New Assessment of Forearm Strength: Reliability and Validity

Christopher Kevin Wong, Neil Moskovitz

OBJECTIVE. The objective was to determine the reliability of a portable forearm strength hydraulic dynamometer with a doorknob handle and assess its validity compared with a Cybex 6000 (Cybex International, Inc., Medway, MA) isometric torque assessment.

METHOD. Eighteen volunteers (with a total of 30 forearms) participated in this one-session methodological study to determine the intra- and interrater reliability and criterion validity of a forearm dynamometer.

RESULTS. Intrarater reliability for both assessors for pronation was (intraclass correlation coefficient \( [ICC_{3,1}] = .937–.961 \)) and for supination was (\( ICC_{3,1} = .923–.968 \)). Interrater reliability for pronation was \( ICC_{3,2} = .927 \) and for supination was \( ICC_{3,2} = .847 \). Criterion validity of the Baseline hydraulic dynamometer (Fabrication Enterprises Inc., White Plains, NY) compared with the Cybex 6000 was .574–.664 for pronation and .749–.750 for supination.

CONCLUSION. The Baseline hydraulic dynamometer with a more functional doorknob handle had good intra- and interrater reliability and demonstrated moderate validity compared with Cybex 6000 strength testing.

The ability to manipulate objects with the hands depends on the balanced muscular function of the upper extremity and the interrelated functions of the forearm and other joint segments (Alizadehkhaiyat, Fisher, Kemp, Vishwanathan, & Frostick, 2007). In clinical assessment instruments used to assess functional progress during wrist and forearm rehabilitation, forearm strength contributes up to 25% of the overall functional assessment (Sauer, Lozano-Calderon, & Ring, 2008). Thus, forearm pronation and supination strength are integral parts of the rehabilitation of people with elbow disorders, such as lateral epicondylitis (Alizadehkhaiyat et al., 2007; Erak, Day, & Wang, 2004; Kohia et al., 2008), rheumatoid arthritis (Shigeyama, Inoue, Hashizume, Nagashima, & Senda, 1997), forearm fractures (Dubberley, Faber, MacDermid, Patterson, & King, 2006; Droll et al., 2007; Sauer et al., 2008), and nerve impairment (Rainville, Noto, Jouve, & Jenis, 2007; Rosén, Dahlin, & Lundborg, 2000) as well as the development of baseball (Szymanski, Szymanski, Molloy, & Pascoe, 2004) and tennis athletes (Alizadehkhaiyat et al., 2007; Ellenbecker, Roetert, & Kiewald, 2006).

Forearm strength assessment has often been limited to grip strength (Kohia et al., 2008; Rosén et al., 2000). When forearm pronation and supination have been assessed, a variety of methods have been used, including manual muscle tests (Rainville et al., 2007), weight-lifting maximum repetitions (Szymanski et al., 2004), research torque cells devices (Matsuoka, Berger, Berglund, & An, 2006; O’Sullivan & Gallway, 2005; Shigeyama et al., 1997), work simulators (Droll et al., 2007; Dubberley et al., 2006), and isokinetic rehabilitation and assessment devices such as the Cybex 6000 (Ellenbecker et al., 2006). The gold standard for strength assessment of forearm pronation and supination muscles could be considered to be work simulators and isokinetic devices such as the Cybex 6000, which has consistently demonstrated test–retest reliability coefficients of >.90 for
strength assessments (Bandy & McLaughlin, 1993). O’Sullivan and Gallwey (2005), however, pointed out that “forearm torque strength is not commonly measured” (p. 707), perhaps because clinicians lack a portable clinical assessment device that is both reliable and valid.

Work simulators and isokinetic assessment devices both measure isometric torque as the patient or client attempts to twist a bar-shaped vertical handle (Droll et al., 2007; Drubberly et al., 2006; Ellenbecker et al., 2006). The elbow has often been set in a position of 90° flexion (Gordon, Pardo, Johnson, King, & Miller, 2004; Shigeyama et al., 1997), a position found to maximize supination strength (O’Sullivan & Gallwey, 2002) because the position optimizes the moment arm of the biceps. Pronation strength was strongest in 45° elbow flexion (O’Sullivan & Gallwey, 2002). The position of the forearm has also been found to affect forearm strength and muscle activity. On the one hand, strength has been greatest when the relevant muscles were lengthened (i.e., supination torque was greatest in a pronated forearm position and vice versa; Matsuoka et al., 2006; O’Sullivan & Gallwey, 2002). On the other hand, forearm muscle activation as measured with electromyography has been greater when the muscle was in the shortened position (i.e., supination activation was greatest in the supinated position; Gordon et al., 2004). Grip position may also affect strength, because it has been found that forearm position alters grip strength (Richards, Olson, & Palmiter-Thomas, 1996). Although the bar-shaped vertical handle is common (Gordon et al., 2004; Matsuoka et al., 2006; Shigeyama et al., 1997), a bar handle inclination angle of 70° has been tried to more closely approximate the power grip position (O’Sullivan & Gallwey, 2005).

In the course of performing a typical range of activities of daily living (ADLs), it is inevitable that people will grasp many different objects, such as doorknobs or screwdrivers, with a variety of different grasps. A new Baseline hydraulic dynamometer (BHD; Fabrication Enterprises Inc., White Plains, NY) designed to assess forearm pronation and supination strength has multiple attachments that mimic different everyday objects that may be manipulated. The BHD is a portable unit that can be outfitted with a bar-shaped vertical handle, doorknob, lever-style door handle, or screwdriver to simulate a variety of functional grips used in ADLs.

The objective of this study was to determine the reliability of the BHD portable forearm strength hydraulic dynamometer outfit with a doorknob handle and to assess its validity compared with a Cybex 6000 isometric torque assessment.

Method

Participants

This study examined a convenience sample of 18 healthy volunteers without disabilities recruited from a school of health sciences. All 18 volunteers were allied health science students: 17 were right-hand dominant, and 1 was left-hand dominant (Table 1). Six forearms were excluded because of ipsilateral upper-extremity pain or past dysfunction: 2 because of pain at rest, 2 because of rotator cuff pathology, 1 because of shoulder osteoarthritis, and 1 because of history of wrist fracture. Ultimately, 12 dominant and 18 nondominant forearms were included. The institutional review board of Touro College School of Health Sciences approved this study, and all participants signed an informed consent.

Design

We used a single-group repeated-measures design to establish the (1) test–retest intrarater reliability, (2) interrater reliability, and (3) criterion validity, compared with the Cybex 6000, of forearm pronation and supination strength assessment using the BHD.

Procedures

All volunteers came for one fall afternoon session during which pronation and supination strength were assessed with the BHD and the Cybex 6000. The BHD was outfitted with a 5.5-cm-diameter doorknob handle (5.8-cm depth) mounted securely on a tabletop platform. Each participant was instructed by a single assessor to sit grasping the doorknob with both shoulder and elbow positioned in visually approximated 45° flexion. The forearm was positioned in neutral and strapped to the platform with a hook-and-loop elbow band (Figure 1). The wrist was positioned in slight extension, and the participant was allowed to grasp the doorknob with a degree of ulnar deviation that was comfortable to generate an isometric twisting force to the knob. Isometric twisting force on the BHD results in force measured in kilograms. The Cybex 6000 was set up with a standard vertical bar handle (12.5 cm length, 3.7 cm diameter) with elbow and shoulder in 45° flexion; each participant was seated with his or her forearm stabilized in neutral and resting on a cushioned stand. The wrist was positioned in neutral with approximately 0° of ulnar deviation because of the vertical position of the bar handle (Figure 2). The Cybex 6000 results in torque measured in Newton-meters (Nm).

Two assessors measured the pronation and supination strength of each forearm using the BHD; a third assessor measured forearm pronation and supination strength using the Cybex 6000. All assessors were 3rd-yr doctor of physical therapy students specifically trained in BHD and Cybex forearm strength assessment during 5 hr of training over three sessions by the first author (Wong), who is a licensed physical therapist and orthopedic-certified specialist. Test order for the assessors was randomized, and all assessors were blinded to the other assessors’ results as well as to their own past results. Test order for pronation or supination was also randomized.

Participants were instructed to perform one pretest maximal isometric contraction with the verbal prompt “turn as hard as

Table 1. Participant Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Measurement</th>
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<tr>
<td>Participants</td>
<td>18 (10 men, 8 women)</td>
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<tr>
<td>Forearms</td>
<td>30 (17 male; 13 female)</td>
</tr>
<tr>
<td>Age (average)</td>
<td>26.8 ± 4.4 yr</td>
</tr>
<tr>
<td>Weight (average)</td>
<td>77.1 ± 19.5 kg</td>
</tr>
<tr>
<td>Height (average)</td>
<td>174.1 ± 11.7 cm</td>
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<tr>
<td>BHD pronation (average)</td>
<td>65.3 ± 23.1 kg</td>
</tr>
<tr>
<td>BHD supination (average)</td>
<td>61.9 ± 27.3 kg</td>
</tr>
<tr>
<td>Cybex pronation (average)</td>
<td>5.4 ± 2.8 Nm</td>
</tr>
<tr>
<td>Cybex supination (average)</td>
<td>5.0 ± 2.3 Nm</td>
</tr>
</tbody>
</table>

Note: BHD = Baseline hydraulic dynamometer; Nm = Newton-meters.
you can” spoken at conversational volume. The assessors then repeated three trials of each strength assessment using the same verbal prompt, recording the average of the three trials for each motion, with 30-s rests between each repetition. After a 1-min rest period, each participant then performed three trials of the next motion with 30-s rests between repetitions. Each participant had a 3-min rest period before being assessed by the next assessor.

Statistical Analysis

The test–retest intrarater reliability of an assessment is obtained when the same assessment is administered by the same rater twice. Interrater reliability of an assessment is obtained when the same assessment is administered by two or more assessors. Criterion-referenced validity of a new assessment method can be determined by comparing the results of the new method with those of an accepted or gold-standard method. Data were collected to analyze (1) the test–retest intrarater reliability of the two assessors using the BHD to assess forearm pronation and supination strength, (2) the intrarater reliability of the two BHD assessors, and (3) the criterion-referenced validity of the BHD assessments of the two assessors compared with Cybex strength assessment by the third assessor.

All statistical analysis was performed with SPSS 16.0 statistical package (SPSS–UK Ltd., Surrey, UK). Test–retest intrarater reliability was assessed using single-measure intraclass correlation coefficients (ICC3,1). Interrater reliability of the average measures was assessed by calculating ICC3,2. An acceptable level for good reliability was set at ICC ≥ .75 using common guidelines for the magnitude of reliability (Portney & Watkins, 2000). Criterion-referenced validity was determined by calculating Pearson’s correlation coefficient; an acceptable range was set at r ≥ .70 for average measures of BHD and Cybex 6000 strength assessments.

Results

Participant characteristics are presented in Table 1. Intrarater reliability of the two assessors for pronation strength (ICC3,1) ranged from .937 to .961; for supination strength, it ranged from .923 to .968. Interrater reliability for pronation strength (ICC3,2) was .927; for supination strength (ICC3,2), it was .847 (Table 2). The Pearson correlation coefficient for the two assessors using the BHD compared with the Cybex 6000 strength assessment for pronation ranged from .574 to .664 and for supination ranged from .749 to .750.

Discussion

Using the doorknob-equipped BHD, both assessors demonstrated good intrarater reliability for assessment of both pronation and supination strength with all ICC coefficients >.90. Interrater reliability between the two assessors for both motions was also good, although assessment of supination strength (ICC = .847) demonstrated lower reliability than pronation (ICC = .927). The reliability for forearm strength assessed with the BHD was consistent with the range of reliability coefficients (.82–.99) reported for intrarater reliability of upper-extremity strength assessments with other dynamometers (Bohannon, 1986; Magnusson, Gleim, & Nicholas, 1990; May, Burnham, & Steadward, 1997), suggesting that the BHD with doorknob handle can be used to
Table 2. Intraclass Correlation Coefficients (ICCs) for Intra- and Interrater Reliability of Forearm Strength

<table>
<thead>
<tr>
<th>Reliability</th>
<th>Intrarater 1 (95% CI)</th>
<th>Intrarater 2 (95% CI)</th>
<th>Interrater (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pronation</td>
<td>.937 (.892–.966)</td>
<td>.961 (.931–.979)</td>
<td>.927 (.845–.966)</td>
</tr>
<tr>
<td>Supination</td>
<td>.923 (.869–.958)</td>
<td>.968 (.944–.983)</td>
<td>.847 (.692–.924)</td>
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Note. CI = confidence interval.
forearm strength such as Cybex. Future research should pursue forearm strength measures in symptomatic and dysfunctional patient populations, such as those with lateral epicondylitis or healing fractures. A potential line of inquiry is to involve correlating forearm strength assessed using the doorknob-outfit BHD with the functional performance level of related ADLs, such as opening a door or a jar. The BHD comes with other adaptive attachments designed to mimic functional tasks, including a 20-cm-long, 3-cm-diameter screwdriver and a 24-cm-long, 2-cm-thick, lever-style door handle. Future research may investigate the reliability and validity of the BHD using these alternate attachments. Another line of inquiry is to determine whether strength changes documented using the BHD occur after a course of treatment and whether any strength change correlates to changes in functional performance. Such research may be useful to support treatment interventions for those with upper-extremity dysfunction and pain.

Conclusion
The BHD is a portable, reliable, and valid tool for measuring forearm strength when outfitted with a doorknob-shaped handle. Assessing strength with a device that mimics common functional tasks of daily living may provide the clinician with more insight into a person’s abilities and limitations. ▲

Acknowledgment
These data were previously reported in the context of another study in a research poster at the 2009 American Physical Therapy Association Annual Conference in Baltimore, Maryland.

References