Volumetric Comparison of Seated and Standing Test Postures

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Key Words: assessment process, occupational therapy • edema • hand evaluation

Published protocols for the volumetric assessment of upper-extremity edema differ regarding patients’ posture. The present study was designed to determine the effect of posture on test–retest reliability and mean volume. Thirty women were tested in both seated and standing postures. For the dominant hand, test–retest reliabilities for the seated posture were identical to those for the standing posture. Test–retest reliability was slightly stronger for the nondominant hand in sitting than for the same hand in standing. Both postures afforded clinically acceptable test–retest reliabilities. The mean volumes in sitting were significantly lower than those in standing (p < .0001), thus suggesting that volumetric measures should be considered discontinuous if the patient’s test posture is altered. Mean volumes of the dominant hand averaged 9.3 ml more than those of the nondominant hand. It is suggested that this discrepancy be considered in the establishment of goals for edema control and in the determination of the need for continued edema treatment.

Upper extremity edema is a common problem in the rehabilitation of persons with burns (Mallick & Carr, 1982), cerebrovascular accident, gouty arthritis (Smyth, Velayos, & Amoroso, 1963), rheumatoid arthritis (McKnight & Schomburg, 1982), mastectomy (Engler & Sweat, 1962), generalized lymphedema (Bunchman & Lewis, 1974), and soft-tissue trauma associated with sprains (Cote, Prentice, Hooker, & Shields, 1988) and surgery (Barclay, 1959; Hunter & Mackin, 1990; Nicholas, 1977). Edema is most commonly attributed to an inadequate or compromised pumping mechanism acting on the venous and lymphatic system (Vasudevan & Melvin, 1979). Edema reduces the functional abilities of the hand by predisposing the metacarpophalangeal joints toward extension, thus contributing to collateral ligament shortening (Nicholas, 1977; Strickland, 1987).

Although high-technology options exist for the evaluation of upper extremity edema (Goltner, Gass, Haas, & Schneider, 1988), occupational therapists most commonly measure edema using the less expensive and more accessible options of either circumferential or volumetric assessment. In circumferential assessment, edema is evaluated through the measurement of the circumferential measurement of the edematous hand and wrist. She attributed much of the variability in this assessment to inconsistent placement and tension of the measuring tape. In cases in which edema is localized in the fingers, Kasch (1990) suggested that a jeweler’s ring sizer could be used, thus reducing the error associated with tape tension. In volumetric assessment, edema is evaluated through the measurement of the water displaced when a limb is immersed. Several authors have promoted volumetric assessment over circumferential evaluation, especially when edema involves the hand and wrist in addition to the digits (Bear-Lehman & Abreu, 1989; Greenhill, 1979; Swedborg, 1977). Even those who consider volumetric assessment to be overly complicated and time consuming concede that the tool is “an accurate way of following the progression of the disease [lymphedema] and the outcome of any therapy” (Bunchman & Lewis, 1974, p. 64).

Commercially available volumeters were first manufactured in 1977 (J. Creelman, personal communication, July 1, 1990). They have since become a ubiquitous clinical tool as well as a frequently used measure among researchers. Although Eccles (1956) is credited with developing the earliest clinical volumeter, the commercial volumeter is based on Brand and Cohen’s (see Ramanny) prototype (Creelman, 1989; Hunter & Mackin, 1990). The commercial hand–forearm volumeter consists of a plastic tank (3½ in. by 5 in. x 11 in.) with a dowel centered in the lower third of the container to control the depth of hand immersion (Creelman, 1989). A spout at the top of the container allows the displaced water to drain and to collect in the 500-ml graduated cylinder that
accompanies the volumeter in the commercial set. The
cylinder is marked by 5-ml graduations.

Several sources of variability have been noted in vol­
umetry, and a protocol of administration has been de­
veloped to reduce the effect of these variables during volu­
metric assessment. The variables cited most frequently
are orientation of the hand in the device, speed of immers­
on, verticality of the forearm axis, aeration of the water,
forearm stillness during the assessment, pressure against
the dowel, placement of the volumeter in the test envi­
nvironment, and placement of the graduated cylinder during
reading (Fess & Moran, 1981; Hunter & Mackin, 1990;
estingly, despite detailed descriptions of volumetric pro­
cedure, authors usually do not report whether the subject
was seated or standing while the test was conducted
(McKnight & Schomburg, 1982, Schultz-Johnson, 1988;
Smyth et al., 1963; Waylett-Rendall & Seibly, 1991). In­
deed, the most authoritative voices disagree on the cor­
correct patient posture for testing. For example, the Ameri­
can Society of Hand Therapists specified the seated
position for the assessment, noting that “the patient,
with dressings and jewelry removed from the extremity,
should then be seated comfortably next to the volu­
meter and instructed to slowly immerse the hand and
forearm until a firm pressure from the stop rod is per­
ceived in the third web space” (Fess & Moran, 1981, p. 8). Likewise, Hunter and Mackin recommended that
the evaluation be performed while seated, with the use
of a chair that “easily allows the lowering of one third of
the forearm into the plastic hand volumeter” (p. 190),
and that the volumetric tank be positioned on a stable
stand. They even specified that the patient be “instruc­
ted to sit with the back well against the chair and the feet
flat on the floor” (p. 190).

Conversely, the manufacturer of the volumeter
specifies that the standing posture be used (Creelman,
1989). The photographs in Eccles’s (1956) article attest to
his preference for the standing posture as well.

Volumetric assessment is used by occupational
therapists and physical therapists throughout the United
States and internationally. It was my belief, therefore, that
clinical practice might benefit from a clarification of the
effects that test posture could have on the assessment.
The present study was conducted to determine whether
test posture would significantly affect either test-retest
reliability or volumetric results.

Method

Subjects

Thirty right-hand-dominant women ranging from 18 to 25
years of age volunteered for and participated in the study.
The subjects reported themselves to be in good health
and without any known injury or disease affecting either
upper extremity.

Instrument

In keeping with the literature’s recommendation, a com­
mercially available plastic hand-sized volumetric tank was
used for the present study (Fess & Philips, 1987; Hunter
& Mackin, 1990; Schultz-Johnson, 1988). The accuracy of
this assessment tool is reported as ±1% (Creelman,
1989; J. Creelman, personal communication, July 1, 1990;
Hunter & Mackin, 1990; Schultz-Johnson, 1988). Because
the volume of an average hand has been reported as 500
ml, this accuracy is sometimes reported as being ±5 ml in
the adult hand (Creelman, 1989; Creelman, personal
communication, July 1, 1990; Hunter & Mackin, 1990;
Schultz-Johnson, 1988). Waylett-Rendall and Seibly’s
(1991) research suggested that up to 10 ml of difference
may be expected when normal hands are repeatedly mea­
sured by the same examiner.

Procedure

In addition to a commercial hand volumeter set (i.e.,
volumeter tank, graduated cylinder, and filling pitcher),
testing in the seated posture required two identical stan­
dard armless chairs with firm backs and seats and a stable
wooden support to raise the volumeter from the floor.
Testing in the standing posture required a stable, level
table 32-in. high and a commercial hand volumeter set. A
single volumeter and graduated cylinder were used dur­
ing the study.

The table and floor surfaces of the assessment area
were marked with tape to ensure consistent placement of
the subjects, volumeter, chairs, and wooden support.
When testing subjects in the seated position, I placed
the volumeter on a wooden support between two chairs. The
subjects alternated between the chairs, thus permitting
standard volumetric assessment of both the dominant
and nondominant hands without necessitating move­
ment of the volumeter.

Three data gatherers were trained and tested until
they reached 100% agreement on both administra­tion
procedure and measurement for volumetric assessment.
In situations where the water line fell between the 5 ml
markings, the readings were recorded to the lower
number.

Each subject had a single test session in which three
measurements were taken in the seated and standing
positions for both the dominant and nondominant hands.
For each assessment, the volumeter was filled with room-
temperature tap water from a still source until the water
overflowed from the spout. The subjects (a) removed all
jewelry, (b) were oriented to the assessment procedure,
(c) slowly immersed the hand (thumb toward spout)
without contacting the sides of the device, (d) continued
immersion until the dowel rod rested firmly in the web
space between the middle and ring fingers, (e) main­
tained the hand immobile in this position until the flow of
water had been collected and the measuring cylinder removed, and (e) withdrew the hand. Each subject's arm, along with the graduated cylinder, was thoroughly dried between measurements.

When measures were being performed in the seated test position, the subject sat with her back against the chair and her feet flat on the floor. In the standing position, each subject stood within a square marked by tape that had been placed on the floor.

The order of testing was individually assigned for each subject with the use of a modified Latin square to control for both test order and relative position within order (Keppel, 1982).

Results

Reliability
Test-retest reliability for each test condition was established with the use of a Pearson correlation coefficient, which was performed on the first two of the three measurements. The test–retest correlations in sitting for the nondominant hand (r = .99), sitting for the dominant hand (r = .99), standing for the nondominant hand (r = .91), and standing for the dominant hand (r = .99) were all significant at the p < .0001 level. These high correlations indicate an extremely strong test-retest reliability regardless of test posture or hand being tested.

Comparison of Mean Volume
A 2 x 2 (Posture x Hand) analysis of variance (ANOVA) with repeated measures was performed with the mean value from the three measurements in each condition. This ANOVA was performed with the Biomedical Data Processing Statistical Software Package, Program 2V (Dixon, 1983). Each of the two main effects (posture and hand) significantly influenced the volumetric results (see Table 1). The posture effect showed a significant difference in hand volumes when the subjects were measured while seated versus while standing (p < .0001), with the mean seated volume averaging 5.3 ml less than the mean standing volume (see Table 2). The second main effect demonstrated that the dominant and nondominant hands produced significantly different volumetric readings (p = .0006) (see Table 1), with the nondominant hand averaging 9.4 ml less than the dominant hand (see Table 2).

The interaction effect of posture and hand was not significant (p = .45) (see Table 1). Therefore, the volumes of the dominant and nondominant hands were not significantly different when taken in the seated or standing postures.

Discussion
On the basis of the Pearson correlation coefficients, the test–retest reliability of volumetry appears equally acceptable in both the seated and standing postures. Both postures offer highly reliable test-retest assessment of hand volume. Even the nondominant hand in standing, which received the lowest test–retest value (r = .91), was well within the range of reliability acceptable for clinical assessments. Clinicians who frequently have to defend their test procedures in court, however, may wish to ensure the highest level of test-retest reliability by consistently performing the test in the seated posture.

The stability of the seated posture may contribute to its greater test-retest reliability by permitting the patient consistent control of dowel pressure against the web space. Possibly, when subjects are tested in the standing posture, they press more firmly against the dowel, thereby using it as a supporting surface during the minor balance shifts that accompany less-controlled upper extremity movements in standing. This may explain why a slightly reduced reliability is seen when the nondominant hand is tested in a standing posture but not when the dominant hand is assessed in the same posture.

Therapists who conduct volumetric tests using a standing posture may be unwittingly encouraging their patients to press more forcefully against the web stop or to move more during immersion as a result of the less-stable standing posture. Because test posture has a statistically significant effect on volumetric assessment, with volume consistently higher when standing than when sitting, therapists should note the client’s assessment posture on the record forms and view only those measurements taken in the same posture as continuous measures of the edema trend. In cases in which a patient’s status requires a change in test posture, the therapist should

Table 1
Volume Analysis of Variance With Two Levels of Repeated Measures (N = 30)

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posture</td>
<td>842.70</td>
<td>1</td>
<td>842.70</td>
<td>46.52</td>
<td>.0001</td>
</tr>
<tr>
<td>Error</td>
<td>525.30</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand</td>
<td>2650.80</td>
<td>1</td>
<td>2650.80</td>
<td>14.71</td>
<td>.0006</td>
</tr>
<tr>
<td>Error</td>
<td>5224.20</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posture x Hand</td>
<td>4.80</td>
<td>1</td>
<td>4.80</td>
<td>0.58</td>
<td>.4517</td>
</tr>
<tr>
<td>Error</td>
<td>239.20</td>
<td>29</td>
<td></td>
<td></td>
<td>.25</td>
</tr>
</tbody>
</table>

Table 2
Volumes for Three Measurements of Dominant and Nondominant Hands in the Seated and Standing Postures (N = 30)

<table>
<thead>
<tr>
<th>Posture</th>
<th>Dominant</th>
<th>Nondominant</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td>Seated</td>
<td>370.60 (40.62)</td>
<td>360.80 (38.65)</td>
<td>365.70 (39.62)</td>
</tr>
<tr>
<td>Standing</td>
<td>375.50 (41.58)</td>
<td>366.50 (39.41)</td>
<td>371.00 (40.42)</td>
</tr>
<tr>
<td>Combined</td>
<td>373.05 (40.83)</td>
<td>363.65 (38.80)</td>
<td></td>
</tr>
</tbody>
</table>
acknowledge that the postural change is likely to influence the volume reading and that the measurements should not be considered continuous.

The results of this study support van Velze, Kluever, van der Merwe, and Mennen's (1991) finding that a significant difference exists in the volumes of dominant and nondominant hands. The expected difference between dominant and nondominant hands has important ramifications when one considers that therapists often compare volumes of affected and unaffected arms to monitor progress in addition to "comparing the injured extremity to itself over time" (Schultz-Johnson, 1988, p. 26). The realistic establishment of goals for edema treatment and timing for discontinuation of treatment may be assisted by the recognition that the nondominant hand of women averages 10 ml smaller than the dominant when measured with a commercially available instrument.

Study Limitations
This study was conducted on a small and homogeneous group of subjects. All of the subjects were right handed, female, and college aged. Other populations' results could differ significantly. For example, van Velze et al. (1991) noted a smaller volume difference between dominant and nondominant hands of left-handed men as compared with right-handed men.

Conclusion
The greatest reliability in testing is afforded when volumetric assessment is performed in the seated posture. Additionally, measurements taken in the standing posture are consistently and significantly larger than those seen when the subject is seated. As a result, therapists may wish to conform to the American Society of Hand Therapists' guidelines (Fess & Moran, 1981) (including the seated posture) when performing a volumetric assessment. If for some reason the subject cannot be tested in the seated posture, the therapist should record that the assessment was performed in a standing posture and continue future volumetric measurement in that posture. If the test posture is changed because the patient's status alters, the therapist should record the change in posture and consider only those measurements taken in the same posture as reflective of a trend of volume change.

Acknowledgments
I thank Greg Goertzen, OTR, Erin Henry, OTR, and Michelle Knoblich, OTR, for gathering data; Krista Coleman, MS, PT, and Cheryl Meyers, MA, OTR, for editorial assistance; and the University of Kansas Medical Center's Department of Biometry for statistical assistance.

I gratefully acknowledge the University of Kansas School of Allied Health Research Fund for its supporting grant.

This paper is based on a poster session presented in April 1989 at the 69th Annual Conference of the American Occupational Therapy Association in Baltimore, Maryland.

References
Swedborg, I. (1977). Volumetric estimation of the de-

