isokinetic range of motion lent itself to repeatability as the peak torque would occur during the range and the same result could be seen.

Limitations of the study include small sample size and the determination of joint angles for the isometric tests using goniometry. However, this was found to be a practical method of determining joint angles quickly in order to replicate testing positions. The protocol developed and tested here only took 1.5hr to complete and the tests were performed by undergraduate students with basic anatomy training. The design of the protocol is simple and easily reproduced in order to quickly gather isokinetic and isometric measures of the hip in two planes, the knee and the ankle in the sagittal plane, as well as both active and passive range of motion bilaterally.

CONCLUSION

A repeatable lower-extremity testing protocol was developed for the CYBEX Humac Norm Isokinetic dynamometer. Dynamometry can be a reliable method for acquiring strength measures in young healthy adults; however, additional protocol refinement is needed, particularly for the hip abductors, for applications to older populations with lower-extremity musculoskeletal disease, such as knee OA.

Supported by NSERC Discovery Grant (# 312519-05) and CFI New Opportunities Fund (#10306).

REFERENCES

[1] S. Meireles, L. Oliveira, M. Andrade, A, Silva, and J. Natour," Isokinetic evaluation of the knee in patients with rheumatoid arthritis", *Joint Bone Spine.* vol. 69, pp. 566-573, 2002.

[2] S. Harridge, A. Kryger, and A. Stensgaard, "Knee extensor strength, activation, and size in very elderly people following strength training", *Muscle & Nerve* vol. 22,pp. 831-9,1999.

[3] M. Lomaglio and J.Eng, "Muscle strength and weight-bearing symmetry relate to sit-to-stand performance in individuals with stroke", *Gait & Posture* vol. 22, pp.126-31, 2005.

[4] A. Hsu, P.Tang, and M. Jan, "Test-retest reliability of isokinetic muscle strength of the lower extremities in patients with stroke", *Arch. Phys. Med. Rehail.* vol. 83, pp.1130 –7, 2002.

[5] C. Wang, S. Olson, and E. Protas, "Test-retest strength reliability: Hand-held dynamometry in community-dwelling elderly fallers", *Arch. Phys. Med. Rehail.* vol.83, pp.811-5, 2002.

[6] C. Ford-Smith, J. Wyman, J. Elswick and T. Fernandez, "Reliability of stationary dynamometer muscle strength testing in community-dwelling older adults", *Arch Phys Med Rebil.* vol.82, pp. 1128-32, 2001.

[7] M. Aquino et al., "Isokinetic assessment of knee flexor/extensor muscular strength in elderly women", *Rev. Hosp. Clin. Fac.* vol. 57, pp. 131-4, 2002.

[8] C. Emery, M. Maitland and W. Meeuwise, "Test-retest reliability of isokinetic hip adductor and flexor muscle strength", *Clin. J. Sport Med.* vol.9, pp.79-85, 1999.

[9] R. Mawdsley and J. Knapik, "Comparison of isokinetic measurements with test repetitions", *Phys. Ther.* vol. 62, pp.169-77, 1982.

[10] D. Pincivero, S. Lephart and R. Karunakara, "Reliability and precision of isokinetic strength and muscular endurance for the quadriceps and hamstrings", *Int. J. Sports Med.* vol. 18, pp.113-7, 1997.

[11] H. Clarkson, *Musculoskeletal assessment Joint range of motion and manual muscle strength,* 2nd Edition, Lippincott Williams & Wilkins, USA, 2000.

[12] G. Salem, M. Wang, J. Young, M. Marion, and G. Greendale "Knee strength and lower-and higher-intensity functional performance in older adults", *Medicine & Science in Sports & Excersice.* vol.32, pp.1679-84, 2000.

[13] P. Shrout and J. Fleiss, "Interclass correlations: uses in assessing rater reliability", *Psychol Bull*. vol.86, pp.420-8, 1979.

[14] M. Barnes, "Spasticity: A rehabilitation challenge in the elderly", *Gerontology.* vol.47, pp.295-9, 2001.

[15] M. Johnson, M. Millie, K. Martinez, G. Crombie, and M. Rogers, "Age-related changes in hip abductor and adductor joint torques", *Arch. Phys. Med. Rehabil.* vol.85, pp.593-7, 2004.

[16] E. Kellis and V. Baltzopoulos "Isokinetic eccentric exercise", *Sports Med.* vol.19, pp.202-22, 1995.

[17] D. Kerrigan, M. Todd, U. Della Croce, L. Lipsitz and J. Collins, "Biomechanical gait alterations independent of speed in the healthy elderly: Evidence for specific limiting impairments", *Arch. Phys. Med. Rehabil.* vol.79, pp.317-22, 1998.

[18] M. Porter, A. Vandervoort, and J. Kramer, "A method of measuring standing isokinetic plantar and dorsiflexion peak torques", *Medicine & Science in Sports & Exercise.* vol.28, pp.516-22, 1996.

[19] C. McGibbon and D. Krebs, "Discriminating age and disability effects in locomotion: Neuromuscular adaptations in musculosketal pathology", *J. Appl. Phys*. vol. 96, pp.149-60. 2004.

[20] J. Perry, *Gait Analysis: Normal and Pathological Function*, 1st Edition, Slack Incorporated, USA, 1992.

[21] J. Judge, R. Davis and S. Ounpuu, "Step length reductions in advanced age: The role of ankle and hip kinetics", *J. Gerontol. A. Biol. Sci. Med. Sci.* vol.51, pp. 303-12, 1996.