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The Modified Romberg Balance Test: Normative Data in U.S. Adults

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Objective: To generate normative values for performance on the modified Romberg Test of Standing Balance on Firm and Compliant Support Surfaces stratified by age, sex, and race/ethnicity and to determine fall risk associated with different levels of performance.
Study Design: National cross-sectional survey.
Setting: Ambulatory examination centers.
Patients: U.S. adults 40 years and older who participated in the 2001–2004 National Health and Nutrition Examination Survey (n = 5,086).
Interventions: Time to failure on the modified Romberg Test of Standing Balance on Firm and Compliant Support Surfaces.
Main Outcome Measures: History of falling in the previous 12 months.
Results: We observed that the time to failure decreased with increasing age across all sex and race/ethnicity categories. We found that once individuals went below a time to failure of 20 seconds, there was a significant greater than 3-fold increase in the odds of falling. In general, participants crossed the 20-second threshold at the age of 60 to 69 years.
Conclusion: We established nationally representative normative values for performance on the modified Romberg test and noted differences in the rates of change across demographic groups. In addition, we demonstrated the fall risk associated with different levels of performance. These data will aid the clinician in interpreting and risk stratifying their patient's performance on this postural test. **Key Words:** Aging—Balance—Falls—Race—Romberg—Sex—Vestibular dysfunction.

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A recent analysis from the National Health and Nutrition Examination Survey (NHANES) found that performance on the modified Romberg Test of Standing Balance on Firm and Compliant Support Surfaces was significantly associated with self-reported fall risk during the previous 12 months (1). The modified Romberg test, which has been shown to approximate computerized dynamic posturography testing (2), shows promise as a screening test of vestibular-mediated balance function that predicts the clinically important risk of falling during normal daily activities.

However, the development and widespread application of a screening test requires the establishment of normal parameters for that test in the population. Several small studies have estimated normative performance on the modified Romberg test (3,4), although performance times by age, sex, and race in a large population have not been defined. Moreover, the fall risk associated with a given performance level is also unknown.

In this report, we use data from the 2001–2004 NHANES to assess time to failure on the modified Romberg test and to generate nationally representative normative values for performance on this test. We consider differences in normal levels by age, sex, and race and evaluate how performance on this test predicts fall risk. The objective of this study was to aid the clinician in interpreting a patient's performance on the modified Romberg test and in predicting a given patient's fall risk.

METHODS

Study Population

NHANES is an ongoing cross-sectional survey of a nationally representative sample of the civilian, noninstitutionalized population of the United States. Every 2 years, the NHANES survey enrolls randomly selected participants for a comprehensive health screening; the 2001–2002 and 2003–2004 NHANES

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performed balance testing on 5,086 adults 40 years and older. Further details of the NHANES sampling process have been published previously (5,6).

Balance Questionnaire and Testing

Before balance testing, participants completed a questionnaire regarding a history of dizziness and falls in the past 12 months. Balance testing consists of the modified Romberg Test of Standing Balance on Firm and Compliant Support Surfaces. This test examines the participant's ability to stand unassisted under 4 test conditions that are designed to specifically test the sensory inputs that contribute to balance—the vestibular system, vision, and proprioception (Table 1) (7).

Balance testing was scored on a pass/fail basis. Test failure was defined as a subject 1) needing to open his or her eyes, 2) moving his or her arms or feet to achieve stability, or 3) beginning to fall or requiring operator intervention to maintain balance within a 30-second interval. Each subject who failed a Test Condition was eligible for another attempt to pass. Because each successive Test Condition was more difficult than the condition preceding it, balance testing was concluded whenever a subject failed to pass a Test Condition (during the initial test or in the retest). We focused on Test Condition 4—standing with eyes closed on a 16 × 18 × 3-inch foam pad—in which participants relied primarily on vestibular input. Of 5,086 participants, 257 did not pass previous test conditions and did not participate in Test Condition 4. An additional 86 participants had missing data for Test Condition 4, for a total of 343 excluded participants (6.7%). The time to failure (measured manually by stopwatch in seconds) was recorded in all subjects who participated in Test Condition 4; for subjects who passed Test Condition 4, the time to failure was set as 30 seconds (the maximum testing time). Further details of balance testing procedures are available (http://www.cdc.gov/nchs/data/nhanes/ba.pdf).

Sociodemographic Variables

Age at interview was binned by decade. Race/ethnicity was grouped as non-Hispanic white (hereafter *white*), non-Hispanic black (hereafter *black*), Mexican-American, or "other."

Analysis

We estimated the time to failure on Test Condition 4, stratified by sociodemographic characteristics. Logistic regression was used to estimate the odds of falling associated with different times to failure. All analyses were adjusted for the survey design using the SURVEY procedures in SAS software (SAS Institute, Inc., Cary, NC, USA). Sample weights were incorporated into all analyses by using the WEIGHT statement in SAS software per National Center for Health Statistics instructions. All prevalences and odds ratios are presented from weighted analyses. $p < 0.05$ was considered statistically significant.

TABLE 1. *Four test conditions of the modified Romberg Test of Standing Balance on Firm and Compliant Support Surfaces, NHANES 2001–2004*

Test condition	Description	Sensory inputs
1	Eyes open, firm surface	Visual, proprioceptive, vestibular
2	Eyes closed, firm surface	Proprioceptive, vestibular
3	Eyes open, compliant surface	Visual, vestibular
4	Eyes closed, compliant surface	Vestibular only

TABLE 2. *Time to failure on Test Condition 4 (95% CI) in U.S. men and women (≥40 yr) by race/ethnicity and age, NHANES 2001–2004*[a]

Demographic category	Time to failure[b] (s) Men	Women
White, non-Hispanic (yr)	n = 1,914	n = 1,959
40–49	25.8 (24.6–27.1)	27.0 (26.3–27.8)
50–59	23.2 (21.7–24.7)	22.9 (21.5–24.2)
60–69	**19.7 (18.4–21.0)**	**18.3 (17.0–19.6)**
70–79	**15.4 (14.1–16.7)**	**13.2 (11.7–14.6)**
>80	**9.0 (7.2–10.9)**	**9.1 (7.8–10.4)**
Black, non-Hispanic (yr)	n = 602	n = 647
40–49	23.6 (22.1–25.2)	25.0 (23.2–26.9)
50–59	21.0 (17.9–24.0)	23.4 (21.5–25.2)
60–69	**18.8 (16.9–20.7)**	20.6 (19.1–22.1)
70–79	**14.4 (12.0–16.8)**	**12.4 (9.3–15.5)**
>80	**10.5 (0–24.0)**	ND
Mexican-American (yr)	n = 610	n = 610
40–49	25.4 (24.2–26.7)	24.5 (22.8–26.2)
50–59	22.9 (20.2–25.5)	20.5 (17.6–23.3)
60–69	**16.9 (15.4–18.3)**	**16.2 (14.7–17.7)**
70–79	**9.7 (8.2–11.1)**	**9.1 (6.3–12.0)**
>80	**2.5 (1.3–3.8)**	ND
Other (yr)	n = 200	n = 243
40–49	24.5 (21.5–27.6)	24.4 (21.7–27.2)
50–59	**16.8 (13.5–20.2)**	21.2 (18.0–24.4)
60–69	**13.9 (9.2–18.7)**	**17.1 (13.5–20.7)**
70–79	**9.7 (4.3–15.1)**	**9.7 (0.0–19.6)**
>80	ND	ND

Values in bold indicate a time to failure of less than 20 seconds.
[a]n = 6,785, sample weights applied.
[b]Time to failure (s) of Test Condition 4 of the modified Romberg test.
CI indicates confidence interval; ND, insufficient data.

RESULTS

We evaluated the normative performance levels on the modified Romberg test (measured as the time to failure on Test Condition 4 in seconds) by age, sex, and race/ethnicity groups (Table 2). We found that the time to failure decreased markedly with age, such that in white men, for example, participants aged 40 to 49 years were able to maintain balance for a mean of 25.8 seconds, compared with participants aged 80 years and older who could not stay upright for longer than 9.0 seconds.

We then examined how the time to failure on Test Condition 4 influenced the odds of falling. We observed that as the time to failure shortened, the prevalence of falls increased, such that only 2% of participants who passed Test Condition 4 (whose time to failure was coded as 30 s) reported a fall in the previous 12 months, whereas participants who maintained balance on the modified Romberg test for less than 10 seconds had a 7% fall prevalence (Table 3). We found that the odds of falling increased as the time to failure shortened: compared with participants who did not fail the modified Romberg test, participants who failed in 20 to 29 seconds, 10 to 19 seconds, and less than 10 seconds had a 2.0-, 3.4-, and

TABLE 3. *Prevalence (95% CI) and odds ratios of falling (95% CI) by time to failure on Test Condition 4, NHANES 2001–2004*[a]

	History of falls[c]	
Time to failure[b] (s)	% (95% CI)	OR (95% CI)
30	2.0 (1.2–2.9)	1.0
20–29	4.1 (0.0–9.5)	2.0 (0.5–8.3)
10–19	6.7 (3.8–9.7)	3.4 (1.9–6.4)
<10	7.0 (5.6–8.4)	3.6 (2.4–5.4)

CI indicates confidence interval; OR, odds ratio.
[a]n = 6,785, sample weights applied.
[b]Time to failure (s) of Test Condition 4 of the modified Romberg test.
[c]Participants reported falling in the past 12 months; 10 participants had missing data.

3.6-fold increase in odds of falling, respectively. In general, the odds of having fallen became significantly higher at a time to failure of 20 seconds or less. We evaluated the age at which individuals crossed the 20-second elevated fall risk threshold. We observed that participants in all sex and race/ethnicity categories had a time to failure of less than 20 seconds at 60 to 69 years old, with the exception of black women who crossed this threshold at 70 to 79 years and men from the "other" race/ethnicity category who fell below this threshold at 50 to 59 years (Table 2, bold values).

DISCUSSION

We demonstrated in previous work that performance on the modified Romberg Test of Standing Balance on Firm and Compliant Support Surfaces is significantly associated with fall risk (1). We previously characterized performance on the modified Romberg test as a binary pass-or-fail variable; in this analysis, we further considered age-standardized normative performance levels by evaluating time to failure on the modified Romberg test. Normative time to failure data were generated across demographic groups, such that the expected performance of particular individuals (e.g., a 65-year-old black woman) could be predicted. As a corollary, these data can be used to identify deviations from normal performance in the clinical setting.

We noted that, in general, the time to failure on the modified Romberg test decreased linearly with age. Further, we observed that with decreasing performance times on the modified Romberg test, there was a concomitant rise in fall risk. Specifically, we found that once individuals dropped below a time to failure of 20 seconds, there was a significant greater than 3-fold increase in the odds of falling. For the most part, participants crossed this elevated fall risk threshold at age 60 to 69 years. A failure time of 20 seconds on the modified Romberg test was also found to distinguish between subjects with and without vestibular dysfunction in a previous study (3). Individuals who fall below this threshold may benefit from counseling about fall risk reduction strategies.

The modified Romberg Test of Standing Balance on Firm and Compliant Support Surfaces has potential usefulness as a screening test for vestibular dysfunction and for elevated fall risk, and the delineation of normative values for this test is central to its clinical application. These data are meant to aid the clinician in interpreting and risk stratifying their patient's performance on this postural test. These normative data may also help clinicians track the effectiveness of interventions in modifying fall risk in their patients. Future studies will be required to determine the precise physiologic substrates assayed by the modified Romberg test; such information could further inform the development of rational, targeted fall risk reduction therapies.

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