Research Report

The Interrater Reliability of Force Measurements Using a Modified Sphygmomanometer in Elderly Subjects

Background and Purpose. Physical therapists working with elderly people require an instrument that provides reliable force measurements and can be used in a clinical setting. The modified sphygmomanometer has been identified as potentially fulfilling these requirements, yet there is an absence of research on the reliability of measurements taken with this instrument on elderly patients. This study was undertaken to investigate the interrater reliability of force measurements, in a group of elderly subjects, using a modified sphygmomanometer. **Subjects.** Thirty-six hospitalized subjects (mean age=75.28 years, SD=9.43, range=62–95) participated in the study. **Methods.** With the modified sphygmamanometer, 3 examiners evaluated the isometric force of the elbow extensors and hip extensors using a break test and a make test, respectively. **Results.** Intraclass correlation coefficients (2,1) reflecting reliability were .87 for the elbow extensors and .65 for the hip extensors. The estimation of the components of variance for hip extensors revealed that these results were due in part to the raters but that random error contributed to a much larger extent. **Conclusion and Discussion.** The modified sphygmomanometer appears to be practical to use, and the high correlations found in this study for the elbow extensors suggest that reliable measurements can be obtained with this instrument. Further research is needed, however, to specify the manner in which the modified sphygmomanometer can be used when assessing different muscle groups. [Kaegi C, Thibault M-C, Giroux F, Bourbonnais D. The interrater reliability of force measurements using a modified sphygmomanometer in elderly subjects. *Phys Ther.* 1998;78:1095–1103.]

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Several methods and instruments are used by physical therapists to evaluate the muscle forces their patients generate. A large number of clinicians commonly use an ordinal-scale manual technique of rating forces from 0 to 5 (or grades Zero through Normal).[1,2] This type of measurement, however, has been criticized as lacking sensitivity, as well as reliability,[1,3,4] and being limited at times by the evaluator's own strength.[3] Other methods of measuring force, as in the case of weights attached to a limb, have not been investigated thoroughly.[5] As Isherwood et al[1] stated, in a clinical setting, the use of instruments such as the cable tensiometer and the strain gauge is limited because certain difficulties are encountered (ie, they are cumbersome, time-consuming, and restricted in terms of assessing some muscle groups). For a number of years, isokinetic machines that measure force have also been used in some settings. These instruments, however, are costly and require a certain amount of space because of their size. Most importantly, positioning the patient is often time-consuming, especially if several muscle groups are to be tested.[6–8]

An alternative instrument that may be used to assess muscle force is the modified sphygmomanometer. A modified sphygmomanometer is made when a conventional sphygmomanometer is adapted by removing the outer sleeve of the cuff, folding the remaining inflatable bladder in thirds, and inserting the bladder into a cotton casing (12.5 × 9 × 1.5 cm).[9] The modified sphygmomanometer is then placed in a position to resist the movement caused by the muscle group to be measured, and the force exerted by the patient is read from the dial. The first documented use of a modified sphygmomanometer was in 1958 for the evaluation of grip strength of patients with rheumatoid arthritis.[10] Since then, modified sphygmomanometers have been used by a number of authors for this type of measurement.[11–20] In 1981, Helewa et al[7] expanded the application of the modified sphygmomanometer to the evaluation of the forces other than those associated with grip strength. In subsequent studies, the modified sphygmomanometer was used to measure the force of the shoulder abductors,[6,9,21] shoulder flexors,[21] elbow flexors,[1,21,22] elbow extensors,[21] hip flexors and extensors,[21] hip abductors,[9,23] knee extensors,[9,21] ankle dorsiflexors and plantar flexors,[21] and abdominals.[24] Some of these studies involved subjects without impairments,[1,21–24] yet other studies included patients with rheumatoid arthritis[6,9] or low back pain[24] and dependent elderly community-dwellers.[21] With the modified sphygmomanometer, 2 different types of tests can be conducted: a "break" test or a "make" test.[25,26] A break test requires the patient to resist against an increasing force provided by the examiner who is pushing on the inflatable sack. A make test is performed when the modified sphygmomanometer is stabilized, either by the evaluator or against a rigid surface, and the patient initiates and progressively increases the force to achieve a maximal effort.

The benefits of the modified sphygmomanometer and the reliability of measurements obtained with the device have been investigated by several authors. Helewa et al,[7] using the modified sphygmomanometer and break tests on 5 patients with rheumatoid arthritis, demonstrated that measurements obtained by 5 physical therapists were as reproducible as, and were taken faster than, measurements obtained by a method where the patient was required to maintain his or her limb in a certain position while weights were progressively added. A limitation of the study, however, was the small number of subjects involved. Again, in subsequent studies,[6,24,27] Helewa and colleagues mentioned that the modified sphygmomanometer can be used to measure muscle force quickly and at low cost. Although the experimental design included only one examiner, Balogun et al,[15] measuring the force of prehension in 34 subjects without impairments using a modified sphygmomanometer, calculated a Pearson product-moment correlation coefficient of .99. In another study examining the force of prehension in 88 subjects with arthritis, as measured by one rater, Agnew and Maas[16] also found strong Pearson product-moment correlation coefficients ranging from .89 to .97.

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Still considering grip force measurements taken with the modified sphygmomanometer, Hamilton et al[18] reported a Spearman rho correlation coefficient of .85 when 29 college-aged subjects were tested by one examiner during 3 sessions. A reasonable number of subjects were used in this study, yet it should be noted that this statistical analysis is approximately 91% as efficient as the Pearson product-moment correlation coefficient.[28] Bohannon and Lusardi[22] calculated an intrarater intraclass correlation coefficient (ICC) of .96 when the force of the elbow flexors of 32 subjects without impairments was assessed by one tester. For the same muscle group, ICCs of .84 and .89 (intrarater) and .95 (interrater) were found by Isherwood et al[1] when 2 examiners used a modified sphygmomanometer on 10 students without impairments. Wright et al[23] reported an interrater ICC of .57 when 4 examiners studied the force of the hip abductors in 4 children without impairments. In a study with 4 subjects without impairments and 4 testers, Busch and Arnold[29] found Pearson product-moment correlation coefficients ranging from .62 to .79 for the shoulder abductors, hip abductors, and knee extensors; however, the interrater ICCs were reported as not being stable. For the abductors of the shoulder in 5 patients with rheumatoid arthritis measured by 5 physical therapists, Helewa et al[6] achieved an interrater ICC of .93. Only 2 groups of authors, however, have used the modified sphygmomanometer specifically with elderly subjects. Giles,[9] in a case report of a 73-year-old patient with rheumatoid arthritis in which 3 muscles as well as prehension were assessed, concluded that this instrument was a valuable tool. Rice et al,[21] with the help of 4 evaluators, studied 10 muscle groups of 118 elderly subjects with the modified sphygmomanometer and stated its usefulness, yet they noted that the use of this instrument presented some limitations for younger, more vigorous subjects.

As very little information is available pertaining to force evaluations made with the modified sphygmomanometer on elderly patients, this study was undertaken to investigate the interrater reliability of measurements obtained with the modified sphygmomanometer when used to assess the isometric force of the hip and elbow extensors in a group of patients temporarily staying in a geriatric hospital. These 2 muscle groups were chosen as they are often considered critical for the patient's autonomy and can have a direct influence on the person's transfer capacity and on the ability to use assistive devices for ambulation.

Method

Experimental Design

Measurements of maximal isometric force of the hip extensor and elbow extensor muscle groups were taken by 3 evaluators. The order of presentation of the evaluators was counterbalanced by applying 1 of 6 possible sequences of raters for each subject. As each subject was recruited into the research project, 1 of these sequences was randomly assigned. Each sequence was completed 6 times, and, in this manner, 36 subjects were evaluated. The elbow extensors were always assessed first, followed by the hip extensors.

Subjects

Subjects were identified as those patients who were admitted for a temporary stay (ie, less than approximately 70 days) at our hospital and who gave written consent after being informed of the objectives and procedures of the study. Thirty-six subjects, 28 women and 8 men, participated in the study. The range in age was from 62 to 95 years ($\bar{X}$=75.61, SD=10.06) for the women and from 65 to 85 years ($\bar{X}$=74.13, SD=7.22) for the men. Their primary diagnoses were varied. The most common diagnoses were hip fractures (n=8), stroke (n=13), and degenerative joint disease of the knee (n=4). Most subjects had several associated conditions. The nonaffected or less affected limbs were studied, and subjects were excluded from the study if an isometric resistance applied to the elbow or hip extensors was painful. Seven sessions of data collection were conducted over a 4½-month period.

Procedure

Three female evaluators (2 physical therapists and 1 rehabilitation therapist), in addition to a female physical therapist who acted as an assistant, volunteered for the study. The ages of the evaluators were 29, 33, and 41 years, and the age of the assistant was 30 years. All of the physical therapists had a Bachelor of Science degree; the rehabilitation therapist had fulfilled a 3-year technical course in the field of rehabilitation. One physical therapist evaluator's work experience (7 years) dealt solely with elderly patients. The other physical therapist evaluator had, for 14 years, treated adults with peripheral and central nervous system problems, before joining our staff 4 years before the study to work in geriatrics. The rehabilitation therapist's background consisted of 1 year of outpatient orthopedic services, followed by 9 years of practice with elderly patients. The physical therapist who served as an assistant had likewise worked almost exclusively with elderly patients during her 4-year work experience.

The 2 principal researchers (CK and M-CT) held a training session with the 3 evaluators and the assistant prior to the beginning of the data collection. Having previously described the research protocol and the evaluation technique to the evaluator in detail, the researchers provided a 2-hour session focused on demonstrating and practicing the measurement method and answering any of their questions. Proper positioning of the subject as well as presenting the possible compensatory movements that may appear were also emphasized. The verbal feedback to be given to the subjects was standardized. Through simulations, each examiner, with the assistant, performed a minimum of 3 complete evaluations. Our results can be generalized to most clinical settings as long as therapists train themselves by using procedures that are identical to those used in our study and by using equipment similar to that used in our study.

Prior to the evaluation sessions, the assistant compiled information pertaining to each subject on a data sheet (eg, age, sex, primary diagnosis, treating physical therapist, side to be evaluated). This therapist was also responsible for positioning each subject on the treatment table. The readings made by each evaluator were communicated directly to the assistant, who wrote them on a second data sheet. Any compensatory movements (eg, lifting of the pelvis, pronation of the forearm) noted by the examiners or reactions of the subject were also marked on this page. The assistant ensured that the rest periods were adhered to.

Three new portable aneroid sphygmomanometers,* each with a dial divided into increments of 2 mm Hg, were transformed into modified sphygmomanometers.[9] When testing, the instrument was inflated to 200 mm Hg, and then sufficient air was released to achieve a pressure reading of 20 mm Hg. Once the inflated sack was placed on the muscle group to be measured, the subject exerted force and the result was read from the dial. Before each measurement, the evaluator verified that the baseline was exactly 20 mm Hg. The same modified sphygmomanometer was used at all times, with the other 2 instruments serving as backups. The stability and reliability of the pressure measurements taken with the modified sphygmomanometer were tested prior to the commencement of data collection. Known weights (5, 10, 15, 20, 25, and 30 kg) covering the range of the modified sphygmomanometer were used. The weights were applied onto a plate (9 × 6.5 cm) that was placed on the modified sphygmomanometer, with a consistent baseline reading of 20 mm Hg. The output was read and recorded on a calibration sheet. To verify that the modified sphygmomanometer gave consistent readings, calibration tests were also performed halfway through and at the termination of data collection. A statistical analysis was done to compare the differences between the 3 slopes and the elevations of the calibrations.[30] The modified sphygmomanometer output was linear up to 260 mm Hg. A flattening of the curves, however, was observed over this level. Between 20 and 260 mm Hg, which represented the range of subjects' output, the calculated Pearson product-moment correlation coefficients were high (r=.99). In addition, the results indicated that the slopes (F=1.46; df=2,12) and the elevations between the slopes (F=1.08; df=2,14) did not differ between the 3 sessions.

Each subject was positioned lying on his or her back on a plinth (31 cm high) with a quadriceps femoris muscle block (46 × 17 × 20 cm) placed under the knees. When evaluating the force of the elbow extensors, the subject's arm was placed close to the trunk with the elbow flexed at 90 degrees and with a neutral rotation at the shoulder and forearm. The examiner then placed the modified sphygmomanometer longitudinally along the forearm just proximal to the ulnar styloid process and applied a progressive force perpendicular to the forearm (ie, a break test of the elbow extensors). Initially, the subject performed a submaximal warm-up effort to ensure comprehension of the task. The therapist then asked the subject for 3 maximal isometric contractions, allowing a rest period of 1 minute between measurements. During each effort, the subject was verbally encouraged by the evaluator to give a maximal contraction. The rater avoided gripping the modified sphygmomanometer. The reading was taken when the examiner noted that the subject was no longer able to maintain the starting position and thus was unable to counteract the evaluator's force.

The force of the hip extensors was measured using the same position on the plinth. The quadriceps femoris muscle block maintained a resting position of approximately 30 degrees of flexion at the hips with neutral rotation and 0 degrees of abduction and of 60 degrees of flexion at the knees. The modified sphygmomanometer was placed in the popliteal fossa and rested on the block. The rater placed a hand under the subject's iliac crest of the tested side and gave verbal feedback to the subject with the aim of preventing movements at the pelvis. The subject was asked to relax his or her body, and the resulting weight of the lower limb on the modified sphygmomanometer created a pressure that was recorded as the new baseline and ultimately subtracted from the reading. After a warm-up effort, the evaluator asked the subject to push progressively downward into the modified sphygmomanometer (ie, a make test) until a maximal force was reached. Verbal encouragement was again given by the rater. Three maximal contractions were required, with identical rest periods, as for the elbow measurements.

Data Analysis

The raw data for the elbow were used for the analyses, whereas the data for the hip measurements were obtained by subtracting each subject's baseline modified sphygmomanometer reading from the reading taken by

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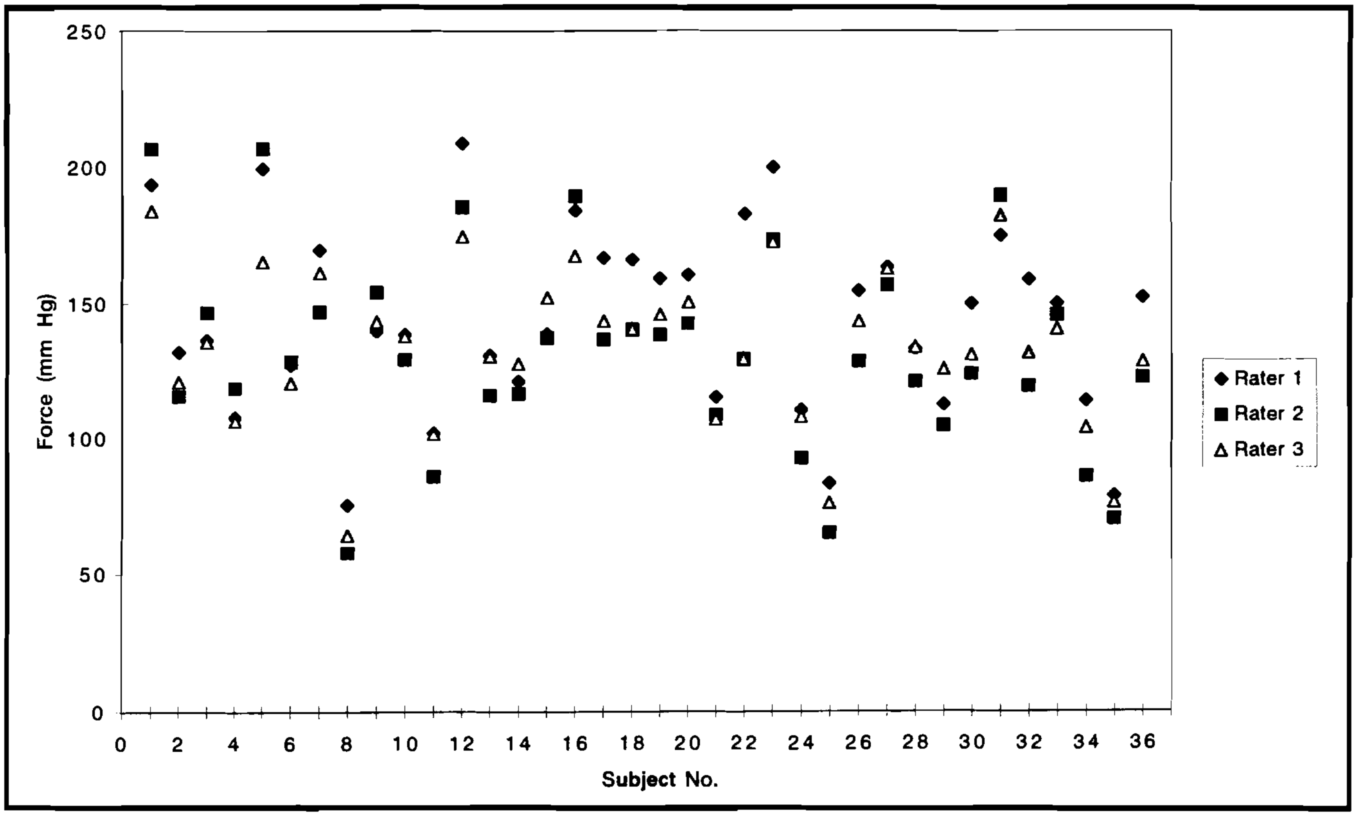

Figure 1.
Average elbow extensor measurements obtained by 3 raters.

each rater. The mean of the 3 readings for each evaluator was then calculated for each subject and for each muscle group. These means were then used for all analyses. The ICCs (2,1) were calculated for the elbow and hip extensor measurements of force.[31]

Results

The average of the measurements taken by each rater, for each of the subjects, is presented graphically in Figures 1 and 2. The ICCs were .87 for the elbow extensors and .65 for the hip extensors. A breakdown, based on a mathematical equation (Fig. 3) incorporating the mean squares calculated for the raters, subjects, and random error, was performed to determine the estimated components of variance, as explained by Shrout and Fleiss.[31] The results of this analysis for the elbow and hip extensors are presented in the Table. The greatest part of the variance was due to random error and the variability of the subjects in relation to that of the raters. The resultant ICC for the elbow extensors was high, yet the ICC for the hip extensors was somewhat lower. The lower ICC calculated for the hip extensors appeared to be due, at least in part, to the raters, but a much larger variation was due to random error.

Discussion and Conclusion

Other analyses were attempted in a *post hoc* fashion. We investigated the reliability of the raters' measurements when using subgroups of subjects' diagnoses. There was, however, an insufficient number of subjects having common diagnoses, thus preventing statistical analyses. Subjects were also subdivided into 2 groups (strong and weak) that were determined arbitrarily by the raters' measurements. The data obtained revealed no general tendency differentiating the 2 groups. The fact that 10 of the 36 subjects were evaluated by a rater who was their treating physical therapist did not appear to influence the results.

Numerous articles have been written over the years emphasizing the importance of having reliable measurements for assessing patients. Many methods for evaluating force have been presented. In our opinion, numerous factors must be considered when choosing one method over another. The modified sphygmomanometer is easy to use and requires little time to apply. This instrument is inexpensive and has the added feature of being portable, allowing therapists to evaluate patients in different settings (eg, a physical therapy department, a hospital room, the home). In addition to the practicality and availability of an instrument, however, the reliability of its measurements for use with patients must be considered.

In our study, the interrater reliability of measurements obtained with the modified sphygmomanometer was

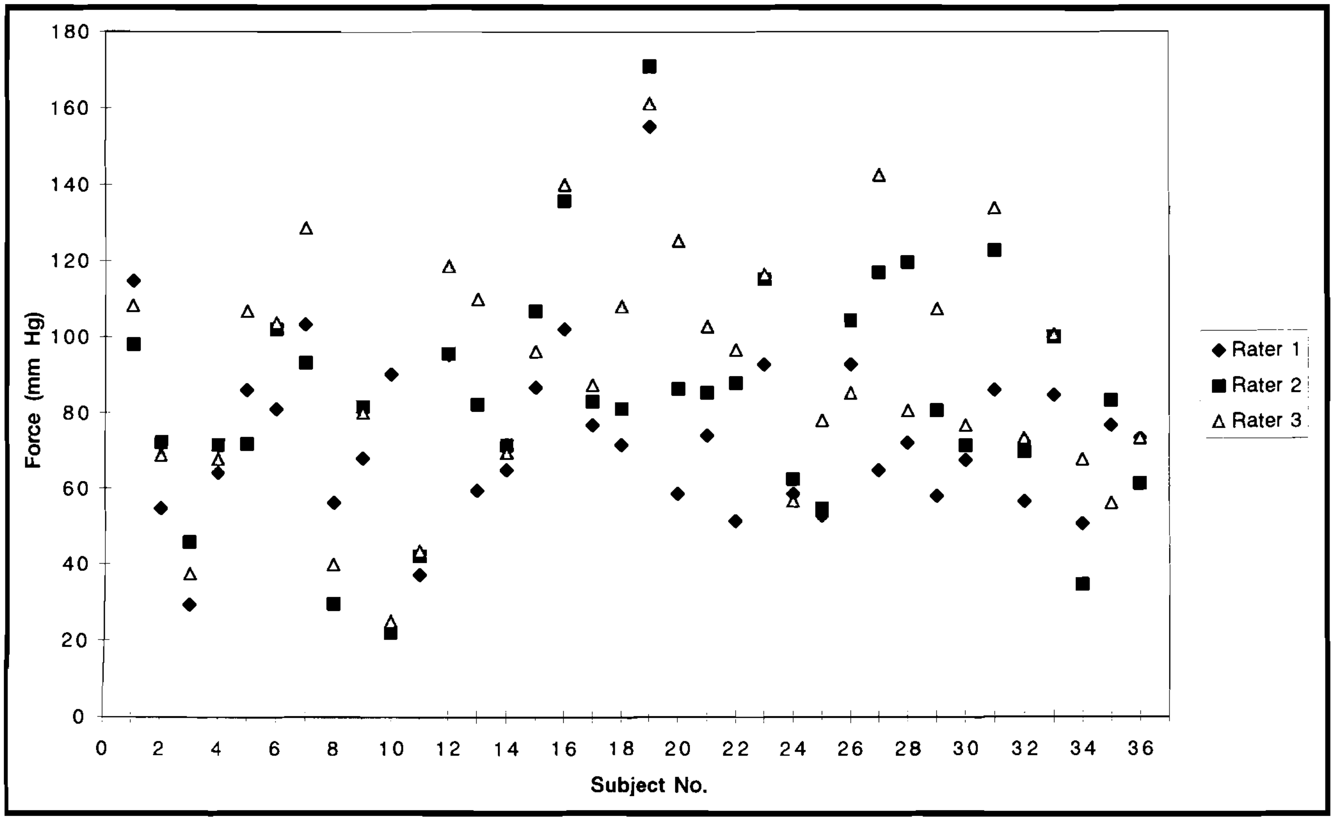

Figure 2.
Average hip extensor measurements obtained by 3 raters.

assessed by 3 therapists on 2 different muscle groups in elderly patients. The ICCs were high for the elbow extensors but lower for the hip extensors. The estimated components of variance revealed that the raters were not the most prominent source of variation for the force measurements of the hip extensors. We believe that the poorer reliability found when measuring the hip may have been due, in part, to the starting position that was chosen for the subjects. When measuring the hip extensors, even with standardized procedures, small compensatory movements may occur at the pelvis, and these movements could influence the interrater reliability.

When determining the test position for the subjects in our study, we took many different elements into consideration, including the positions used in reference manuals[32–34] and previous studies.[8,21,35,36] For manual muscle testing, the side-lying position was proposed for evaluating the hip extensors with the effect of gravity minimized, and the prone position or standing on one lower extremity was proposed for testing against gravity.[32–34] Similar positions were chosen by various authors when using instruments to measure hip extensor isometric force,[8,21,35] as well as the supine position with the hip flexed to 90 degrees.[36] The study by Agre et al[8] regarding maximal isometric force measurements of 6 lower-extremity muscle groups, in which the hip extensors were evaluated with the subjects in a prone position, revealed poor intratester and intertester reliability. These authors wrote that these results were possibly related to the test positions, as the large body parts made it difficult for the evaluators to provide sufficient stabilization. Similarly, Rice et al[21] commented that the standing test position used in their research was not entirely satisfactory because of inadequate body stabilization. Some elderly people may not be able to assume conventional evaluation positions due to cardiovascular or musculoskeletal changes that accompany aging.[32,37–40] Smidt and Rogers[26] contend that test positions should ensure stabilization of the proximal part, and Kendall and McCreary[34] emphasized that the comfort of the patient is of greater concern than adhering to a test position that may cause the patient to experience pain. In our opinion, the clinical information that is needed is an estimate of a muscle group's force, to be used as a comparison with subsequent readings, rather than a value that represents the absolute maximal force that a muscle can generate.

We believe that the test positions used in the studies mentioned previously[8,21,35,36] were not appropriate for this population. The standardized test position that we ultimately chose for our study was selected in an attempt to ensure stability and comfort. Although instructions were provided to the evaluators to minimize possible

$$ICC = \frac{\sigma^2_s}{\sigma^2_s + \sigma^2_r + \sigma^2_e}$$

$$\sigma^2_s = \frac{MS_s - MS_e}{k}$$

$$\sigma^2_r = \frac{MS_r - MS_e}{n}$$

$$\sigma^2_e = MS_e$$

k = number of raters

n = number of subjects

MS_s = mean square - subjects

MS_e = mean square - random error

MS_r = mean square - raters

Figure 3.
Mathematical equation used to determine the estimate components of variance.[31]

Table.
Estimated Components of Variance

	Elbow	Hip
$\hat{\sigma}^2$ subjects	1002,88	584,92
$\hat{\sigma}^2$ raters	41,77	64,99
$\hat{\sigma}^2$ error	104,85	244,28

compensations, movements may have occurred that influenced the reliability of the measurements.

Another possible explanation for the lower reliability found for the hip extensors is that the make test was less motivating for the subjects, leading to a greater variability in their efforts with the different examiners. Bohannon[25] compared make and break tests using a hand-held dynamometer and found the reliability of measurements for each procedure to be high. We have observed that patients have a greater desire to excel when a break test is used, because they appear to be motivated to compete against the rater's increasing resistance. When using a make test for the hip extensors in our study, we believe the subjects responded only to their own motivation and to the evaluators' verbal encouragements. Although detailed instructions were given to the raters during the training session regarding the type and frequency of verbal encouragement to be used during the evaluations, it is possible that subjects reacted differently to the encouragement.

Some authors[6,21] have mentioned a limitation on the use of the modified sphygmomanometer as a force instrument because its upper limit of 300 mm Hg makes it inappropriate for stronger patients. In some studies,[13,15,21] this limit was surpassed at times when examining grip force or quadriceps femoris muscle force. In other studies,[7,9,16] the subjects did not exceed the 300-mm Hg mark. Bohannon and Lusardi[22] contend that, considering that subjects sometimes exceed the upper limit of the modified sphygmomanometer and that their study demonstrated a curvilinear relationship above 210 mm Hg, caution must be used when accurate force measurements are required for stronger subjects. In our study, the output was nonlinear over 260 mm Hg, yet none of the 36 subjects attained this threshold. Further research could provide additional information as to whether the force of other muscle groups of hospitalized elderly patients could be measured with a modified sphygmomanometer having an upper limit of 300 mm Hg.

The reliability of measurements obtained with other instruments in the assessment of the force of various muscle groups of patients has been investigated. Research conducted on subjects without impairments or disabilities has shown that the cable tensiometer and strain gauges can sometimes yield reliable measurements, yet the same conclusions may not apply to their use with patients.[5] Furthermore, the cable tensiometer requires more extensive set-up time, and strain gauges that are appropriate for the clinical setting have yet to be developed.[5] Although some research addressing the reliability of measurements of muscle force obtained using isokinetic machines has been performed on patients, this type of instrumentation is impractical for physical therapists working with elderly persons. Hand-held dynamometers are regarded as clinically useful, yet research on the reliability of measurements using these instruments on patients is very limited.[2,36,41]

With the management of health care resources, physical therapists are required more and more to balance quality of care with cost-effectiveness. The low cost, versatility, and ease of use of the modified sphygmomanometer as a force instrument have been recognized by clinicians. Our results are encouraging and have implications for physical therapists working with elderly people. We believe it is always preferable that the same therapist assess a patient's force from one session to another. Clinicians may have some confidence in choosing the method used in our study, however, when more than one rater evaluates the force of the elbow extensors, as high interrater reliability was demonstrated, but only if therapists are trained in the manner described in this report. The reliability of measurements obtained by therapists who do not train together remains to be investigated. Because the reliability for the hip extensors was fair, we recommend that therapists pay added attention to avoid compensatory movements when patients exert their force.

Further studies are needed to identify an alternative test method to be used for this muscle group, with the aim of improving the interrater reliability, and for determining the training needed for testers. The numerous positive aspects that have been identified in this and previous articles regarding the use of the modified sphygmomanometer in evaluating force underscores its potential usefulness in the field of geriatrics. Research regarding the reliability of measurements taken with the modified sphygmomanometer on other muscle groups is needed in order to develop standardized testing procedures for the use of this instrument.

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