2018 ACCES23-CMBEC41

Joint Conference
Charlottetown PEI
May 8-11, 2018

ADAPTING ISOKINETIC DYNAMOMETRY FOR INDIVIDUALS WITH TRANSRADIAL AMPUTATION: A NEW TOOL

Jessica Chouinard, Victoria Chester and Usha Kuruganti
The Andrew and Marjorie McCain Human Performance Laboratory, Faculty of Kinesiology, University of New Brunswick, Fredericton, NB

INTRODUCTION

The loss of a limb can diminish an individual's ability to perform everyday activities [1]. Amputation prevalence rates have been difficult to estimate worldwide, as many countries do not keep records [2]. However, the National Limb Loss Information Centre has estimated 1.7 million United States residents live with an amputation and that one in every 200 individuals suffers from limb loss. Over the past 20 years, 82% of new amputations have emerged as a result of the aging population and increasing prevalence of vascular disease [3,4]. Lower limb amputations have been shown to occur three times more often than upper limb amputations and are commonly linked to vascular disorders. However, trauma-related and congenital amputations occur more frequently in the upper limbs [5,6] with 57 percent of upper limb amputations occurring below the elbow (transradial).

Quantitative clinical assessment of function including strength assessment has been challenging due to the complexity of the muscle physiology of those with amputations. It is important to examine muscle function in prosthesis users in both the residual and intact limb to better understand mobility. One of the challenges of studying muscle function with prosthesis users is the ability to use standard muscle function devices to examine parameters such as muscle force. Furthermore, it is critical that muscle function is examined under both static and dynamic conditions to improve mobility. Davidson [7] observed that there were no measures or devices available to specifically evaluate the functional ability of those with upper limb amputations. While there are few devices commercially available to obtain such measurements, it is precisely these devices that will aid in the development, understanding and research in the field of prosthetics [7, 8,9,10]. The few devices available to measure function include hand held dynamometry and the ambulatory accelerometry technique [7]. It remains challenging to accurately measure dynamic muscle strength from those with transradial amputations, with or without the use of a prosthesis.

One method of safely examining dynamic movements is the use of isokinetic dynamometers. These machines allow measurement of upper and lower extremity isokinetic movements at controlled angular velocities while ensuring no stress is placed on the individual (even if the participant is unable to move the lever arm). These devices are popular in rehabilitative medicine [11] and can provide information regarding dynamic muscle contractions. Isokinetic dynamometers are considered the gold standard method to measure produced joint torque [12]. Currently no commercially available isokinetic dynamometer adapter exists for prosthesis users to take advantage of isokinetic technology. Ideally, prosthesis users would be able to use this technology with and without their prosthetic limb.

The purpose of this project was to develop an adapter that can be used by those with transradial amputations to safely and effectively operate an isokinetic dynamometer. The tool that was developed connects to the arm of the dynamometer and is adjustable for different prosthesis users with varying residual limb length. One participant was presented with the adapter and asked to produce a series of contractions to determine the adapter's usability.

METHODS

Tool Design

The design objective of the adapter was to accommodate individuals with amputations with varying residual limb length to use the isokinetic dynamometer in both stationary (isometric) and dynamic (isokinetic) modes. In addition, the adapter was designed to accommodate the limb with and without a prosthetic attachment. Specifically, the following design requirements were considered:

- Adjustability in three planes
- Accommodation for various limb lengths and sizes and for patient comfort
- The ability to perform full range of motion
- Construction from a rigid material to allow for data collection in a closed system.

The isokinetic dynamometer is shown in Figure 1.

The adapter (patent pending) was created in two parts: a steel structure and the carbon fiber receiver creating the interface between the user and the machine. Both parts were custom machined in-house. (Figure 2).

The adapter was designed to accommodate users of different anthropometrics. It was assumed that a design based on the 95th percentile of the forearm length (31.6 cm) and forearm circumference (33.6 cm) of US Army Men would fit most trans-radial amputees' residual limbs [13].

The adapter was designed to accommodate both a residual limb from amputation as well as a prosthesis. Adjustability was critical and the adapter was designed to attach to the isokinetic dynamometer and adjust up and down, in and out of the elbow and in the sagittal plane.

Prosthesis User Testing

One 64-year-old male who had his right arm amputated below the elbow following a traumatic accident participated in the testing of the adapter. The participant was recruited through the Atlantic Limb Deficiency Clinic. This research project was approved by the university research ethics board.

Instrumentation

The adapter was tested using the Cybex HUMAC®/NORM™ Testing and Rehabilitation System, model 770 (CSMI). All data were recorded with the associated computer software (HUMAC2009v10.000.0037) at a frequency of 100 Hz.

Testing

The participant was asked to lay down on the isokinetic dynamometer and the adapter was placed over his residual limb and adjusted for comfort (Figure 3). The adapter was then connected to the elbow flexion and extension arm of the dynamometer (Figure 4). For the isometric testing, the elbow angle was set at 90 degrees as determined by measurements performed by the system software and reconfirmed with a goniometer where the actual elbow angle was found to be between 80 and 84 degrees. The participant was asked to perform a five-second isometric elbow extension practice trial, followed by a 90-second rest period. Then the participant was asked to perform three sets of five-second isometric elbow extensions, followed by 90 seconds of rest.

Once the participant completed the isometric contraction protocol, he was asked to complete the isokinetic testing (elbow flexion and extension). There was a resting period of ten minutes between each protocol to reduce fatigue. The isokinetic testing occurred through a range of motion between 120 and 135 degrees (measured with a goniometer) depending on the movement tested, elbow flexion or elbow extension. The shoulder was placed in complete adduction with the upper arm along the participant's trunk. During the isokinetic contraction testing, the participant was provided a practice trial followed by three identical trials with 90 seconds of rest between each trial. While testing isokinetic flexion, the dynamometer speed was set at 25 degrees per second for concentric elbow flexion and at 90 degrees per second for concentric elbow extension. While testing isokinetic elbow extension, the dynamometer speed was set at 25 degrees per second for concentric elbow extension and at 90 degrees per second for concentric elbow flexion.

The entire testing protocol (isometric and isokinetic movements) was completed twice with three weeks in between testing days. The strength data were then compared between the two days.

RESULTS

The shape of the adapter allowed for adequate adjustments to align the axis of rotation of the elbow with the axis of rotation for the dynamometer. Thus, the execution of both isokinetic elbow flexion and extension resulted in a dynamic motion isolated at the elbow. The participant's strength data was compared between two testing sessions separated by three weeks. The results are shown in Table 1. The strength data suggests that while there were changes in the values of strength attained between days, the participant was able to produce both isometric and isokinetic contractions. The participant was also asked for their feedback regarding the design and the usability of the adapter.

DISCUSSION AND CONCLUSIONS

The prosthesis user that was tested noted that the comfort and ease of use could be a concern depending on the length of the residual limb. It was noted that the selected fabric that formed the interface between the adapter and the user caused skin irritation due to its rough surface. The edges of the straps holding the participant's forearm produced some skin marks that could potentially lead to breaks in the skin. As a remedy to further skin irritation, the residual limb was wrapped in a thin, adherent, and soft material. It was important to have a thin material to avoid restriction in elbow range of motion. Future refinement of the device will consider embedding this material into the adapter for greater user comfort.

The adapter designed has a unique shape that allows infinite adjustments to align the axis of rotation of the joint involved in the motion, the elbow in this situation, with the axis of rotation of the dynamometer. The prototype adapter will enable trans-radial amputees to use the HUMAC®/NORM™ Testing and Rehabilitation System and possibly other compatible isokinetic dynamometer for rehabilitation purposes. The prototype adapter, or any improved version, will facilitate improved research that examines trans-radial amputees muscle activity under controlled dynamic conditions.

Nonetheless, further testing is required to assess the validity and the reliability of the prototype adapter used for an elbow range of motion in order to label this adapter a research tool. An additional suggestion would be to test the prototype adapter not only with trans-radial amputees, but also with trans-humeral amputees.

FIGURE AND TABLES

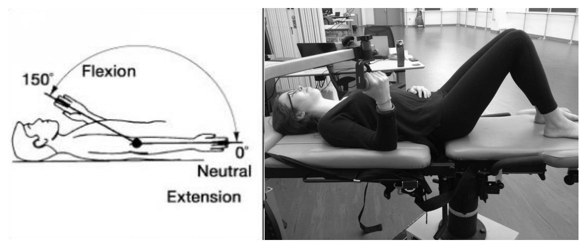

Figure 1: Isokinetic Dynamometer Adjusted for Elbow Extension. Able-bodied participant using the standard isokinetic adapter.

Figure 2: Prototype Adapter. The adapter connects to the centre of rotation of the isokinetic dynamometer.

Figure 3: Prosthesis User with Adapter Fitting. The user was asked to lay comfortably on the dynamometer and place his residual limb in the adapter.

Figure 4: Prosthesis Adapter in Preparation for Exercise. The prosthesis user has placed his residual limb in the adapter and is prepared to complete a series of contractions using the device.

Table 1: Isometric and Isokinetic Peak Torque (Nm) During Isometric and Isokinetic Elbow Extension and Flexion. Day 1 and Day 2 data are separated by three weeks. Percent change indicates the decrease (-) and increase (+) in torque data between the two testing sessions.

	Isometric Peak Torque (Nm)		**Percent Change**
	Day 1	**Day 2**	
Extension	34.0	26.6	-21.8
	Isokinetic Peak Torque (Nm)		**Percent Change**
	Day 1	**Day 2**	
Extension	44.3	50.4	+13.8
Flexion	20.0	16.1	-19.5

ACKNOWLEDGEMENTS

The authors want to acknowledge the valuable help of Wendy Hill, Research Occupational therapist at the Institute of Biomedical Engineering (IBME) at the University of New Brunswick who contributed to the functional testing of the prototype adapters and Greg Bush, Research Prosthetist (IBME) and Steve Blazeski, Prosthetics Research Technician (IBME) for their contribution to the design process.

REFERENCES

[1] T. Kuiken, G. Li, B. Lock, R. Lipschutz, L. Miller, K. Stubblefield, and K. Englehart, "Targeted muscle reinnervation for real-time myoelectric control of multifunction artificial arms," Journal of American Medical Association, 301(6), pp. 619–628, 2009.

[2] A. Esquenazi, "Amputation rehabilitation and prosthetic restoration. From surgery to community reintegration," Disability and Rehabilitation, *26*(14/15), pp. 831-836, 2004.

[3] Olefsky, J.M., "Prospects for Research in Diabetes Mellitus," Journal of American Medical Association, 285(5), pp. 628-632, 2001.

[4] Ritchie & Connell, 2007) S.A. Ritchie, and J.M.C. Connell, "The link between abdominal obesity, metabolic syndrome and cardiovascular disease," Nutrition, Metabolism and Cardiovascular Diseases, 17(4), pp. 319-326, 2007.

[5] A. Esquenazi and R.H. Meier, "Rehabilitation in limb deficiency. 4. Limb amputation," Archives of Physical Medicine and Rehabilitation, *77*, pp. S-18, 1996.

[6] Amputee Coalition of America, Amputee Coalition of America. *National limb loss information center: Fact Sheet.* Retrieved 02/29, 2012, from http://www.amputeecoalition.org/fact_sheets/amp_stats_cause.html, 2012.

[7] J. Davidson, "A comparison of upper limb amputees and patients with upper limb injuries using the Disability of the Arm, Shoulder and Hand (DASH)," Disability and Rehabilitation, 26, pp. 917- 923, 2004.

[8] L.M. Hermansson, A.G. Fisher, B. Bernpång and A.C. Eliasson, "Assessment of capacity for myoelectric control: a new Rasch-built measure of prosthetic hand control," J Rehabil Med, 37, pp. 166-171, 2005.

[9] J. Raad, Rehab Measures - Hand Held Myometry/ Dynamometry. The Rehabilitation Measures Database. Retrieved May 27, 2014, from http://www.rehabmeasures.org/Lists/RehabMeasures/ DispForm.aspx?ID=1052

[10] V. Wright, " Prosthetic Outcome Measures for Use With Upper Limb Amputees: A Systematic Review of the Peer-Reviewed Literature, 1970 to 2009," American Academy of Orthotists & Prosthetists, 21(4S), P3-P63, 2009.

[11] L.R. Osternig, " Isokinetic dynamometry: implications for muscle testing and rehabilitation," Exerc Sport Sci Rev, 14, pp. 45-80, 1986.

[12] J.B. de Araujo Ribeiro Alvares, R. Rodrigues, R. de Azevedo Franke, B.G. da Silva, R.S. Pinto, M.A. Vax, and B.M. Baroni, « Inter-machine reliability of the Biodex and Cybex isokinetic dynamometers for knee flexor/extensor isometric, concentric and eccentric tests," Phys Ther Sport, 16, pp. 59-65, 2015.

[13] Department of Defense. (1991). Military Handbook: Anthropometry of U.S. Military Personnel (Metric). (DoD-HDBK-743A). Washington , DC: U.S. Government Printing Office.