

## Validity and reliability of the Motion Sensitivity Test

Faith W. Akin, PhD; Mary Jo Davenport, PT, MS

*Auditory and Vestibular Dysfunction Research Enhancement Award Program, Audiology and Speech Pathology Service, James H. Quillen VA Medical Center, Mountain Home, TN; Department of Physical Therapy, East Tennessee State University, Johnson City, TN*

**Abstract**—The Motion Sensitivity Test (MST) is a clinical protocol designed to measure motion-provoked dizziness during a series of 16 quick changes to head or body positions. The MST has been used as a guide for developing an exercise program for patients with motion-provoked dizziness and as a treatment outcome measure to monitor the effectiveness of vestibular rehabilitation therapy. This study determined validity, test-retest reliability, and interrater reliability of the MST. Fifteen individuals with motion-provoked dizziness and ten control individuals were tested during sessions occurring 90 min and/or 24 hr after baseline testing. The MST was found to be reliable across raters (intraclass correlation coefficient [ICC] = 0.99) and test sessions (ICC = 0.98 and 0.96). Test validity was good. The results indicated that the MST can be used reliably in clinical practice to develop exercise programs for patients with motion-provoked dizziness and to provide evidence of intervention efficacy.

**Key words:** dizziness, falls, habituation, vestibular function tests.

### INTRODUCTION

According to studies from the National Institutes of Health (NIH), 90 million Americans (42% of the population) will complain to their doctors of dizziness at least once in their lifetime [1]. The prevalence is increased in the elderly with ~25 to 30 percent of community-dwelling elders experiencing frequent dizziness [2,3]. Chronic dizziness can lead to persistent unsteadiness and increased risk

of falling and thus contribute to physical, psychological, and social disability [4].

More than 50 percent of the accidental deaths in the elderly are due to balance-related falls of which dizziness is frequently an associated symptom [1]. Falls account for 250,000 hip fractures each year in persons over age 65 [5]. Twenty-five percent of these individuals die within a year and fifty percent are unable to return to an independent lifestyle [6,7]. The total direct cost of fall injuries is currently \$20 billion a year and is expected to reach \$32.4 billion by the year 2020 [8].

A common complaint of patients with balance disorders is motion-provoked dizziness. Motion-provoked dizziness refers to a disturbing sense of vertigo or dizziness associated with head movement. This dizziness is often

**Abbreviations:** ICC = intraclass correlation coefficient, MST = Motion Sensitivity Test, VRT = vestibular rehabilitation therapy.

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Address all correspondence and requests for reprints to Faith W. Akin, PhD; Audiology and Speech Pathology Service, James H. Quillen VA Medical Center, Mountain Home, TN 37684; 423-926-1171, ext. 7553; fax: 423-979-3403; email: faith.akin@med.va.gov.

caused by some permanent and stable vestibular dysfunction that can be elicited during head movement [9]. Vestibular dysfunction may cause a decrease in vestibulo-ocular reflex gain that results in dizziness and/or visual blurring during movements of the head. According to Norré and Beckers, motion-provoked dizziness resolves when sufficient central compensation occurs following a vestibular imbalance [9]. Although most patients with vestibular disturbances recover spontaneously owing to central compensation, some patients continue to experience chronic dizziness, particularly during head movements.

Vestibular rehabilitation therapy (VRT) is a relatively new treatment for many patients suffering from dizziness and/or balance disorders. VRT stimulates and enhances normal compensatory mechanisms through repeated performance of eye, head, or body movements that provoke dizziness. VRT includes habituation exercises, adaptation exercises, and gait and balance exercises. Habituation exercises are a key component of VRT for patients who experience motion-provoked dizziness. Habituation is defined as a long-term reduction in the pathological response to particularly noxious stimuli [10]. Habituation exercises to treat vertigo were first described by Norré and DeWeerd in the early 1980s and consist of individually selected symptom-provoking head motions designed to encourage vestibular compensation [11,12]. For example, a habituation exercise might be repeated rolling over in bed for a patient whose symptoms were provoked by this activity. The timing and magnitude of the habituation response to customized daily exercises vary among patients, occurring in as little time as 2 weeks in some patients while taking up to 6 months in others. Most patients will begin to experience dramatic relief of symptoms within 4 to 6 weeks of performing daily habituation exercises [13].

The Motion Sensitivity Test (MST) is a clinical technique to measure motion-provoked dizziness in patients with vestibular disturbances using a series of 16 quick changes to head or body position. The severity and duration of the dizziness are recorded for each position and a cumulative score, the MST quotient, is calculated. The MST was adapted by Smith-Wheelock et al. from Norré and Beckers' vestibular habituation training test battery that was developed to account for the variability in specific positions that provoke symptoms in dizzy patients [14,15].

The MST has been used as a guide for developing an exercise program to meet the individualized needs of patients with motion-provoked dizziness and as a treatment outcome measure to monitor the effectiveness of VRT

[10,16,17]. Although the test has been used for nearly a decade to guide treatment and to measure small changes in symptoms over time, the reliability of the MST has not been investigated. If the MST is to be used clinically to evaluate change in the severity and duration of a patient's motion-provoked dizziness, then the reliability of the instrument needs to be determined. Test-retest reliability would indicate that the MST could be used to measure change in symptoms over time. Interrater reliability would indicate that the MST score is consistent when measured by different clinicians. Once reliability is determined, the MST can be used to measure treatment outcome in patients undergoing VRT for motion-provoked dizziness. Finally, the validity of the test needs to be established to be certain that the test appropriately identifies individuals with motion-provoked dizziness. This study determined the test-retest reliability, interrater reliability, and validity of the MST.

## METHODS

### Subjects

Two groups of community-dwelling individuals participated in the study, and data were collected at two regional senior citizen centers. The first group included 15 subjects (8 males and 7 females), ranging in age from 43 to 86 (mean = 65 years), with complaints of motion-provoked dizziness during routine movements associated with daily living. The extent of symptoms varied from dizziness occurring in a single head position to dizziness occurring with multiple head movements. The second group included 10 control subjects (6 males and 4 females), ranging in age from 37 to 79 (mean = 66 years), with no complaints of motion-provoked dizziness. Subjects' approval was obtained and the procedures followed the standards of the institutional review board.

### Motion Sensitivity Test

The MST was administered according to the clinical protocol described by Smith-Wheelock et al. [14]. Each subject performed 16 different head and/or body movements in the following order:

1. Sitting to supine.
2. Supine to left side.
3. Supine to right side.
4. Supine to sitting.
5. Left Dix-Hallpike (sitting to supine, head hanging to the left).

6. Head up from left Dix-Hallpike.
7. Right Dix-Hallpike (sitting to supine, head hanging to the right).
8. Head up from right Dix-Hallpike.
9. Sitting with head tipped to left knee.
10. Head up from left knee.
11. Sitting with head tipped to right knee.
12. Head up from right knee.
13. Head turns while sitting.
14. Sitting head tilts.
15. 180° turn to right while standing.
16. 180° turn to left while standing (a sample blank form of the MST used in this study can be found in the **Appendix** that appears in the on-line version only).

Each subject was instructed to indicate the onset and offset of any dizziness that occurred in each position. The duration of dizziness, which was recorded with a stopwatch, was assigned the following values: 1 point for 5 s to 10 s of dizziness, 2 points for 11 s to 30 s of dizziness, and 3 points for >30 s of dizziness. Once the duration was recorded for a position, the subject was asked to rate verbally the intensity (severity) of the dizziness just experienced on a scale of 0 to 5 (0 = no symptoms; 5 = severe dizziness). By adding the duration score to the intensity score, investigators calculated a raw score for each position. The maximum raw score for each of the 16 positions is 8 points (3 points for dizziness lasting >30 s and a score of 5 points for severe dizziness); the total possible MST raw score is 128 (8 points × 16 positions). The MST quotient was calculated with the use of the formula [14]

$$\text{MST quotient} = \frac{[\sum(\text{duration} + \text{intensity}) \times \text{No. of dizziness-provoking positions}]}{\div 2,048} \times 100.$$

The MST quotient equals the number of positions that provoked symptoms times the intensity and duration total for all positions divided by 2,048. In the formula, 2,048 = 16 (total number of positions) × 128 (total possible MST raw score). One can then calculate a percentage score by multiplying by 100. Thus, an MST quotient of 0 indicates no symptoms, whereas an MST quotient of 100 indicates severe unrelenting symptoms in all positions. In the formula, the number of positions in which dizziness occurs is weighted more than the intensity and duration of the dizziness. For example, a subject may have maximum intensity and duration scores (i.e., 5 and 3, respectively) in 3 of the 16 positions for a 2.6 MST quotient. In contrast, another

subject may have mild dizziness (intensity = 1) and short duration (duration = 1) in all positions for a 25 MST quotient. If a subject reported dizziness prior to the MST (at rest), then the intensity score at rest was subtracted from the intensity score for each position, so the MST quotient only reflected the dizziness that occurred from position changes.

### Procedure

To determine the test-retest reliability of the MST, examiners tested the subjects with motion-provoked dizziness at two intervals ~24 hr apart. Eight of the fifteen subjects with motion-provoked dizziness were able to remain for a third test session at 90 min after baseline. To determine interrater reliability, two examiners simultaneously measured the duration and recorded the intensity of symptoms during 20 sessions performed on the motion-provoked dizziness group. The examiners were blinded to the observations of one another, but both were present in the same room for the test sessions. These sessions were randomly selected among the 38 test-retest sessions (fifteen baseline sessions, eight 90 min after baseline sessions, and fifteen 24 hr after baseline sessions). To determine if asymptomatic subjects experience dizziness on the MST, examiners also performed the test on a group of 10 control subjects during one test session.

### Analysis

Test-retest and interrater reliability of the MST was evaluated with the use of intraclass correlation coefficients (ICCs). This statistical index was chosen because of its broad clinical applicability and because it reflects both correlation across test sessions and agreement among examiners [19]. ICCs were calculated with the use of one-way analysis of variance (ANOVA) to produce the mean square data to factor out the variance. The ICC for interrater reliability was determined with the use of the formula

$$\text{ICC}(1,1) = \frac{[\text{BMS} - \text{WMS}]}{[\text{BMS} + (k - 1)\text{WMS}]},$$

in which BMS = between subjects mean square, WMS = within groups mean square, and  $k$  = number of sessions. The ICC for test-retest reliability is determined by

$$\text{ICC}(3,1) = \frac{[\text{BMS} - \text{EMS}]}{[\text{BMS} + (k - 1)\text{EMS}]},$$

in which BMS = between subjects mean square, EMS = error mean square, and  $k$  = number of examiners.

## RESULTS

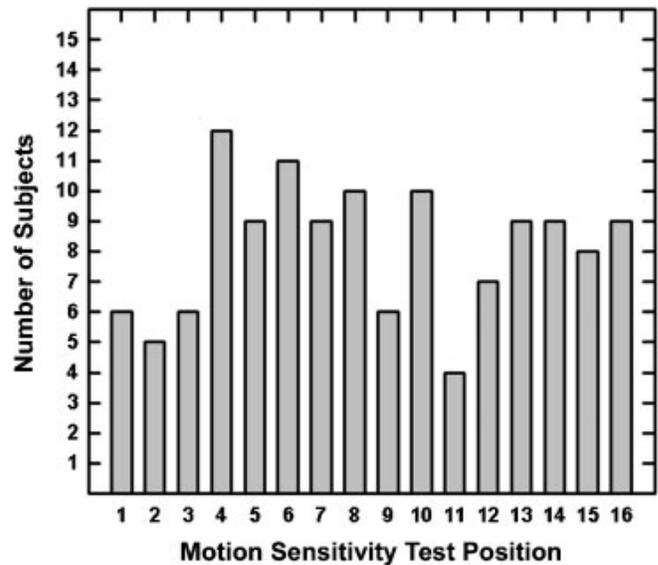
All subjects with motion-provoked dizziness reported symptoms on the MST indicating a test sensitivity of 100 percent. The MST quotients (see **Table**) ranged from 0.2 to 91.4 (mean = 21.6) across all test sessions. The number of subjects reporting dizziness in each position during one test session is shown in **Figure 1**. Four to six subjects reported dizziness in positions 1 (sitting to supine), 2 (supine to left side), 3 (supine to right side), 9 (sitting, head tipped to left knee), and/or 11 (sitting, head tipped to right knee), while seven to twelve subjects reported dizziness in all the other positions (see on-line **Appendix**). These results were similar across all test sessions. The duration scores for dizziness ranged from 0 (0 s to 5 s) to 3 (>30 s) and intensities ranged from 0 (no symptoms) to 5 (severe symptoms) in the subjects with motion-provoked dizziness.

The MST quotients for the control group ranged from 0 to 0.5 (mean = 0.06) across all test sessions. Although eight subjects reported no dizziness in all positions (MST quotient = 0), two control subjects reported dizziness in positions 6 (up from left Dix-Hallpike) or 8 (up from

### Table.

Individual and mean MST quotients for motion-provoked dizziness group at each test session. Only 8 of 15 subjects were tested at 90 min interval.

Subject	Baseline	90 min	24 hr
1	4.8	3.2	5.5
2	16.3	8.9	5.1
3	2.4	2.2	0.7
4	91.4	87.5	89.8
5	27.0	57.0	39.6
6	20.2	11.3	14.0
7	0.6	1.2	4.8
8	1.9	1.2	0.9
9	23.9	—	39.9
10	0.2	—	0.2
11	22.0	—	7.9
12	3.0	—	0.9
13	52.7	—	67.2
14	53.1	—	63.3
15	1.5	—	0.3
<b>Mean</b>	21.9	21.6	24.0
<b>SD</b>	25.9	32.5	29.7

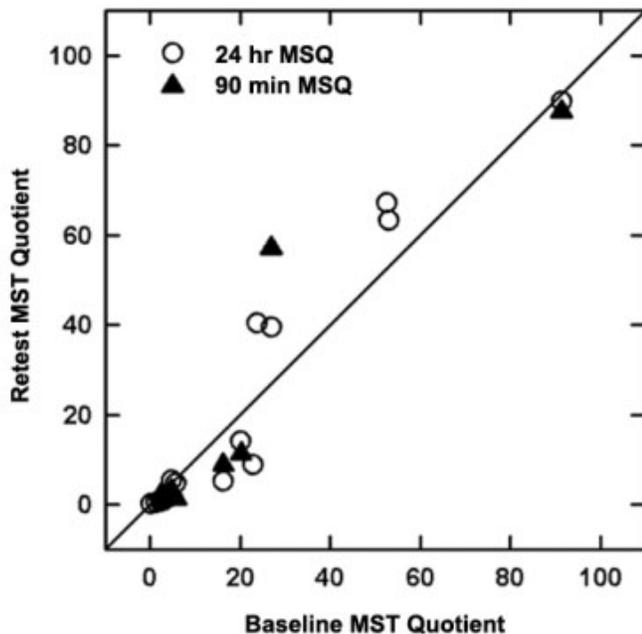


**Figure 1.**

Histogram showing number of subjects reporting dizziness for each position in MST (n = 15) (see on-line **Appendix**).

right Dix-Hallpike) (MST quotients were 0.5 and 0.15). These findings indicated a test specificity of 80 percent.

To determine the test-retest reliability of the MST quotient, examiners performed the MST on subjects with motion-provoked dizziness at two intervals ~24 hr apart. The MST was repeated at 90 min after the baseline test in a subset of eight subjects. The means and standard deviations (SDs) of the MST quotient for each test session are shown in the **Table**. A bivariate plot shows individual MST quotients obtained at the baseline, 90 min, and 24 hr test intervals (**Figure 2**). The abscissa represents the MST quotient obtained during the first test session (baseline), and the ordinate represents the MST quotient obtained during the retest session (90 min or 24 hr). The diagonal line represents equal MST quotients for the baseline and retest sessions. Data points plotted above the line show subjects with greater MST quotients in the retest session, and data points plotted below the line show subjects with greater MST quotients in the baseline test session. Subjects with mild dizziness had minimal MST quotient variability for (MST quotient < 10), whereas those with more severe motion-provoked dizziness (MST quotient > 10) demonstrated more variability across test sessions. The minimal variability for subjects with low MST quotients was likely owing to floor



**Figure 2.**

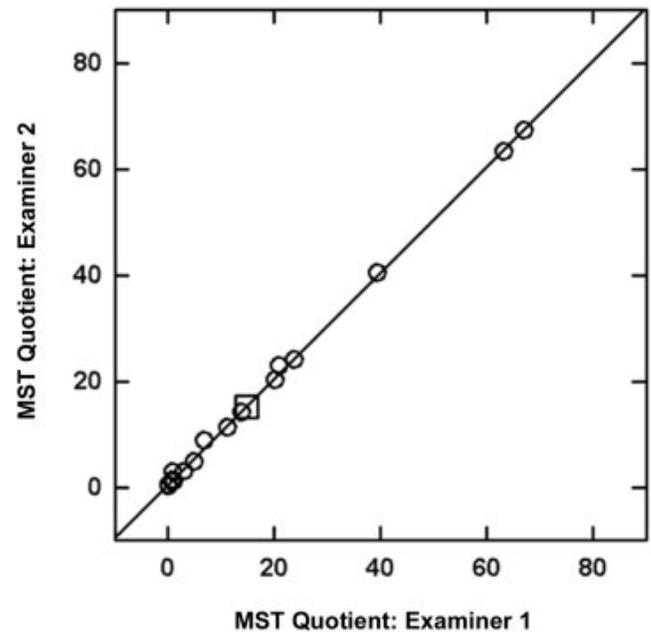
Bivariate plot of MST quotient plotted for each subject with motion-provoked dizziness at baseline (abscissa) and 90 min and 24 hr later (ordinate). Diagonal line represents equal MST quotients for baseline and retest sessions. Data points plotted above line show subjects with greater MST quotients in retest session, and data points plotted below line show subjects with greater MST quotients in baseline test session.

effects. The ICC for test-retest reliability was 0.98 for 90 min and 0.96 for 24 hr test sessions.

Interrater reliability of the MST was determined for patients with motion-provoked dizziness during randomly chosen test sessions. Two examiners simultaneously scored subject responses on the MST and calculated the MST quotients. A bivariate plot of individual MST quotients obtained by both examiners is shown in **Figure 3** with examiner 1 on the abscissa and examiner 2 on the ordinate. The diagonal line represents equal MST quotients. The square symbol on **Figure 3** represents the mean MST quotient obtained by both examiners. Essentially, no variability was found in MST quotients between the two examiners with an ICC of 0.99, indicating excellent interrater reliability.

## DISCUSSION

The results of this study revealed that the MST has good validity. Good test validity indicates that a test measures what it intended to measure. All subjects with self-



**Figure 3.**

Bivariate plot of individual MST quotients plotted for examiner 1 (abscissa) and examiner 2 (ordinate). Diagonal line represents equal MST quotients for both examiners. Data points plotted above line show subjects with greater MST quotients recorded by examiner 1, and data points plotted below line show subjects with greater MST quotients recorded by examiner 2. Square represents mean MST for both examiners.

reported motion-provoked dizziness were symptomatic on the MST, whereas only two control subjects reported dizziness on the test. These findings indicate that the MST has good sensitivity and specificity for detecting motion-provoked dizziness. It is noteworthy that the two control subjects who experienced slight dizziness on the MST reported symptoms when rising up from the Dix-Hallpike position. The dizziness was short in duration (<10 s) and ranged from 1 to 3 in intensity. This finding with the two control subjects may be owing to intracranial hemodynamic shifts that occur when the head is raised from the Dix-Hallpike positions. Hemodynamic fluid shifts can result in paroxysmal positional decreases in cerebral blood flow or transient ischemic episodes. Transient ischemic episodes in basilar vertebral insufficiency can produce a brief sensation of dizziness that is unrelated to vestibular function [20]. Thus, the brief dizziness that may occur when a patient rises from the Dix-Hallpike position may be clinically insignificant.

Test-retest reliability of the MST was good, indicating that the MST is a reliable instrument to monitor

changes in a patient's motion-provoked dizziness. These findings indicate that an individual's self-assessment of dizziness does not change significantly between two sequential test sessions (90 min or 24 hr). Although a subject may remember responses in the MST 90 min following the baseline test, a 24 hr period may eliminate memory of previous responses. Because symptoms were recorded for 16 different positions, however, the subject's memory of earlier responses is likely to have played a role in the high correlations.

The MST quotient includes calculation of three parameters: (1) the number of positions in which symptoms occurred, (2) the duration of motion-provoked dizziness in each position, and (3) the intensity of motion-provoked dizziness in each position. Although the MST quotient is weighted more heavily upon the number of positions in which symptoms occurred, the quotient does not specifically reflect each parameter. For example, an MST quotient of 25 offers no information about the specific intensity or duration of the motion-provoked dizziness in each position. Thus, although a change in the MST quotient reflects a difference in overall motion-provoked dizziness, the change does indicate whether or not differences occur in symptom intensity, symptom duration, or the number of positions provoking dizziness.

An interesting observation was that more variability was found across test sessions for subjects with more severe motion-provoked dizziness (MST quotient > 10) than subjects with mild symptoms (MST quotient < 10). Presumably, this finding occurred because there was more room to vary for higher MST quotients, and a floor effect for low MST quotients. Further research is necessary to determine the relationship between the degree of symptom severity and scores on repeated testing.

Finally, the MST has excellent interrater reliability (ICC = 0.99). The high interrater reliability also indicates that the test-retest reliability can be generalized to other examiners. Thus, the MST may be a valuable instrument for measuring treatment outcome in patients undergoing VRT.

## CONCLUSIONS

This study determined the validity and the reliability of the MST. If the MST proved to be a valid and reliable measure of motion-provoked dizziness, then the test could be used as an outcome measure for VRT. The data indicated that the MST is a valid and reliable instrument for monitoring motion-provoked dizziness. In addition,

the test is easy to administer, requires minimal equipment, and is easy to score. The results of this study support its use as a treatment outcome measure for VRT.

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