Objective. The purpose of this study was to establish test–retest reliability values for the newly designed grip and wrist attachments of the BTE Primus® and to determine criterion-related validity of the new grip attachment against the Jamar dynamometer. An additional purpose was to explore the differences in grip and wrist flexion strength between wheelchair users and control participants without disabilities and to examine the effect of body position on strength in persons without disabilities.

Method. Wheelchair users and matched controls (13 per group) were tested for grip and wrist flexion strength on the BTE Primus and for grip on the Jamar dynamometer.

Results. The BTE Primus grip attachment was found to be valid and reliable. No significant differences were found in static and dynamic grip or wrist flexion strength between the two groups or in the sitting versus standing position for the control group.

Conclusion. The findings suggest that the BTE Primus may be used to assess grip and wrist flexion strength validly and reliably for both wheelchair users and persons without disabilities.

Orit Shechtman, Leanne MacKinnon, Catherine Locklear

Key Words: hand strength testing • reliability of tests • validity of tests

Spinal cord injury (SCI) and lower-extremity amputation are two conditions that may lead to wheelchair use. As a consequence of lower body dysfunction, persons with paraplegia and lower-limb amputation must rely on their upper extremities for functional mobility. Repetitive activities, such as wheeling and transferring, place stress on the bones, joints, and soft tissues of the upper extremities, resulting in cumulative trauma disorders that may, in turn, cause decreased strength and function of the upper extremities (Pentland & Twomey, 1994a, 1994b). Wheeling and transferring activities allow persons with SCI or lower-extremity amputation to interact in the community and are thus related to life roles and occupations important for independence, self-esteem, and quality of life (Pentland & Twomey, 1994b).

Findings about upper-extremity pain in wheelchair users are clearer than those about upper-extremity strength. Many authors agree that approximately 60% of persons with SCI experience upper-extremity pain, which is most often either located in the shoulder joint or related to carpal tunnel syndrome (Gellman et al., 1988; Gellman, Sie, & Waters, 1988; Pentland & Twomey, 1994a; Sie, Waters, Adkins, & Gellman, 1992). Additionally, shoulder pain and rotator cuff impingement are common problems in wheelchair athletes (Burnham, May, Nelson, Steadward, &...
Reid, 1993; Curtis & Black, 1999). However, the question of whether strength in wheelchair users is greater or lesser than their counterparts without disabilities seems to depend on the specific muscle group tested as well as on the type of strength testing (isometric vs. isokinetic) (Burnham et al., 1993; Calmels, Berthouze, Barral, Domenach, & Minaire, 1992; Pentland & Twomey, 1994; Powers, Newsam, Gronley, Fontaine, & Perry, 1994).

The Baltimore Therapeutic Equipment (BTE) Work Simulator (and its latest version, the BTE Primus®) is a device that measures static and dynamic muscle strength. The device is used for both evaluation and treatment in a wide variety of rehabilitation settings and with many different patient populations. The BTE Work Simulator is designed not only to measure the strength of various muscle groups, but also to simulate activities of daily living and job tasks (BTE, 1995). The BTE Primus was designed to accommodate persons who use a wheelchair for mobility. However, to date, standardization of the grip and wrist attachments (or any other attachments) for wheelchair users does not exist. Standardizing the various attachments for wheelchair users is important because of documented differences in muscle strength between wheelchair users and persons without disabilities (Burnham et al., 1993; Calmels et al., 1992; Pentland & Twomey, 1994; Powers et al., 1994) and between sitting and standing positions (Teraoka, 1979). Standing is the standardized testing position on the BTE Primus (BTE, 1995); however, wheelchair users obviously cannot be tested in standing. Thus, separate standardized testing positions and protocols, reliability and validity values, and normative data are needed to assess wheelchair users with the BTE Primus.

Standardization of an assessment includes developing administration and interpretation protocols and establishing reliability, validity, and normative values for the instrument (Fess, 1995). The process of determining criterion-related validity involves administering both tests to one group of participants and correlating the scores on the target test with those of the criterion measure (Portney & Watkins, 1993). The Jamar dynamometer is the gold standard criterion test for grip strength (Fess, 1992; Mathiowetz, Weber, Volland, & Kashman, 1984). In the present study, strength scores on the BTE Primus grip attachment (the target test) were correlated with scores on the Jamar dynamometer. Normative data provide for comparison of the patient to the general population and may assist in establishing long-term goals for the rehabilitation process (Benson & Schell, 1997). Normative values for specific patient populations would also be helpful so that therapists can refer to them when assessing therapeutic progress.

Some attachments of the BTE Work Simulator have

1. Establish preliminary reliability, validity, and mean data values for static and dynamic grip and wrist flexion on the BTE Primus for wheelchair users and persons without disabilities.
2. Determine whether a significant difference exists in static and dynamic grip and wrist flexion measurements between wheelchair users and seated persons without disabilities.
3. Examine the effects of body position (sitting vs. standing) on grip and wrist flexion measurements in persons without disabilities.

**Method**

**Participants**

All participants were adults (18–55 years of age) without cognitive impairment. Inclusion criteria for wheelchair users (mean age = 36.23 ± 6.89 years) were using a manual wheelchair for more than 50% of functional mobility and having an SCI at or below the T2 level, an above-knee amputation, or both (duration of injury = 13.14 ± 8.83 years). Exclusion criteria were having current upper-extremity dysfunction and being ambidextrous. The exclusion criterion for control participants without disabilities (mean age = 34.92 ± 9.56 years) was having a known history of physical disability. Thirteen wheelchair users (10 with paraplegia, 2 with amputations, 1 with both conditions) and 13 control participants gave written consent to testing. The control participants were matched by gender (9 men, 4 women), age (within 5 years), and activity level (low, medium, high) to the wheelchair users. All participants had moderate to high activity levels, and 5 wheelchair users were basketball players. The participants were recruited from the student body at the University of

1. Baltimore Therapeutic Equipment Company, 7455-L New Ridge Road, Hanover, Maryland 21076.
2. Sammons Preston, 4 Sammons Court, Bolingbrook, Illinois 60440.
Florida, the GatorSport Exploration Camp (for adults with disabilities) sponsored by the Occupational Therapy Department at the University of Florida, and from the local wheelchair basketball team.

**Instruments**

Attachment #162 (grip; see Figure 1) and attachment #701 (wrist flexion; see Figure 2) of the BTE Primus were used for the static and dynamic grip strength measurements. The Jamar dynamometer was used as a gold standard criterion measure for establishing the validity of static grip strength testing on the BTE Primus.

All participants completed a demographic questionnaire designed to ensure matching between wheelchair users and control participants for age, gender, and activity level. In the activity level portion of the questionnaire, participants listed all physical activities that they performed regularly, including duration (min/day) and frequency (days/week). They were then asked to classify their activity level into one of the following categories: low (≥ 30 min, 1–2 times per week), moderate (≥ 30 minutes, 3–5 times per week), or high (≥ 30 min, 6–7 times per week).

Participants also completed the McGill Pain Questionnaire (Melzack & Katz, 1992), which was used to exclude participation in the study because of upper-extremity dysfunction. The McGill Pain Questionnaire was found to be a reliable and valid tool for pain measurement (Melzack & Katz, 1992). The score is based on a combination of words chosen from 20 subscales describing different aspects of pain. The word combination is used to specify the sensory and affective qualities of pain and to express the subjective overall present pain intensity. We modified the McGill Pain Questionnaire by instructing participants to respond on the sole basis of their upper-extremity and back pain, thereby excluding phantom pain in participants with amputation and lower-extremity pain related to injury in participants with SCI.

**Procedure**

Before strength testing, all participants signed the consent form (approved by the Institutional Review Board of the University of Florida’s Health Science Center) and completed the demographic and pain questionnaires. They then began strength testing with their dominant arm. Hand dominance was determined by asking the participants if they were right-handed or left-handed and which hand they used for writing. Participants performed all static grip tests first, followed by dynamic grip tests.

**Static strength tests.** Three static strength tests were performed in random order: a static grip strength test on the Jamar dynamometer, a static grip strength test on the BTE Primus, and a static wrist flexion strength test on the BTE Primus. Each test consisted of three repeated trials, and each trial was held for 6 sec. A 30-sec rest interval was provided after each trial and a 2-min rest period was given after each test. After completion of the three static strength tests, a 10-min rest period was given. During this rest period, the participant completed the past pain version of the McGill Pain Questionnaire. Following the rest period, the series of three static strength tests was repeated.

Overall, in the two sessions of static strength testing, each participant performed 12 grip trials (6 on the Jamar, 6 on the BTE Primus) and 6 wrist flexion trials (all on the BTE Primus) with the dominant hand. The average of the three trials on each test was recorded as the maximal static strength score and used in subsequent analyses.

**Dynamic strength tests.** After completing two sessions of static strength testing, another 10-min rest interval was given, followed by dynamic strength testing. Both dynam-
ic grip and wrist flexion strength tests were performed on the BTE Primus. Each test consisted of three trials of as many maximal dynamic contractions as possible in 10 sec at a load of 50% of maximal static strength. A 30-sec rest interval followed each trial, and a 2-min rest period was given between the dynamic grip and wrist flexion strength tests. The series of dynamic strength tests was repeated after an additional 10-min break. The average of the three trials, expressed in engals, was recorded as the participant’s maximum dynamic strength and used in subsequent analyses.

An engal is a unit of power defined as the effort required to move a load of 1 in.-lb ° in 1 sec (BTE, 1995). The rest periods were an attempt to eliminate the effects of fatigue as indicated by Trossman and Li (1989). For a flow chart demonstrating a sample testing order, see Table 1.

Testing protocol. The order of the three static strength tests was randomly assigned for the wheelchair users, and that same order was used for their matched controls. The randomization was as follows: Each wheelchair user was randomly assigned to begin strength testing either with grip or with wrist flexion; then, the grip strength testing, beginning with either the Jamar dynamometer or the BTE Primus, was randomly assigned. The second session of static strength tests was given in the same order as the first, as were the dynamic strength tests (excluding the Jamar dynamometer). The wheelchair users performed both series of static strength tests sitting, whereas the control participants performed one series of static strength tests sitting and one standing. The order of sitting and standing also was randomly assigned.

The BTE Primus and Jamar dynamometer were balanced and calibrated daily (BTE, 1995; Fess, 1987). During testing, the computer monitor of the BTE Primus and the dial of the Jamar dynamometer were positioned so that the participant could not see the display. No visual or auditory feedback was provided. To ensure consistency, the participant was not coached during testing and only standardized verbal directions were given. To test all subjects while sitting, a standard chair with four legs, full back support, and no armrests was used. When testing on the BTE Primus while sitting, the chair’s leg position was marked with tape on the floor to ensure that the exact position was replicated in subsequent testing sessions. To familiarize the participants with each task, the test administrator demonstrated the test and gave a submaximal practice trial immediately before each test in the first session.

For both static and dynamic strength testing on the BTE Primus, the participant either was seated in a chair or was standing. The height of the attachment was adjusted and recorded to ensure consistency during subsequent testing. The position of other body parts was the same as for testing on the Jamar dynamometer and as recommended by the American Society of Hand Therapists (ASHT; Fess, 1992). In short, the participant was sitting with shoulders level, adducted, and neutrally rotated. The elbow was flexed at 90°, forearm in neutral, and wrist in 0° of dorsiflexion. The participant grasped the tool in a handshake position. The only differences in position for the wrist flexion test were as follows: the forearm was pronated as well as supported by and strapped to the platform of the attachment to maintain position. The wrist was positioned in neutral for the static testing and was initially positioned in full extension for the dynamic power testing. During all strength tests, the participants held a small block between the upper arm of the dominant hand and the lateral thorax to prevent substitution patterns. One deviation from the ASHT-recommended position was that the control participants were instructed to place their legs in an outstretched position while sitting in an attempt to equalize the stabilizing ability of wheelchair users and controls by preventing the control participants from stabilizing themselves with their legs. Another deviation from the ASHT-recommended position was when the control participants were tested while standing. Both the Jamar dynamometer and the BTE Primus grip attachments were placed at the second handle position for all participants (Fess, 1992).

Data Analysis

The average of three trials of each strength test was calculated for each participant and used in the subsequent data analyses. Descriptive statistics were conducted on static and dynamic strength scores for men and women in the two groups. Correlation coefficients were calculated to establish validity and test–retest reliability of the BTE Primus grip and wrist attachments. To determine the criterion-related validity, a Pearson product-moment correlation coefficient was calculated on the average scores rendered from the BTE Primus versus the average scores on the Jamar dynamometer. To determine test–retest reliability, Pearson product-moment correlations were calculated on scores in the first versus the second testing sessions (Portney & Watkins, 1993).

Comparisons were conducted on groups (wheelchair

<p>| Table 1 |</p>
<table>
<thead>
<tr>
<th>Sample Testing Order</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test</strong></td>
</tr>
<tr>
<td>Grip (Jamar dynamometer)</td>
</tr>
<tr>
<td>Grip (BTE Primus)</td>
</tr>
<tr>
<td>Wrist flexion</td>
</tr>
<tr>
<td>Repeat static</td>
</tr>
<tr>
<td>Grip (Jamar dynamometer)</td>
</tr>
<tr>
<td>Grip (BTE Primus)</td>
</tr>
<tr>
<td>Wrist flexion</td>
</tr>
<tr>
<td>Dynamic</td>
</tr>
<tr>
<td>Grip (BTE Primus)</td>
</tr>
<tr>
<td>Wrist flexion (BTE Primus)</td>
</tr>
<tr>
<td>Repeat dynamic</td>
</tr>
<tr>
<td>Grip (BTE Primus)</td>
</tr>
<tr>
<td>Wrist (BTE Primus)</td>
</tr>
</tbody>
</table>

*Note.* BTE = Baltimore Therapeutic Equipment.
users vs. control participants), instruments (BTE Primus vs. Jamar dynamometer), and body position (sitting vs. standing). To ensure matching of the participants, two-tailed independent t tests (Portney & Watkins, 1993) were conducted to compare mean age and mean activity level between the wheelchair users and the control participants. Two-tailed independent t tests were also conducted to compare the two groups on the scores of the dynamic grip strength test and the static and dynamic wrist flexion tests. A repeated-measures analysis of variance (ANOVA) was conducted to reveal differences in static grip strength scores (Portney & Watkins, 1993). The between-subject factor was group (wheelchair users vs. control participants), and the within-subject factor was instrument (BTE vs. Jamar dynamometer in the seated position for both groups).

Finally, to compare grip and wrist flexion scores between the seated and standing body positions, analyses were conducted on the control group only. For static grip strength, repeated-measures ANOVA was conducted with two within-subject factors: position (sitting vs. standing) and instrument (BTE Primus vs. Jamar dynamometer). For the static wrist flexion test and the dynamic grip and wrist flexion tests, paired t tests (two-tailed) were conducted. All differences were considered significant at the .05 level. Bonferroni corrections were made for multiple t tests (8), setting the significance level at .00625.

Results

Pearson product-moment correlations were calculated to assess validity and reliability of the BTE Primus grip and wrist attachments. Criterion validity was established only for the grip attachment by correlating static grip strength scores on the Jamar dynamometer with those on the BTE Primus. Separate correlations were conducted for the two participant groups. For the wheelchair users, good correlation coefficients were found for the first (r = .634) and second (r = .740) sessions of static testing. For the control participants, high correlation coefficients were found for the first (r = .819) and second (r = .917) sessions. Test–retest reliability was assessed for the BTE Primus grip and wrist attachments and for the Jamar dynamometer. Good to high correlation coefficients (r = .79–.98) were found for static and dynamic grip and wrist flexion in both wheelchair users and control participants (see Table 2).

Group comparisons showed no significant differences between the two groups for age (t = .400, p = .693) and activity level (t = .862, p = .397), indicating that the matching of the participants according to age and activity level was successful. Group comparisons also showed no significant differences in dynamic grip strength, static wrist flexion strength, and dynamic wrist flexion strength (see Table 3).

The two-way ANOVA revealed no significant differences in static grip scores between the two groups (F = .013, p = .937) and between the BTE Primus and the Jamar dynamometer (F = .294, p = .593) as well as no significant interaction (F = .088, p = .679). Effect size was calculated for all nonsignificant findings to determine whether a Type 2 error due to the small sample size was likely. For example, a small effect size was found for both static and dynamic grip strength (see Table 3), which indicated 6% power. To achieve 70% power at an alpha level of .05, 1,924 participants would have been needed in each group. This power analysis indicated that these nonsignificant differences between groups were likely accurate and that a Type 2 error was probably not present.

The effect of body position on strength scores in control participants is presented in Table 4. There were no significant differences between sitting and standing for either dynamic grip strength or wrist flexion scores. A small effect size for both comparisons indicated that the differences were indeed nonsignificant (see Table 4). On the other hand, both static grip and wrist flexion strength were near significance. Their medium and large effect sizes, respectively (see Table 4), indicated that differences in static strength between the seated and standing body positions may be significant with a larger sample size. Specifically, for static grip strength scores, the repeated-measures ANOVA revealed no significant differences for either position (sitting vs. standing, F = 3.675, p = .08) or instrument (F = .042, p = .84) as well as no significant interaction (F = .04, p = .95). Because of the near significance for sitting versus standing (p = .08), we further examined this comparison by scrutinizing each instrument separately. No significant differences were found for the Jamar dynamometer (t = .882, p = .395) with a small effect size (d = .349, power = 11%) or for the BTE Primus with a medium effect size (see Table 4). The power analysis for the BTE Primus revealed that 55 participants would have been required in each group to achieve 70% power. For static wrist flexion strength, no significant differences were found between sitting and standing because of the Bonferroni correction, which set the significance level at .00625. The power analysis for the BTE Primus revealed that 15 participants would have been required in each group to achieve 70% power at an alpha level of .05.

Discussion

Reliability and Validity

The results of the present study suggest that the new grip attachment of the BTE Primus is a valid and reliable instrument for measuring grip strength. In terms of validity, good
correlation coefficients were found between grip strength scores on the BTE Primus and the Jamar dynamometer for the wheelchair users, and high correlations were found for control participants. Similarly, Beaton et al. (1995) found high correlations \((r = .896-.987)\) between the BTE Work Simulator’s grip tool and the Jamar dynamometer in seated participants without disabilities. In terms of test–retest reliability of the BTE Primus grip tool, we found high correlations for both static and dynamic grip strength scores. Previous studies showed similar results for the BTE Work Simulator. Anderson et al. (1990) found a high test–retest reliability \((r = .978)\) when testing static grip strength of 16 men on separate days, and Trossman et al. (1990) found a high test–retest reliability \((r = .978\) for the right hand, \(r = .987\) for the left hand) when testing static grip strength in 30 right-hand-dominant men and women on separate days. We also found high test–retest reliability values for both static and dynamic wrist flexion strength on the BTE Primus in both participant groups. These results are similar to Anderson et al.’s findings for the Work Simulator \((r = .91)\).

The higher test–retest reliability of the wheelchair users compared with the control participants on the Jamar dynamometer is probably because the controls were tested once while sitting and once while standing, whereas the wheelchair users were tested while sitting both times. Mathiowetz et al. (1984) found somewhat lower test–retest reliability values on the Jamar dynamometer \((r = .88)\) for their seated control participants. On the other hand, the lower validity and reliability values found for the wheelchair users compared with the controls on the BTE Primus may be attributed to the instrument not being accommodating for persons sitting in a wheelchair. The armrests and wheels of the wheelchairs did not allow the exercise head of the BTE Primus to be lowered far enough to attain the proper positioning of 90° at the elbow. Therefore, the wheelchair users had to sit in an unfamiliar chair without armrests or trunk support and without being able to stabilize themselves with their legs.

Thus, different body mechanics may have been used for stabilizing when gripping the two instruments, and the need of the wheelchair users to adjust their body positions to accommodate the BTE Primus may have decreased their ability to replicate grip trials. This interpretation was further supported by the different relationships between static and dynamic strength in the two groups. The wheelchair users showed a moderate correlation between dynamic and static strength on the BTE Primus \((r = .624)\) and a low correlation coefficient \((r = .371)\) between dynamic strength on the BTE Primus and static strength on the Jamar dynamometer. In comparison, the control participants had high correlations between dynamic and static strength on both the dynamometer \((r = .869)\) and the BTE Primus \((r = .778)\). These differences may reflect inconsistencies in stabilizing techniques between the wheelchair users and the controls.

### Strength Comparisons

The group comparisons indicated that physically active wheelchair users and their matched controls did not differ in either static or dynamic grip and wrist flexion strength. The clinical implications of these findings have to do with the use of norms. Normative data are developed to describe a certain characteristic of a specific population, such as grip strength, so that a person’s score can be compared to that of a representative population (Innes, 1999). Thus, norms provide objective data for comparison of patients to a certain population when interpreting evaluation data. Norms are then used to establish treatment goals (Benson & Schell, 1997), predict future performance (Portney & Watkins, 1997), predict future performance (Portney & Watkins, 2001).

### Table 3

<table>
<thead>
<tr>
<th>Strength Test</th>
<th>Wheelchair Users</th>
<th>Controls</th>
<th>(r)</th>
<th>(p)</th>
<th>(d)</th>
<th>Power (%)</th>
<th>Number of Participants Needed for 70% Power and (\alpha = .05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static grip (lb)</td>
<td>86 (20)</td>
<td>88 (30)</td>
<td>.225</td>
<td>.824</td>
<td>.09</td>
<td>6</td>
<td>1924</td>
</tr>
<tr>
<td>Dynamic grip (engals)</td>
<td>5472 (1989)</td>
<td>5757 (1827)</td>
<td>.381</td>
<td>.706</td>
<td>.15</td>
<td>6</td>
<td>1924</td>
</tr>
<tr>
<td>Static wrist flexion (lb)</td>
<td>59 (18)</td>
<td>57 (24)</td>
<td>.246</td>
<td>.808</td>
<td>.10</td>
<td>6</td>
<td>1924</td>
</tr>
<tr>
<td>Dynamic wrist flexion (engals)</td>
<td>10100 (5063)</td>
<td>11771 (3966)</td>
<td>.937</td>
<td>.358</td>
<td>.40</td>
<td>16</td>
<td>122</td>
</tr>
</tbody>
</table>

Note: BTE=Baltimore Therapeutic Equipment.

### Table 4

<table>
<thead>
<tr>
<th>Strength Test</th>
<th>Sitting</th>
<th>Standing</th>
<th>(r)</th>
<th>(p)</th>
<th>(d)</th>
<th>Power (%)</th>
<th>Number of Participants Needed for 70% Power and (\alpha = .05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static grip (lb)</td>
<td>88 (30)</td>
<td>91 (29)</td>
<td>1.625</td>
<td>.130</td>
<td>.60</td>
<td>31</td>
<td>55</td>
</tr>
<tr>
<td>Dynamic grip (engals)</td>
<td>5757 (1827)</td>
<td>5808 (2230)</td>
<td>0.154</td>
<td>.880</td>
<td>.06</td>
<td>6</td>
<td>1924</td>
</tr>
<tr>
<td>Static wrist flexion (lb)</td>
<td>57 (24)</td>
<td>55 (20)</td>
<td>2.504</td>
<td>.028</td>
<td>1.20</td>
<td>85</td>
<td>15</td>
</tr>
<tr>
<td>Dynamic wrist flexion (engals)</td>
<td>10100 (5063)</td>
<td>10343 (4823)</td>
<td>0.673</td>
<td>.514</td>
<td>.30</td>
<td>11</td>
<td>1924</td>
</tr>
</tbody>
</table>

Note: BTE=Baltimore Therapeutic Equipment.
that a larger sample size may have revealed that both static
wrist flexion scores. These findings indicate
that an acceptable sample size (Innes, 1999). Nevertheless, it seems obvious that the sample size of
the present study is too small to establish norms. Thus, the
findings of no differences in strength between the two
groups may suggest that clinicians could use the norms
established on persons without disabilities to assess physically
active wheelchair users’ grip and wrist strength on the
BTE Primus; however, this should be done with caution.

Both static and dynamic wrist flexion scores in the present
study were similar to scores in previous studies that
collected normative data on the BTE Work Simulator
(Anderson et al., 1990; Berlin & Vermette, 1985). However, static grip strength scores in the present study
were greater and dynamic grip strength scores were smaller
than the previously established norms (see Table 5). The
greater static grip strength scores in the present study may
be due to the new grip tool design of the BTE Primus and
to different elbow position in the previous studies. This
assumption is supported by the fact that the static grip
strength scores on the Jamar dynamometer in the present
study were within the range of the norms documented by
Mathiowetz et al. (1985), which were derived from 638
participants. Alternatively, the lower dynamic grip strength
scores in the present study may be attributed to fatigue
because dynamic strength was tested after all static strength
tests were completed.

We also compared static and dynamic grip and wrist
flexion strength scores rendered from the seated versus
standing positions in the control participants. Although
body position did not seem to affect dynamic strength
scores as suggested by the small effect size, a medium effect
size existed for the static grip scores and a large effect size
for the static wrist flexion scores. These findings indicate
that a larger sample size may have revealed that both static
grip and wrist flexion strength are affected by body posi-
tion. Thus, separate grip and wrist flexion strength norms
may be needed for sitting and standing on the BTE
Primus. Indeed, a controversy exists in the literature regard-
ing this issue. Whereas in one study with a sample size of
61 participants, no differences in grip strength existed
between sitting and standing (with the elbow in 90° flex-	ion) (Teraoka, 1979). The differences in the two studies, however, may stem not only from the dif-
fferences in sample size, but also from differences in elbow
position.

The limitations of the present study include the small
sample size and the nonhomogeneous wheelchair user
group, which consisted of both men and women, athletes
and nonathletes, and persons with SCI and amputation.
However, the effect size analysis indicates that no differ-
ces in strength existed between the two groups. Future
research should involve a larger, more homogenous sample,
which would include participants with varying activity lev-
els. In addition, protocol-related limitations, including
fatigue during the dynamic strength testing (despite the
rest intervals) and the use of the second handle position of
the grip tools (which may have limited strength exertion in
participants with large hands), may have prevented the par-
ticipants from exerting maximal effort.

Conclusion
The findings of the present study indicate that the BTE
Primus may be used to assess grip and wrist flexion strength
validly and reliably for both wheelchair users and persons
without disabilities. However, clinicians should be cautious
when using norms established on persons without disabili-
ties to assess physically active wheelchair users’ grip and
wrist strength on the BTE Primus. In addition, clinicians
should be aware that testing persons in the seated versus
standing position may affect the scores of static grip and
wrist flexion strength tests.

Table 5
Mean Static and Dynamic Grip Strength and Wrist Flexion Scores of Men and Women in Three Studies

<table>
<thead>
<tr>
<th>Strength Test and Gender</th>
<th>Present Study</th>
<th>Berlin and Vermette (1985)</th>
<th>Anderson et al. (1990)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static grip (in.-lb)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>448 ± 79</td>
<td>395 ± 70</td>
<td>320 ± 99</td>
</tr>
<tr>
<td>Women</td>
<td>234 ± 40</td>
<td>277 ± 79</td>
<td>185 ± 43</td>
</tr>
<tr>
<td>Dynamic grip (engals)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>6444 ± 2396</td>
<td>6025 ± 2448</td>
<td>10721 ± 2737</td>
</tr>
<tr>
<td>Women</td>
<td>4376 ± 798</td>
<td>4976 ± 1163</td>
<td>5725 ± 1405</td>
</tr>
<tr>
<td>Static wrist (in.-lb)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>191 ± 31</td>
<td>207 ± 27</td>
<td>194 ± 46</td>
</tr>
<tr>
<td>Women</td>
<td>86 ± 24</td>
<td>109 ± 26</td>
<td>97 ± 40</td>
</tr>
<tr>
<td>Dynamic wrist (engals)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Men</td>
<td>12822 ± 3360</td>
<td>16044 ± 9051</td>
<td>18351 ± 5647</td>
</tr>
<tr>
<td>Women</td>
<td>4755 ± 1524</td>
<td>7787 ± 2892</td>
<td>7862 ± 2984</td>
</tr>
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References


