Do Changes in Mental Energy and Fatigue Impact Functional Assessments Associated with Fall Risks? An Exploratory Study Using Machine Learning

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Do Changes in Mental Energy and Fatigue Impact Functional Assessments Associated with Fall Risks? An Exploratory Study Using Machine Learning

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ABSTRACT

Using a crossover-design, we assessed changes in 30-second chair stand test (30 s-CST), Timed Up-and-Go (TUG) and Berg Balance Scale (BBS) and energy and fatigue in older adults (N = 11) after performance of mental tasks. A Wilcoxon Sign Rank Test and a Friedman’s rank test were used to assess changes in 30 s-CST, TUG, BBS and energy and fatigue respectively. A linear mixed model was used to assess joint variance and random forest classifier and support vector machine (SVM) algorithms were used to verify results. Statistically significant declines in feelings of energy (p = .003), specifically mental energy (p = .015), and BBS (p < .001), specifically during the “standing with eyes closed” (SEC), was noted for participants on days when they completed mental tasks compared to days they did not. The random-forest and SVM algorithms predicted with 79% and 80% accuracy respectively whether the SEC item of the BBS was performed after a decline a mental energy.

ARTICLE HISTORY

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KEYWORDS

Older adults; falls; energy; fatigue; Berg Balance Scale; machine learning

Introduction

It is estimated that by the year 2030, approximately 20% of the population in the United States will be over the age of 65¹ and that 20-33% will fall each year.² Approximately 10% of falls result in serious injuries and, the annual fall related healthcare costs are estimated to be $50 billion.²,³ Increased age may be associated with higher incidences of falls and the severity of complications that follow.⁴ The prevalence of falls may be attributed to diminished neuromuscular functioning, such as impaired balance, muscle strength, sensation, vision and cognition.⁵

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Impaired gait is another factor related to increased risks of falling. Recently, Grobe and colleagues postulated that increased fall risks may be associated with the impact of mental fatigue on gait and postural control. Their theoretical foundation was based on two premises: cognitive dual tasking leads to a decline in gait and postural control and declines in performance of cognitive tasks has been linked to impaired gait and postural control. Studies suggest that mental fatigue leads to decreases in attentional resources and concentration and Grobe and colleagues suggest that based on the link between cognition and gait and postural control declines in attention and concentration will lead to gait abnormalities and decreased postural control.

Declines in gait and postural control with mental fatigue are based on the premise that mental fatigue is characterized by feelings of tiredness or lack of energy associated with cognitive and attentional task performance. Previous work also suggests that mental fatigue impairs physical performance. However, recent studies provide evidence that energy and fatigue are two distinct, but related, psychological states rather than a single bipolar continuum. While the definitions of mental energy and fatigue vary, we are focused on the mood aspect of energy and fatigue. O’Connor describes the mood of mental energy referring to feelings of having the capacity to complete mental activities, while the mood of fatigue refers to having feelings of reduced capacity to complete mental activities. This study hopes to examine both moods of mental energy and fatigue.

Behrens and colleagues recently examined the impact of mental fatigue on gait variability in young and older adults. Their results indicated that mental fatigue in older adults increased gait variability in dual task gait only. Although that study utilized the Profile of Mood Survey- Short Form (POMS-SF) to measure fatigue, it did not report feelings of energy nor did it distinguish between mental and physical aspects of energy and fatigue. That study also did not examine the impact of mental fatigue on balance, a one of the central premises of Grobe and colleagues.

The purpose of this study was to build upon previous work by examining the effects of mental tasks on fatigue and energy and to determine whether these changes impacted functional assessments associated with fall risks. Based on the aforementioned literature it was hypothesized that performance of mental tasks would lead to either decreases in mental energy or increases in mental fatigue which would negatively impact functional assessments in older adults.

Methods
Study design
A placebo-controlled, block-randomized cross-over study examined the effects of performance on mental tasks and rest (placebo) on the
performance of functional tasks in older adults. To ensure true randomization, randomizer.org was used for block assignment.

**Participants**

After receiving university Institutional Review Board (IRB) approval (Approval #18-11.3) participants (N = 11) were recruited (See Table 1 for demographic information) from a small, rural community in upstate New York. Participants were screened by research assistants to ensure they were between the ages of 55 and 69, and had the ability to ambulate without the use of an assistive device. Participants were excluded if they had been previously diagnosed with neurological conditions and balance disorders; had lower extremity surgeries within the last 6 months; wounds on their feet; decreased sensation on the bottom of their feet; or corrective vision worse than 20/200. Seventeen older adults reached out to participate and after screening, eleven participants all with bachelor’s degrees, qualified to participate in the study (Figure 1, Supplementary Figure 1).

**Instruments**

The Microsoft Kinect v2 sensor was used to detect non-clinical changes in mobility, functional balance and strength. The Kinect provides 25 skeletal joint points, namely head; neck; mid spine; spine base; left and right shoulder, elbow, hip, wrist, thumb, hand, hand tip, knee, ankle, foot. The Kinect is capable of acquiring accurate depth images at high rates using the time-of-flight measurement principle and can provide noise characteristics in both axial and lateral directions. It has been used in the past to assess functional balance and mobility, specifically using the TUG and lower extremity functional strength using the 30 s-CST.

**Measures of mood and motivation**

Profile of Mood Survey- Short Form (POMS-SF)- The 30-item POMS-SF was used to assess feelings of energy (vigor) and fatigue. Participants indicated their current intensity of feelings on a 5-point scale ranging from “Not at all” (scored as 0) to “Extremely” (scored as 4). The vigor and fatigue scores are a sum of 5 variables (i.e. vigor = lively + energetic + active + full of pep + vigorous) and can range from 0 to 20. Among healthy participants Cronbach’s alpha, a measure of internal consistency, has been reported as 0.90.

Mental and Physical State and Trait Energy and Fatigue scale (MPSTEF)- The MPSTEF, the reliability and validity of which has been supported was used to assess current state mental and physical energy.
and fatigue. The state component of the scale references how the respondent currently feels and contains 12 items with 3 items for each of the four state outcomes (physical and mental energy and fatigue). Representative statements include “I feel I have energy” and “I have feelings of being worn out.” Responses were collected on a 0 to 100 Visual Analog Scale (VAS) with 0 (left end) indicated “No feelings” to 100 (right end) indicated the “Highest feeling.” In previous studies, the Cronbach’s alpha coefficients range from 0.82-0.91.40

Motivation to perform physical tasks (MM)- A 0-100 VAS scale was used to collect feelings of current motivation to perform mental tasks. The left end (score of 0) indicated “No motivation” while the right end (score of 100) indicated “highest feelings of motivation imaginable.”

**Table 1.** Demographics, fall history, sleep quality, grit, hope, satisfaction with life, food frequency, and physical activity.

<table>
<thead>
<tr>
<th>Total n = 11</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male: Female</td>
<td>4:7</td>
<td></td>
</tr>
<tr>
<td>Caucasian: Non-Caucasian</td>
<td>9:2</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>62.82</td>
<td>4.64</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>76.18</td>
<td>15.46</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>167.11</td>
<td>10.96</td>
</tr>
<tr>
<td>The number of hours of sleep per night</td>
<td>7.36</td>
<td>0.88</td>
</tr>
<tr>
<td>Number of times fallen in the last two years</td>
<td>0.82</td>
<td>1.54</td>
</tr>
<tr>
<td>PSQI</td>
<td>3.55</td>
<td>2.25</td>
</tr>
<tr>
<td>Grit score</td>
<td>2.58</td>
<td>0.32</td>
</tr>
<tr>
<td>Total Hope score</td>
<td>50.00</td>
<td>8.83</td>
</tr>
<tr>
<td>Satisfaction with life score</td>
<td>29.00</td>
<td>2.72</td>
</tr>
<tr>
<td>Total Polyphenol</td>
<td>209.36</td>
<td>63.59</td>
</tr>
<tr>
<td>Total physical activity (MET)/week</td>
<td>8801.91</td>
<td>8263.60</td>
</tr>
</tbody>
</table>

**Figure 1.** Participant recruitment.
**Functional assessments**

30 second chair stand test (30 s CST)- The 30-s CST consisted of participants standing up and sitting down from a chair (seat height of 40 cm), with a backrest and armrests, as many times as possible within 30 seconds. The 30-s CST is a validated predictor of fall risks.\(^{41,42}\) The 30-s CST is a measure of lower extremity strength\(^{42,43}\) and a change of 2 repetitions is considered clinically relevant.\(^{44}\)

Timed-Up-And Go (TUG)- The TUG instructed the subjects to sit in a chair (seat height of 40 cm), with a backrest and armrests, stand up and walk to a cone that was placed 3 m away, turn, return and sit down. Subjects time was recorded.\(^{45,46}\) The TUG is a widely used validated measure of functional mobility\(^{47-49}\) and a 9% decrease in TUG times\(^{50}\) or a 0.8-1.4 second decrease\(^{44}\) have been shown to be clinically relevant.

Berg Balance Scale (BBS)- The BBS is a performance-oriented measure of balance in older adults.\(^{51}\) The BBS is a 14-item screening, where each item is scored on a scale of 0 to 4. A score of 0 is given if the participant is unable to complete the task, and a score of 4 is given if the participant is able to complete the task based on the specific criterion. The maximum total score is 56.\(^{51}\) The items include simple mobility tasks (transfers, standing, sit-to-stand) and more difficult tasks (tandem standing, turning 360°, single-leg stance). The BBS has a high internal test-retest reliability\(^{52}\) and is a widely used clinical measure of functional balance.\(^{47,48}\) Depending upon initial BBS scores a change in 4-5 points is needed for clinically relevant change.\(^{44,53}\)

**Cognitive tasks performed**

Serial subtraction three and seven- Participants were asked to silently subtract backwards in threes or sevens from a random starting number between 800 and 999 that was presented on the computer screen. Participants were instructed to type their answer as quickly and as accurately as possible. The number was cleared after the entry of the first response and participants continued to subtract three or seven from their previous answer. Participants were given an opportunity to complete as many attempts as possible in 2 minutes.\(^{15,34-36}\) The task was not scored.

Continuous Performance Task (CPT)- Participants monitored a continuous series of letters (1-9; Tahoma Regular font, size 20) presented on the screen for 1000 ms. Participants were told to respond to the detection of the letter “X” only when it was preceded by the letter “A” by striking the key on the iPad. The task lasted for 2 minutes.\(^{15,34-36}\) The task was not scored.
Rapid Visual Input Processing Task (RVIP)- Participants were required to monitor a continuous series of digits (1-9; Tahoma Regular font, size 20) presented for 1000 ms. The participant was given a primary and secondary task. The participant’s primary task was to detect the presentation of three successive odd and even digits that were all different (e.g., 9-3-7, 2-6-8), and the secondary task involved the identification of a specific number (i.e., 6). The participants pressed the right key for primary responses and the left key for secondary responses. The task lasted 16 mins and a total of 960 stimuli were presented during that time. The task was not scored.

Finger tapping task- A series of individual letters were verbally provided in random order by a program on the Apple iPad Pro (A1584) every 1000 ms. When participants heard the letter “A” they were asked to tap on the screen. Scores were not included in the study.

The Trail-Making Test Part B- The Trail-Making Test Part B, a measure of cognitive function, is a timed test involving attention, psychomotor speed, visual scanning and sequential abilities. Participants were asked to connect numbers to letters in alphanumerical sequential order (i.e. 1 to A, A to 2, 2 to B) with an Apple Pencil on the Apple iPad Pro (A1584). Scores were not included in this study.

Procedure

Subjects were screened for inclusion and exclusion criteria over the phone and then invited to participate. After an invitation was extended, subjects were instructed to get their normal amount of sleep, not consume caffeine containing food and beverages and to follow their normal medication schedule. Qualified participants completed an informed consent form and using block randomization, were assigned to 1 of 2 groups. One group completed the mental tasks on the first day and the control day on the subsequent visit, while the other group did the inverse (Figure 1). The two days of data collection were separated by a minimum of 24 hours, but within 9 days after the first day of participation (2.4 ± 2.5 days). To account for diurnal variations the second day of testing was within ±30 minutes of the time they started their first day. Because sleep loss has substantial effects on mood and cognition; participants who reported 2 hours more or less than their usual sleep duration (collected during the phone screening) were not tested that day and rescheduled, as were those who reported not taking their prescribed medications or consuming caffeine containing beverages or foods the night before testing. Upon reporting for the study, subjects completed an initial screening to ensure that they followed the pre-testing instructions. Subjects completed a series of surveys that
asked them about their previous night’s sleep, food and beverage consumption and medication. An objective analysis was not completed to verify the veracity of their answers.

After completion of the initial screening, height was measured using a standard stadiometer, weight using a digital scale (Tanita TBF-410, Tanita Corporation, Tokyo, Japan)\(^5^7\), blood pressure using a manual blood pressure cuff and a Littmann Cardiology III stethoscope on the left arm and heart rate using a pulse oximeter (Veridian Deluxe; model 11-50 D, Veridian Healthcare, Gurnee, IL, USA) on the left index finger. Participants completed the MPSTEF, POMS-SF and MM. After completion of the surveys, participants completed the TUG, 30-s CST and the BBS assessments with the Kinect recording the tests. On experimental day, subjects completed a series of questionnaires regarding their demographic and lifestyle factors (see Table 1 and Figure 2) for approximately 30 minutes, and subjects completed the MPSEF, POMS and MM after. After completion of the surveys, subjects performed a series of mental tasks for 30 minutes (Figure 2). Subjects were re-administered the MPSTEF, POMS-SF and MM and functional assessments (TUG, 30-s CST and BBT). On the control day, subjects followed the same protocol however, they were provided a 30-minute rest between the first functional assessments and the second mood surveys and an additional 30-minute rest between the second and third mood surveys (Figure 2). All survey data was collected using SurveyMonkey, Inc. (San Mateo, California, USA, www.surveymonkey.com).

**Primary analysis**

With a N of 11, non-parametric analyses were used\(^5^8–^6^0\) and all analyses were conducted using SPSS Version 24.0. (IBM Corp. Released 2016. IBM SPSS Statistics for Windows: Armonk, NY). A Friedman’s rank-test was used to assess changes in moods and motivation. Changes in scores on the 30 s CST, TUG and BBS, were assessed using a Wilcoxon Sign Rank Test.

**Post-hoc analysis**

To support the findings of the Wilcoxon Sign Rank Test, a linear mixed effect model was used to determine joint variances. Additionally, a random forest classifier\(^6^1\) was trained using 500 trees to detect if a subject was performing the “standing with eyes closed” (SEC) part of the BBS before or after mental tasks were performed. Additionally, we applied a 2D keypoint detector, OpenPose, to generate 25 2D skeletal joints. We used a Support Vector Machine (SVM) with a Radial Basis Function (rbf) kernel to detect
<table>
<thead>
<tr>
<th>EXPERIMENTAL DAY</th>
<th>Running Time (minutes)</th>
<th>CONTROL DAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event</td>
<td></td>
<td>Event</td>
</tr>
<tr>
<td>Vitals: Height, Weight, Body Composition, Heart Rate, Blood Pressure</td>
<td>0-5</td>
<td>Vitals: Height, Weight, Body Composition, Heart Rate, Blood Pressure</td>
</tr>
<tr>
<td>Questionnaires: MPSEF, POMS, MM</td>
<td>6-10</td>
<td>Questionnaires: MPSEF, POMS, MM</td>
</tr>
<tr>
<td>Timed Up and Go Test</td>
<td>11-16</td>
<td>Timed Up and Go Test</td>
</tr>
<tr>
<td>30-second chair stand test</td>
<td>17-18</td>
<td>30-second chair stand test</td>
</tr>
<tr>
<td>BERG balance assessment</td>
<td>19-24</td>
<td>BERG balance assessment</td>
</tr>
<tr>
<td>Questionnaires: Demographics &amp; Medical History, Physical Activity, Sleep Questionnaire, Grit Questionnaire, Hope Scale, Satisfaction with Life, Modified Interest, Self-Management, Food Frequency</td>
<td>25-55</td>
<td>Rest for 30 minutes</td>
</tr>
<tr>
<td>Questionnaires: MPSEF, POMS, MM</td>
<td>56-60</td>
<td>Questionnaires: MPSEF, POMS, MM</td>
</tr>
<tr>
<td>Serial Subtract 3</td>
<td>61-62</td>
<td>Rest for 30 minutes</td>
</tr>
<tr>
<td>Serial Subtract 7</td>
<td>63-64</td>
<td></td>
</tr>
<tr>
<td>Continuous Performance Task</td>
<td>65-66</td>
<td></td>
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<tr>
<td>RVIP</td>
<td>67-83</td>
<td></td>
</tr>
<tr>
<td>Trail Making Test- Part B, Tapping Test</td>
<td>84-94</td>
<td></td>
</tr>
<tr>
<td>Questionnaires: MPSEF, POMS, MM</td>
<td>95-100</td>
<td>Questionnaires: MPSEF, POMS, MM</td>
</tr>
<tr>
<td>Timed Up and Go Test</td>
<td>101-106</td>
<td>Timed Up and Go Test</td>
</tr>
<tr>
<td>30-second chair stand test</td>
<td>107-108</td>
<td>30-second chair stand test</td>
</tr>
<tr>
<td>BERG Balance assessment</td>
<td>109-114</td>
<td>BERG Balance assessment</td>
</tr>
<tr>
<td>Questionnaires: MPSEF, POMS, MM</td>
<td>115-120</td>
<td>Questionnaires: MPSEF, POMS, MM</td>
</tr>
<tr>
<td>Heart rate, Blood pressure</td>
<td>121-125</td>
<td>Heart rate, Blood pressure</td>
</tr>
</tbody>
</table>

**Figure 2.** Study procedures for control day and experimental day.
if a subject was performing the SEC part of the BBS before or after men-
tal tasks.

A post-hoc power analysis was completed using t-family tests using 
G*Power (version 3.1.9.2)

**Results**

**Mood and motivation**

Analysis yielded no statistically significant differences between POMS 
fatigue, motivation to perform physical tasks, state physical energy and 
fatigue, and state mental fatigue (p>.05). Subjects noted a statistically sig-
nificant decline in feelings of POMS energy (p=.003) and state mental 
energy (p=.015) on experimental day while no changes were noted on con-
rol day (Table 2).

**Fall risk assessments**

30-Second chair stand test

There was no significant difference between or within days for 30-s CST 
scores (p>.05). (Table 3).

Timed-up-and-go

There was no significant difference between or within days for TUG scores 
(p>.05). (Table 3).

Berg Balance Scale

Analysis yielded a statistically significant (p<.001) decline in BBS scores on 
the experimental day (-1.450 ± 2.067) and a slight improvement on control 
day (0.820 ± 1.45) (Table 3). Seven out of 11 participants noted a decline in 
BBS scores on experimental day however, only 3 out of those 7 participants 
experienced a clinically meaningful decrease (≥4). On the control day, 6 
out of 11 participants noted an increase in BBS scores however, no subjects 
experienced clinically meaningful improvements in the BBS. There was no 
statistically significant difference between pre- and post-test on control day.

**Post-hoc- machine learning**

When examining the 25 joint variances we noted a statistically significant 
crease (p<.001) in joint variance on experimental day (30.80% to 
98.59%) in the SEC portion of the BBS.62 Random forest algorithms yielded 
an overall classification accuracy of 69.5% on experimental day. We
Table 2. Moods and motivation—mean (standard deviation).

<table>
<thead>
<tr>
<th></th>
<th>POMS Energy</th>
<th>POMS Fatigue</th>
<th>Motivation</th>
<th>Mental Energy</th>
<th>Mental Fatigue</th>
<th>Physical Energy</th>
<th>Physical Fatigue</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Experimental</td>
<td>Control</td>
<td>Experimental</td>
<td>Control</td>
<td>Experimental</td>
<td>Control</td>
</tr>
<tr>
<td>Pre-intervention</td>
<td>10.18</td>
<td>11.00</td>
<td>0.91</td>
<td>0.82</td>
<td>71.60</td>
<td>69.55</td>
<td>171.09</td>
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<tr>
<td></td>
<td>(5.49)</td>
<td>(4.71)</td>
<td>(1.64)</td>
<td>(1.47)</td>
<td>(21.69)</td>
<td>(29.80)</td>
<td>(68.64)</td>
</tr>
<tr>
<td>Mid-intervention</td>
<td>9.55</td>
<td>9.18</td>
<td>0.91</td>
<td>1.64</td>
<td>71.10</td>
<td>66.27</td>
<td>182.09</td>
</tr>
<tr>
<td></td>
<td>(4.18)</td>
<td>(6.030)</td>
<td>(1.58)</td>
<td>(1.96)</td>
<td>(20.59)</td>
<td>(26.40)</td>
<td>(62.29)</td>
</tr>
<tr>
<td>Post-intervention</td>
<td>10.09</td>
<td>7.09</td>
<td>1.18</td>
<td>2.82</td>
<td>69.70</td>
<td>62.55</td>
<td>172.55</td>
</tr>
<tr>
<td></td>
<td>(4.85)</td>
<td>(5.58)</td>
<td>(1.40)</td>
<td>(2.14)</td>
<td>(21.06)</td>
<td>(26.52)</td>
<td>(72.98)</td>
</tr>
</tbody>
</table>
obtained a classification accuracy of 60.0% for the SEC portion of the BBS before and after performance of mental task with an accuracy of 79%, a false positive rate of 40% and a false negative rate of 21.0%. The overall classification accuracy on control days was 44.5% which is very close to a chance rate of 50% further substantiating the results that when mental tasks were not performed there were no discernable changes in movement during the SEC portion of the BBS. Using the SVM linear classifier we obtained an overall accuracy of 75%, with a true positive rate of 80% and a false positive rate of 70% on the experimental day. Our results using 2 D joints and the SVM classifier are comparable to the 3 D joints and the random forest classifier, indicating that both 2 D and 3 D joints predict that when cognitive loads have been applied there is a change in postural control during the SEC portion of the BBS.

Post-hoc power analysis

The post-hoc power analysis yielded an effect size of 0.628 which was then used to calculate total sample size. The post-hoc statistical power analysis showed that 23 participants would provide statistical power of 0.81 to detect a 2 group x 2 time interaction effect size of 0.628 given a p-value of 0.05 assuming a correlation across repeated measures on time of 0.70.63

Discussion

To the authors’ knowledge this is the first study of its kind examining the impact of mental task performance on functional assessments associated with fall risks in older adults. The results of this study may lead to a fuller understanding of the impact of feelings energy on functional balance in older adults. Our results indicate that performing mental tasks, leads to a decline in feelings of mental energy and not an increase in feelings of fatigue, which are similar to previous literature.36,64 Grobe and colleagues7 theorized that performance of mental tasks would lead to a decrease in functional balance and gait. Our study partially supports this theory and deepens our understanding of the impact mental energy on balance by specifically identifying a relationship between a decline in mental energy and a

<table>
<thead>
<tr>
<th>Total n = 11</th>
<th>Pre-30 Second Chair</th>
<th>Post-30 Second Chair</th>
<th>Pre-Timed Up and Go</th>
<th>Post-Timed Up and Go</th>
<th>Pre-Berg Balance Scale</th>
<th>Post-Berg Balance Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SD 6.294</td>
<td>5.901</td>
<td>2.400</td>
<td>2.449</td>
<td>1.991</td>
<td>1.502</td>
</tr>
<tr>
<td>Experimental</td>
<td>Mean 14.909</td>
<td>15.364</td>
<td>10.100</td>
<td>9.936</td>
<td>54.545</td>
<td>53.091</td>
</tr>
<tr>
<td></td>
<td>SD 5.629</td>
<td>6.313</td>
<td>2.127</td>
<td>2.343</td>
<td>2.207</td>
<td>3.239</td>
</tr>
</tbody>
</table>

Table 3. Fall risk assessments (30-second chair stand, Timed Up and Go, Berg Balance).
decline in eyes closed balance. Our study is also the first study to utilize machine learning to confirm changes in postural control with decreased feelings of mental energy.

Studies examining mental fatigue on a bipolar scale with energy, have noted decreased blood glucose levels in lateral and medial pre-frontal cortex and the adjacent white matter, in the pre-motor cortex, putamen and right supplementary motor cortex\(^6\) and decreased activation of the dorsolateral and dorsomedial prefrontal cortex after performance of mental tasks.\(^6\) While these studies have examined fatigue and energy on a bipolar scale, it should be noted that when performing mentally demanding tasks the prefrontal cortex is activated by increasing beta-frequency band power levels\(^7\) and scores on mental tasks have been associated with feelings of energy.\(^3,6\) Therefore, we may theorize that a decline in prefrontal cortex activity is associated with decreases in feelings of energy.

Interestingly, the prefrontal cortex is also heavily involved in postural control\(^6\) as it helps the body prepare for forthcoming actions.\(^0\) Single-cell recordings in primates\(^1\)–\(^4\) and neuroimaging studies in humans\(^5\)–\(^8\) provide evidence that the dorsolateral prefrontal cortex is important in holding temporary representations of working memory. The prefrontal cortex also serves to regulate task-related sensory re-weighting of haptic information that may be used during the control of standing balance in the absence of vision.\(^9\) This suggests that a decline in prefrontal cortex activation with decreased feelings of energy may lead to a decline in functional balance during the SEC portion of the BBS. When examining individual changes in feelings of mental energy and BBS scores, we noted that the three subjects with clinically relevant declines in postural control also had the greatest decreases in feelings of mental energy. Subjects with no change in the BBS score had the lowest changes in feelings of mental energy. These results suggest a relationship between feelings of mental energy and functional balance when the eyes are closed.

**Clinical implications**

The results of this study deepen our understanding of the conditions in which older adults may be at an increased risk of falling. While many studies identify characteristics that place an individual at an increased fall risk, these characteristics are often not easily modifiable. However, this study suggests a specific condition that may increase fall risk that can be immediately modified to reduce fall risk. Based on the results, it may be recommended that older adults avoid completing eyes closed balance activities when they are experiencing decreased feelings of mental energy. Specifically, eyes-closed situations such as washing their hair while standing...
in a shower, should be completed at a time of the day when there is not a substantial decline in mental energy. Additionally, due to the full occlusion of the eyes from reliable landmarks, elements of upper body dressing may be best suited for completion in sitting during episodes of low mental energy. Further, studies are warranted to determine if these findings apply to low lighting conditions or to individuals who have poor visual acuity or if these findings only apply to eyes closed conditions in otherwise healthy older adults.

Of equal importance is the finding of no statistically significant relationship between feelings of mental fatigue and the functional assessments. It is conceivable that many older adults may automatically decrease their physical activity levels when they have decreased feelings of mental energy.\textsuperscript{82} Conversely, older adults may avoid cognitive tasks due to fear that decreased mental energy may make them feel less stable, thus avoiding mentally engaging work which may be beneficial for them.\textsuperscript{83} This study suggests that older adults who are experiencing decreased mental energy are not at an increased fall risk, other than in the eyes closed condition, and should continue to be active.

**Limitations**

As is the case with every study, our study had several limitations. One of the limitations of this study was the use of gross measures of functional mobility, strength and functional balance instead of using more sensitive measures such as the limits of stability test using the Neurocom Balance Master\textsuperscript{84} or using the Biodex to measure isokinetic peak torque.\textsuperscript{85} Additionally, the use of a smartwatch may have been more accurate to measure sleep; however, the measures used in our study have been utilized in other studies.\textsuperscript{15,34–36} Another limitation of our study was the limited sample size with healthy adults over the age of 55 with no history of medical problems thus limiting the generalizability. Future research should use a similar design with larger sample sizes. Another limitation in our study is that our intervention may not have been as effective in all subjects as noted by greater decreases in feelings of energy with some subjects and not with others. Future work should use longer, already established protocols\textsuperscript{36,64} that have demonstrated decreases in mental energy.

**Conclusions**

The purpose of this study was to examine the effects of mental tasks on feelings of energy and fatigue, and functional assessments associated with falls. Our results may indicate that performing mental tasks reduces feelings
of mental energy and impairs functional balance, when eyes are closed. We postulate that decreases in prefrontal cortex activities with mental task performance may cause this decline in functional balance. Future research should examine neural correlates when examining declines in feelings of mental energy and postural control.

Disclosure statement
The authors report no potential conflicts of interest.

References
1. Prevention C for DC and The State of Aging and Health in America 2013. Atlanta, GA: Centers for Disease Control and Prevention, US Dept of Health and Human Services. 2013. This PDF, available from the CDC, illustrates the scope of the problem by exhibiting data on the increasing number of the elderly in our population, as well as the extent of disease and conditions afflicting them Google Scholar. 2015.


44. Bennell K, Dobson F, Hinman R. Measures of physical performance assessments: Self-Paced Walk Test (SPWT), Stair Climb Test (SCT), Six-Minute Walk Test (6MWT), Chair Stand Test (CST), Timed Up & Go (TUG), Sock Test, Lift and Carry


