Reliability and Validity of a Clinical Test of Reaction Time in Older Adults

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ABSTRACT

Purpose: Reaction time is an important indicator of neuromuscular status in older adults. A simple, portable, and inexpensive method of measuring reaction time is needed for use in geriatric clinical settings. The purpose of this study was to examine the reliability and validity of the response speed subtest of the Bruininks-Oseretsky Test of Motor Proficiency (BOT) as an indicator of reaction time in older adults. **Methods:** A volunteer sample of 30 community-dwelling men and women over the age of 65 years performed the response speed subtest of the BOT and an electronic reaction time test during a single test session. Statistical analyses included calculation of the intraclass correlation coefficient (ICC) for reliability testing and the Pearson product-moment correlation coefficient (r) for validity testing. **Results:** Intertester reliability for the BOT response speed subtest using either mean or median scores for 7 test trials for each subject was ICC[2,1]=0.99. Test-retest reliability for the BOT was ICC[2,1]=0.53 using mean scores and ICC[2,1]=0.65 using median scores. Mean scores from both the first and second administrations of the BOT subtest were correlated with electronic reaction time test scores (r=-0.41 and r=-0.45, respectively; $P < .05$). Scores improved significantly from the first to the second test administration. **Conclusions:** Although intertester reliability was excellent, test-retest reliability for the BOT response speed subtest was not in an acceptable range for this sample of community-dwelling older adults. Further study of optimal methods of administration is needed to develop this measure for use in screening and examination of older adults.

Key Words: reaction time, measurement, reliability, validity

INTRODUCTION

Reaction time, defined as the time between presentation of a stimulus and initiation of a response to that stimulus, is one of the most commonly used measures of neurological function.[1] A common paradigm for assessing reaction time is to measure the time between presentation of a light stimulus and subsequent pressing of a response button or switch.[1] This method is considered acceptable for determining reaction time, although the measured interval actually represents response time, the sum of reaction time and movement time. The experimenter must insure that the switch allows finger contact prior to onset of the stimulus, so that the response involves minimal movement.

Many different types of reaction times can be measured, including responses to visual, auditory, and tactile stimuli.[2] Simple reaction time paradigms involve only one stimulus and require only one action in response. In these situations, the desired response is known in advance of the presentation of the stimulus. In choice reaction time paradigms, on the other hand, 2 or more different stimuli are involved. The stimulus conveys information about the desired response, so that the subject cannot anticipate which movement to make (eg, green light means push, red light means pull).

Reaction time paradigms have been used for many years to study central nervous system processing of the information necessary to prepare and execute a response to a perceived stimulus.[3,4] Simple reaction time is often viewed as a pure measure of information processing speed.[5,6] Spirduso[7] considered fast reaction time to be an indicator of good health. Many researchers have demonstrated that reaction time increases with age in adulthood.[3,7-9] The phenomenon of a general slowing of behavior with increased age, affecting both reaction time and movement time,[3,9] has important practical implications. For example, the increased accident rates of older adults[10] and their under-representation in externally paced industrial work[11] have been linked to age-related slowing.

The increase in reaction time in older adults may be associated with an increased incidence of falls in this age group. Each year, falls are reported to occur in approximately one-third of community-dwelling adults over the age of 65 years and in approximately one-half of older adults in intermediate care institutions and nursing homes.[12,13] Lord et al[14] measured the time required by 341community-dwelling women over the age of 65 years to depress a hand switch in response to a light stimulus. One year later, 39.3% of the subjects had fallen, and these women had significantly longer reaction times than those who had not fallen. In a one-year prospective study of 70 persons between the ages of 72 and 96 years, Lord and Clark[15] identified reaction time as one of several physiological variables that discriminated between fallers and nonfallers.

Growing evidence indicates that cognitive processing, including the type of information processing required for reaction time tasks, is associated with balance and falls risk.[16-20] Several different reaction time measures were used in these investigations. Simple reaction times, tested by verbal responses to auditory stimuli, were significantly slower in 45 elderly persons with a history of falls compared to 80 elderly persons with no fall

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history.[16] Simple reaction time was the most significant predictor in a 3-item logistic regression model that was 93% sensitive and 95% specific in distinguishing fallers from nonfallers. In a study of 477 retirement-village residents aged 62 to 95 years, choice stepping reaction time was a significant and independent predictor of falls.[17]

Reaction time measures reflect training effects and appear responsive to intervention in older adults.[21,22] In a study of 551 retirement-village residents, statistically significant differences were found at postintervention testing between subjects who participated in a 12-month group exercise intervention and control group subjects, with the exercise group demonstrating faster simple reaction times (measured using a light as the stimulus and a hand press as the response) and faster choice stepping reaction times.[22] Those in the exercise group met twice weekly for one hour sessions involving walking and other aerobic exercises, balance and coordination training, and specific muscle group strengthening. Subjects in the exercise group had 22% fewer falls than those in the control group during the 12-month trial. The authors suggested that improvements in reaction time and in walking speed may have provided protection against falls. Improved reaction times may reflect increased ability to generate a rapid motor response in the event of a loss of balance, enabling the individual to regain stability by reaching out for support or by taking a step.[15,17,23]

Several researchers have shown improvements in reaction times following interventions designed to increase physical activity in older adults.[24-29] Duration of the aerobic exercise interventions used in these studies varied widely, ranging from 10 weeks[27] to 3 years.[28] Practice is another intervention that has been proposed as a means of improving the ability of older adults to perform fast responses.[30] Both young and older individuals benefit from practice of speeded responses,[31,32] with some research indicating greater benefits of practice for the latter group.[33-35] Age group differences in reaction times can disappear following extended practice.[34,35] The effects of improvement in reaction times on falls incidence was not reported in any of these studies.

The research evidence described above illustrates the importance of reaction time as an indicator of neuromuscular status in older adults.[36] Reaction time is considered one of the most sensitive markers of structural and functional deterioration in the aging central nervous system.[36-38] Reaction time measurements typically are performed only in research settings. For measurement of simple visual reaction times, the typical paradigm involves presentation of a light stimulus and pressing of a response button or key, with electronic circuitry used to record the time between these 2 events.[1] This type of electronic reaction time measurement is reliable[27,39] and has evidence of validity in correlating with age and other cognitive measures, and even in predicting mortality.[40,41]

Accurate measurement of reaction time may be useful to health professionals in working with older adults who are at increased risk for falls or who have disorders known to affect reaction time, such as Parkinson disease.[42,43] Reaction time measurements can be used to monitor an individual's condition over time, to identify persons with extreme slowing, or to determine the effectiveness of an intervention. Unfortunately, no accepted measures of reaction time are available for use in clinical settings. Many of the reaction time measurements used in research require relatively sophisticated and expensive electronic equipment that may not be portable. Computerized reaction time tests may be impractical for use in some settings, and also may introduce measurement error related to timing accuracy and resolution issues, including keyboard buffering.[44]

Our review of the literature revealed no studies of simple clinical measures of reaction time in older adults. To support the need for such a measure, we sent e-mail surveys to 308 members of the Section on Geriatrics of the American Physical Therapy Association. Surveys were sent to every 10th person on the alphabetic listing of Section members with a published e-mail address. The response rate for deliverable surveys was 38%, close to the 40% considered average for e-mail surveys.[45] Of the clinicians responding, 100% considered reaction time an important indicator, but only 17.5% actually included reaction time measurement in examination of their older adult clients. For a majority of the respondents, cost/ portability of equipment and ease of administration were major considerations in decisions about whether to measure reaction times. Ninety three (95.9%) of the respondents indicated that they would use a reaction time measure that was reliable, quick and easy to administer, and inexpensive.

The ability to stop the descent of an unexpectedly dropped object is a reaction time task that can be easily quantified. This task was a subtest of the Bruininks-Oseretsky Test of Motor Proficiency (BOT),[46] a test of motor skills originally designed for use with children between the ages of 4.5 and 14.5 years. In the response speed subtest, a response speed stick (a 61-cm long stick that resembles a ruler) was held against a wall and dropped by the examiner. The subject was instructed to use his/her thumb to stop the descent of the stick along the wall as quickly as possible. Reaction time was represented by the distance the stick fell before being stopped by the subject. Such a test should be performed easily by older adults and might be useful as a clinical indicator of reaction time in this population.

Purpose

The overall purpose of the present study was to investigate the feasibility of using the BOT response speed subtest as a simple indicator of reaction time in older adults. The specific aims were to determine: (1) intertester and test-retest reliability of the BOT response speed subtest in adults over the age of 65 years, and (2) concurrent validity of the BOT response speed subtest scores by comparison with scores on an electronic reaction time test. If shown to have acceptable reliability and validity, this indicator of reaction time could become a routine part of sensorimotor screening and examination in clinics, assisted living facilities, patients' homes, and other practice settings.

METHODS

Subjects

Potential subjects were identified through contacts with faculty and staff at The University of North Carolina at Chapel Hill and through presentations at local senior centers and continuing care retirement communities. Volunteers of either gender or any ethnic background were accepted as subjects provided that they met the inclusion criteria below. A screening interview was conducted by telephone or in person prior to testing. Inclusion criteria were: (1) 65 years of age or older, (2) score of at least 24 on the Mini Mental Status Exam (MMSE),[47] (3) normal or corrected-to-normal vision (by self-report), (4) adequate hearing for completing the study protocol, (5) able to sit independently, (6) able to reach overhead and oppose the thumb to the fifth finger using the dominant upper extremity/hand, and (7) able to understand and speak English. Potential subjects with a diagnosed neurological disorder or cardiovascular or orthopedic problems that could interfere with performance of the test procedures were excluded. Volunteers meeting the inclusion criteria were enrolled as participants after giving their informed consent. The study was approved by the Committee on the Protection of the Rights of Human Subjects at the University of North Carolina at Chapel Hill.

Procedures

Testing was conducted in a well-lit room at a senior center or at the retirement community where the subject resided. Efforts were made to minimize distractions by keeping the door closed and limiting the number of persons in the room. Subjects were oriented to the room and the experimental procedures. All subjects performed both the BOT response speed subtest and the electronic reaction time test, with the order of testing counterbalanced across subjects. These 2 tests are similar in that the subject is required to produce a movement as quickly as possible in response to a visual stimulus. For the BOT, the visual stimulus is downward motion of the response speed stick as it is released, and the response is a thumb movement to stop the stick's descent as quickly as possible. For the electronic reaction time test, the visual stimulus is illumination of a light-emitting diode (LED), and the response is finger/hand movement to depress a telegraph key as quickly as possible.

For the BOT response speed subtest,[46] the subject's task was to stop a falling response speed stick (held against a wall by the tester and then released unexpectedly) as quickly as possible by pressing the stick against the wall with his or her thumb. The procedure for this test was as follows: The subject was seated in a 46-cm high, firm, armless chair facing a wall. A starting point was marked with a 30.5-cm long strip of masking tape attached to the wall horizontally. The tape strip was positioned slightly below the subject's shoulders and far enough off the floor so that the entire response speed stick fit below the tape line when resting perpendicular to the floor. Although the response speed stick is not included in the test kit for the second edition of the BOT, the BOT-2,[48] the stick can still be purchased on-line at low cost (http://ags.pearsonassessments.com). At the beginning of the test, one of the testers placed the response speed stick in a vertical position on the wall with the starting line, labeled in green on the stick, aligned with the tape strip (Figure 1A). The position of the subject's chair was adjusted so that the subject could place his/her dominant hand flat on the wall next to the response speed stick with the stick at midline. The subject placed his/her thumb over, but not touching, the red line marked on the stick. The subject's thumb was approximately 0.5 inches (1.3 cm) away from the stick, as judged visually by the tester. Instructions to the subject were as follows: "Watch the red line on the stick. When the red line moves, stop the stick as fast as you can with your thumb. Just before I let the stick fall, I will say 'Get set!' Then, when you see the red line move, stop the stick with your thumb as fast as you can." For each trial, the tester said "Get set!" and then waited approximately 1, 2, or 3 seconds (randomly varied across trials according to table in BOT Examiner's Manual[46]) before releasing the stick.

The subject's score for each trial was the numbered interval on the stick that was adjacent to the tape strip after the subject stopped the stick (Figure 1B). The stick is divided into 17 unequal intervals for scoring. The numbers decrease from the bottom to the top of the stick, so that faster responses produce higher scores. Two testers simultaneously and independently scored each trial, and were blinded to the other tester's results. The trial was re-administered if the subject failed to look at the stick as it dropped, touched the stick before it was released, or failed to stop the stick before it hit the floor. Two practice trials and 7 test trials were administered in accordance with the standardized instructions for the BOT response speed subtest. Although the mean of the 7 test trials was used as the primary measure of response time, the median also was calculated because that is the measure used in the original BOT.

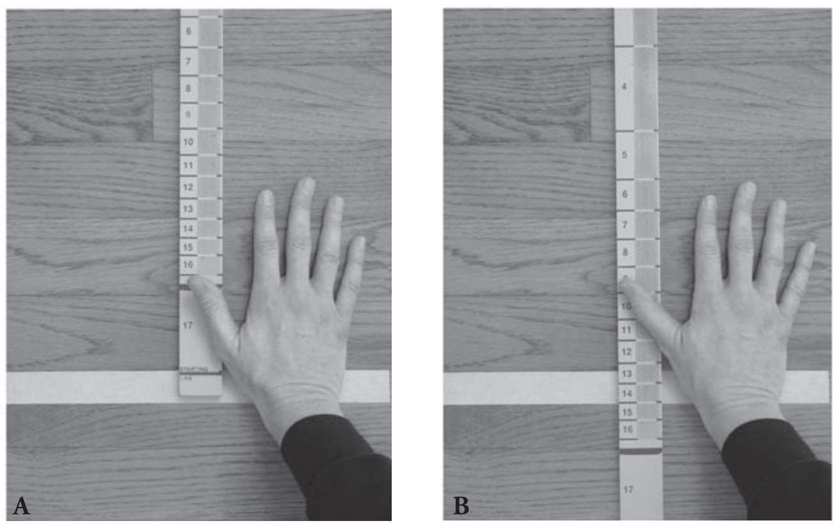

Figure 1. **Starting (A) and ending (B) positions on the response speed subtest. The score for the test result shown here would 13.**

The methodology used for the electronic test was very similar to that described by Lord and colleagues, involving an electronic timer with a light as the stimulus and depression of a switch by the finger as the response.[39] This test has been shown to have good test-retest reliability.[27,39,49] For the electronic reaction time test used in the present study, the subject was seated at a 74-cm high table with a telegraph key placed on the table directly in front of him/her at midline. The subject placed his/her dominant hand on the telegraph key, lightly touching but not depressing the key. Subjects were instructed to press the key as fast as possible following illumination of a red LED mounted 5 inches (12.7 cm), center-to-center, beyond the key (Figure 2). The tester stood behind and to one side of the subject holding a switch connected to the LED. The tester gave a verbal warning of "Get set!" and then, after a randomly varied delay of approximately 1, 2, or 3 seconds, depressed the

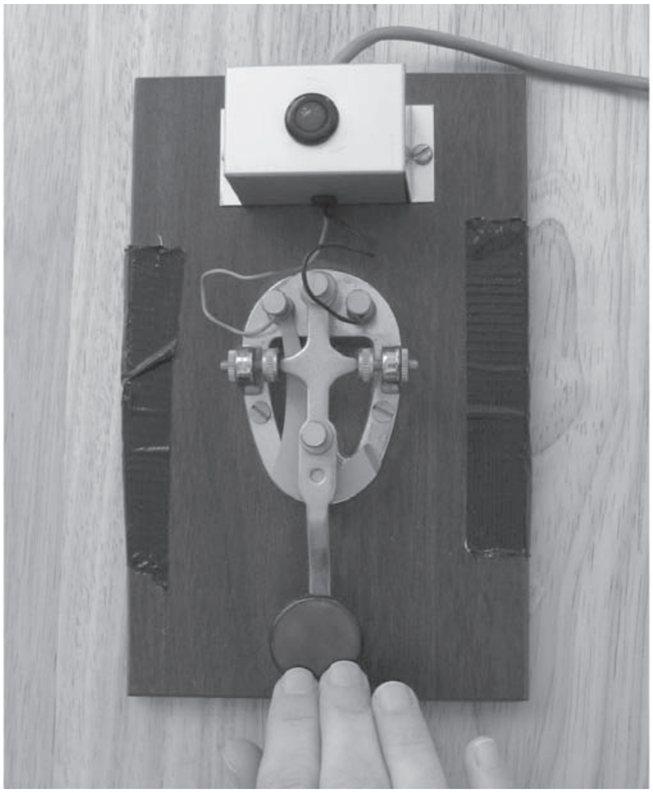

Figure 2. Set-up for electronic reaction time test.

switch to illuminate the LED. A millisecond timer was activated when the LED was illuminated and deactivated when the subject pressed the telegraph key. Reaction time to the nearest millisecond was recorded and the timer was reset after each trial. The trial was repeated if the subject failed to look at the LED in response to the warning signal or pressed the telegraph key prior to the illumination of the LED. The same tester administered the electronic reaction time test to all subjects. Subjects performed 2 practice trials and 7 test trials. The mean of the 7 test trials was used as the electronic measure of reaction time.

After a subject performed both the response speed subtest and the electronic reaction time test, he or she was given a rest period of approximately 10 to 20 minutes and then asked to repeat the response speed subtest. The duration of the rest period was adjusted so that approximately 20 minutes elapsed between the 2 administrations of the response speed subtest. The testing procedure during the second administration of the test was identical to that for the first administration, except that only one tester administered and scored each trial. The tester for each subject was the same person who gave the instructions and released the response speed stick during initial testing of that subject.

Statistical Analysis

Statistical analyses were performed using the SYSTAT software program (Systat Inc, 2902 Central St, Evanston, IL). To address the first research question, inter-tester reliability was assessed by comparing the scores of the 2 testers for the first administration of the response speed subtest. Test-retest reliability was assessed by comparing the scores of the same tester for the 2 different test administrations. For both of these reliability measures, an intraclass correlation coefficient (ICC[2,1]) was calculated using procedures described by Shrout and Fleiss.[50] An F ratio from the repeated measures analysis of variance (ANOVA) was used to aid in the interpretation of each of the ICCs by assessing the significance of differences between the 2 measures.[51] Because the ICC is more sensitive to random than to systematic error, significant differences between repeated measures may exist despite a high ICC value.[51,52] The standard error of measurement (SEM) and the 95% confidence interval (CI) on the SEM also were calculated.

To address the second research question, concurrent validity was assessed by comparing scores on the BOT response speed subtest to scores on the electronic reaction time test. A Pearson product-moment correlation coefficient (r) was calculated. The statistical significance of the correlation coefficient (H_o: r=0) was evaluated by converting the coefficient to a t statistic.[53] This procedure allowed us to test the null hypothesis of r=0 on a two-tailed t distribution with n-2 degrees of freedom. The level of significance for all statistical tests was set at 0.05.

RESULTS

Thirty subjects (22 women and 8 men) between 67 and 87 years of age, mean age 75.5 (5.5) years, participated in the study. All subjects were independent community dwellers. Their mean score on the MMSE was 29.4 (0.8). Only one subject used an assistive device, a cane, secondary to hip osteoarthritis.

Descriptive statistics for subjects' scores on both the response speed subtest and the electronic reaction time test are displayed in Table 1. Inter-tester reliability for scoring subjects on the response speed subtest using either mean or median scores was high [ICC(2,1)=0.99], and the F-ratio for testers was not significant (F=.71; p=.41). The SEM for two testers was 0.10, with a 95% CI on the SEM of 0.09 to 0.14.

Test-retest reliability of the response speed subtest, however, was only moderate[54] [ICC(2,1)=0.53 for mean scores, ICC(2,1)=0.65 for median scores]. The F-ratio for time of testing was significant for mean scores (F=7.98; p=.008) and approached significance for median scores (F=3.72; p=.077),

Table 1. Response Speed Subtest and Electronic Reaction Time Scores

	Response Speed Subtest* (N=30)				Electronic Reaction Time (ms) (N=24)
	First Administration		Second Administration		
	Mean scores	Median scores	Mean scores	Median scores	
Mean	9.0	8.8	10.1	9.8	295.44
SD	2.1	2.4	2.4	2.8	90.56
Range	4.9 – 14.0	4.0 – 14.0	5.3 – 15.1	3.0 – 16.0	177.43 – 533.71

*Response speed subtest of the Bruininks-Oseretsky Test of Motor Proficiency.[46] As described in text, possible scores range from a low of 1 to a high of 17.

indicating that subjects' mean scores improved from the first test administration to the second. The SEM for repeated test administrations was 1.53 (95% CI = 1.12 to 1.90) for mean scores and 1.44 (95% CI = 1.12 to 1.89) for median scores.

Six of the 30 subjects experienced a technical problem with the electronic reaction time device that resulted in very poor illumination of the LED. Consequently, electronic reaction time data for these 6 subjects were excluded from the analysis of concurrent validity. For the remaining 24 subjects, correlations between mean scores of the BOT response speed subtest and the electronic reaction time test were r = -0.41 (t = -2.11; p=0.045) and r = -0.45 (t = -2.35; p=0.027) for the first and second test administrations, respectively (Figure 3).

In view of the significant improvement in mean scores from the first to the second administration of the response speed subtest, post hoc analyses of the reliability of the mean of the 7 trial scores for each subject were performed. Values of the ICC (3,7) were 0.80 and 0.74 for the first and second test administrations, respectively, of the response speed subtest and 0.93 for the electronic reaction time test.

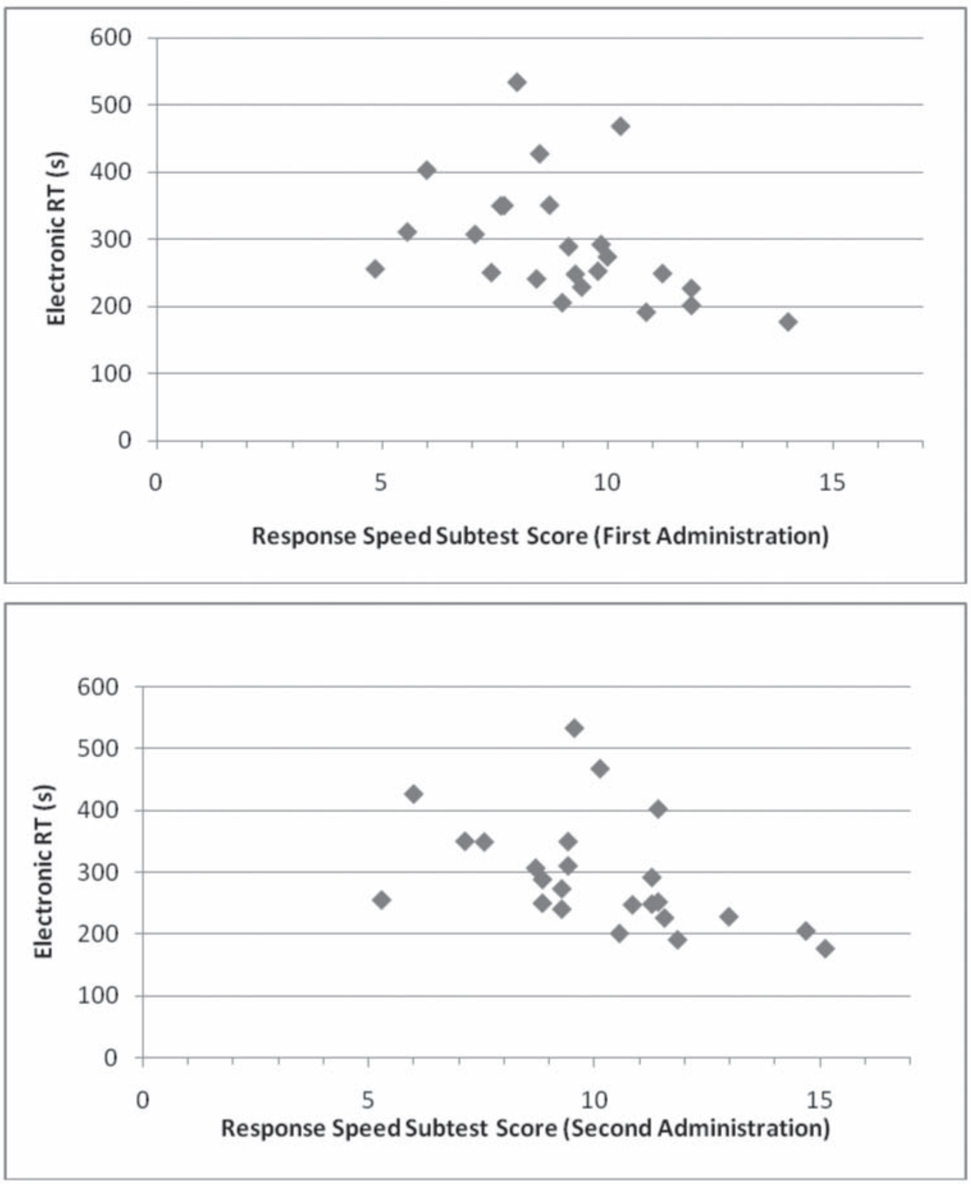

Figure 3. Scatter plot showing relationships between electronic reaction times and response speed subtest scores for the first (top) and second (bottom) test administrations.

DISCUSSION

All subjects completed the BOT response speed subtest, demonstrating that this method of reaction time measurement is appropriate for use with community-dwelling older adults. Results of our study provide evidence of the excellent inter-tester reliability of the response speed subtest when used with this population. Because the numbered scoring intervals are printed directly on the response speed stick, determining an individual's score for each trial is a simple and objective process.

The ICC values for test-retest reliability of the response speed subtest, however, were below the cutoff of 0.75 considered the minimum for good reliability.[54] Less than optimal reliability may influence test validity and may confound interpretation of test results for clinical decision-making. The significant improvement in mean scores from the first to the second test administration suggests a practice effect. Perhaps subjects needed longer exposure to the novel requirements of the response speed subtest in order to achieve a more stable level of performance. Previous researchers have shown that older adults are more negatively affected by novelty and are more sensitive to changes in complexity of a psychomotor task than younger individuals.[33,34] Over repeated trials, however, older adults demonstrate improvements in the speed, accuracy, and consistency of their motor responses.[33,55] The subjects in our study showed no increase in consistency of their responses between the first and second administrations of the response speed subtest, as evidenced by the ICC(3,7) values. Additional trials might have produced more stable performance, but might not be practical for application in clinical settings. Further research is needed to determine the number of practice and test trials of a response speed test necessary to provide a stable representation of psychomotor performance in older adults.

Based on the results for test-retest reliability, use of the median rather than the mean score for each subject may provide slightly better reliability for a response speed test. The developers of the BOT recommended using the median score,[46] which can be determined more quickly and more easily than the mean score, particularly for an odd number of trials. The median also is much less influenced by the presence of isolated high or low values than the mean, and therefore tends to fluctuate less from one series of trials to another.[56] Disadvantages of the median include the fact that it does not reflect the precise magnitude of most of the observations, resulting in loss of information. The median also is much less amenable to mathematical treatment than the mean.[56]

Correlations between scores on the response speed subtest and the electronic reaction time test were in the expected (negative) direction, with higher scores on the response speed subtest associated with shorter reaction times on the electronic test. Although statistically significant, these correlations were modest in size. This finding may be attributed, at least in part, to the greater novelty and complexity of the response speed subtest compared to the electronic reaction time test. Whereas older adults may encounter situations in their everyday lives in which they need to rapidly detect and respond to a light stimulus (eg, stoplights or emergency lights when driving, push buttons on telephones or appliances, touch screens on computers, etc.), they are less likely to have had experience with stimuli similar to the falling stick used in the response speed subtest. In addition, a key press is likely a more familiar and practiced response than that required for the response speed subtest. Subject performance on the response speed test also may have been influenced by attempts to use cues based on the tester's posture, movement, or facial expression to anticipate when the tester would release the stick. No cues were available for the electronic reaction time test, as the tester was not in the subject's field of view when the LED was illuminated. The reliability of the mean of 7 test trials was considerably lower for the response speed test than for the electronic reaction time test, indicating that factors affecting performance varied more from one trial to the next for the former test.

One of the limitations of our study is that subjects may have experienced significant visual and auditory distractions during testing. Because they often were tested at 2 separate stations in the same room, subjects may have observed activities of other subjects and testers and overheard other conversations, instructions, or warning cues. Consequently, the testing environment was less than ideal for eliciting the best performance by older adults. Older adults exhibit greater sensitivity to the learning environment than younger adults, possibly because of less inhibitory control and decreased ability to focus attention on salient aspects of the task.[57-61]

Another limitation of our study relates to the scoring of response speed subtest trials on which the subject failed to stop the stick before it hit the floor. In our study, these trials were repeated in order to provide a meaningful score for all 7 trials for each subject. Use of a score of "0" for these trials, as recommended in the BOT manual,[46] would mean that the same score would be recorded for all trials on which the stick was dropped. The range of variability among these slow responses would be lost. Allowing subjects to repeat these trials, however, increased some subjects' mean scores by eliminating the trials on which they performed most poorly.

We recommend a revised version of the response speed test using a longer stick to provide a wider range of meaningful scores for testing older adults. Use of a substantially longer stick will necessitate a change in test position from sitting to standing, so that the horizontal line used in determination of starting position and for scoring can be high enough on the wall. If the entire stick does not fit below the horizontal line when positioned perpendicular to the floor, scoring of slow responses (corresponding to numbers at the top of the stick) is not possible. Although administration of the test with the subject in a standing compared to a sitting position may appear more relevant for assessment of falls risk, the fact that the subject's hand is in contact with the wall at the start of the test greatly diminishes the balance requirements of the task.[62-64]

With further research to determine optimal methods of administration, the response speed subtest may prove useful in assessment of psychomotor performance in a variety of patient populations. The test could be used as part of a battery for identifying and monitoring risk for falls, for monitoring changes in processing speed over time in individuals with cognitive deficits or disorders such as Parkinson disease or multiple sclerosis, and in evaluating the effectiveness of interventions designed to improve rapid responses. In our view, the response speed subtest has limited utility as an intervention. One reason is that the test does not provide practice of rapid responses of the type used for recovery of balance. Another reason is that other reaction time tasks (ball skills, racquet sports, computer and video games, etc.) are likely to be more motivating.

CONCLUSIONS

Simple, inexpensive measures of reaction time are needed for use in clinical settings such as outpatient clinics and home health. In a sample of community-dwelling older adults, the BOT response speed subtest had excellent intertester reliability, but test-retest reliability was not in an acceptable range. Further research is needed to develop a modified version of the response speed test for use with older adults and to examine effects of practice and environmental distractions.

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CORRECTION:

The page numbers in the previous issue of the *Journal of Geriatric Physical Therapy* were incorrect. In citing the articles published in the June 2009 issue, the correct citations should be:

Lusardi MM. Editor's Message. *J Geriatr Phys Ther.* 2009; 32(2):45.

Fritz S, Lusardi MM. White paper: Walking speed, the sixth vital sign. *J Geriartr Phys Ther.* 2009; 32(2):46-49.

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Johanon MA, Cohen BA, Huiskens KM, McKinley AJ, Scott ML. Outcomes for aging adults following total hip arthroplasty in an acute rehabilitation facility versus a subacute rehabilitation facility: a pilot study. *J Geriatr Phys Ther.* 2009; 32(2): 73-78.

Meier WA, Marcus RL, Dibble LE, Foreman KB, Peters CL, Mizner RL, LaStayo PC. The long term contribution of muscle activation and muscle size to quadriceps weakness following total knee arthroplasty. *J Geriatr Phys Ther.* 2009; 32(2):79-82.

Jones TE, Stephenson KW, King JG, Knight KR, Marshall TR, Scott WB. Sarcopenia: mechanism and treatments. *J Geriatr Phys Ther.* 2009; 32(2):83-89.