Gait & Posture 43 (2016) 31–37

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Effects of adiposity on postural control and cognition

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ARTICLE INFO

Article history:
Received 5 March 2015
Received in revised form 3 September 2015
Accepted 9 October 2015

Keywords:
Adiposity
Fat percentage
Working memory
Posture
BMI

ABSTRACT

In the U.S., it is estimated that over one-third of adults are obese (Body Mass Index (BMI) > 30 kg/m^2). Previous studies suggest that obesity may be associated with deficits in cognitive performance and postural control. Increased BMI may challenge cognitive and postural performance in a variety of populations; however, most relevant studies have classified participants based on BMI values, which cannot be used to accurately assess the effects of adiposity on cognitive performance and postural control. The objective of the current study was to examine motor and cognitive responses for overweight and obese adults compared to normal weight individuals by using both BMI and adiposity measures. Ten normal weight (BMI = 18–24.9 kg/m^2), ten overweight (BMI = 25–29.9 kg/m^2), and ten obese (BMI = 30–40 kg/m^2) adults were evaluated (age: 24 $\pm$ 4 years). Participants were classified into three groups based on BMI values at the onset of the study, prior to body composition analysis. Participants performed (1) working memory task while maintaining upright stance, and (2) a battery of sensorimotor evaluations. Working memory reaction times, response accuracy, center-of-pressure (COP) path length, velocity, migration area, time to boundary values in anterior-posterior direction, and ankle-hip strategy-scores were calculated to evaluate cognitive-motor performance. No significant deficits in working memory performance were observed. Overall, measures of motor function deteriorated as BMI and body fat percentage increased. The relationship between deteriorating postural performance indices and body fat percentage were greater than those found between BMI and postural performance indices.

1. Introduction

The terms overweight and obesity are defined as abnormal/excessive fat accumulation with Body Mass Index (BMI) $\geq$ 25 kg/m^2 and 30 kg/m^2, respectively [1]. The World Health Organization (WHO) estimates that more than 1.9 billion adults are overweight worldwide; with 600 million obese adults in 2014 [1]. In the U.S., the situation is exacerbated with 78.6 million adults being classified as obese in 2012 [2].

Postural instability is defined as the inability to successfully respond to perturbations during upright stance [3] and is frequently associated with reduced sensorimotor function and increased fall risk [4,5]. Impaired motor function due to an increase in adiposity may severely impact quality of life and increase the risk of reduced postural stability and injury by falls [6,7]. Several studies have examined the relationship between obesity and postural control in adults. Hue et al. reported that increased body weight strongly correlated with decreased balance stability [8]. Similarly, increased body weight has been associated with increased anterior–posterior (AP) center of pressure (COP) movement [9]. Increased sway areas and an inability to modulate anticipatory actions suggests that obese participants use different postural strategies to maintain balance [10]. In contrast, Blaszczyk et al. suggested preserved postural control in obese adults [11], a notion later challenged in [12]. A primary limitation in these studies is that they used BMI as the primary classification method for identifying different weight groups; however, BMI only takes body mass and height into consideration. The exclusive use of BMI is flawed as a method to distinguish highly muscular persons from persons with high body fat percentages. Inconsistent outcomes from previous studies might have resulted from the use of BMI for classification. Using measures of fat amount may better illustrate the relationship between excessive adiposity and postural control.

Deficits in cognitive function have been reported as a powerful predictor of falls and correlate to dramatic increases in fall risks [13]. Recently, obesity has been linked with memory deficits and

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http://dx.doi.org/10.1016/j.gaitpost.2015.10.012
0966-6362/

cognitive dysfunction in middle-aged and older adults [14,15]. Increased adiposity, resulting in obesity, may require additional attention for controlling posture [16]. Cognitive-motor interference, defined as decrements in performance that occur when cognitive and motor tasks are performed simultaneously (dual-task conditions), has been linked with falls [15]. A priori, we did not expect to see cognitive deficits in this study due to the narrow age range of participants in the current study; however, these data are the first step in preparing a larger scale evaluation of cognitive-motor deficits with respect to adiposity, aging, and neurological disease. Examining postural control during cognitive tasks will provide valuable information regarding the relationship among motor function, cognitive distraction, and excessive adiposity.

The objective of the current study was to examine responses during cognitive-motor tasks using different assessments of adiposity. The correlations among BMI, body composition, postural control, and cognitive performance were examined to clarify and explore the impact of adiposity on postural stability. We hypothesized that: (1) measures of postural control will deteriorate as indices of adiposity increase; and (2) whole body fat percentage (%Fat_{TOTAL}) and trunk fat percentage (%Fat_{TRUNK}) will exhibit more consistent relationships with postural control as compared to BMI. The results of this study advance our understanding of the true relationship of adiposity, body mass, and body fat distribution on postural control and cognitive performance.

2. Methods

2.1. Subjects

Thirty total individuals participated in the study. Participants were classified into three groups based upon their BMI scores at the onset of the study. The normal weight (BMI: 18.5–24.9 kg/m^2), the overweight (BMI: 25–29.9 kg/m^2) and the obese groups (BMI: 30–40 kg/m^2) each had five females and 5 males (Table 1). Prior to recruitment, participants completed a Physical Activity Readiness Questionnaire (PAR-Q) and the Modifiable Activity Questionnaire (MAQ). Exclusion criteria included: a history of neurological, musculo-skeletal or cardiovascular disorders; age below 18 or above 45 years old; and more than 90 min of exercise per week (indicating physical activity levels above moderate activity). The University of Houston Committee for the Protection of Human Subjects approved all procedures; all participants provided written informed consent.

2.2. Protocols

Each participant attended two testing sessions: (1) evaluation of postural and cognitive functions, and (2) body composition scanning. In (1), computerized dynamic posturography (NeuroCom International, Inc., Clackamas, OR) was used to record kinetic data at 100 Hz. A rectangular stability boundary was estimated by the outer extremes of the feet for each participant on NeuroCom force-plates; boundaries were marked and maintained in all conditions. In all conditions, participants stood upright with feet and body properly positioned, fitted with a safety harness and arms crossed in front of chest. Participants were tested under four conditions: (a) sensory organization test, (b) motor control test, (c) quiet stance, and (d) postural-cognitive evaluation (dual-task). All time series COP data were filtered using Butterworth low-pass filters with a cutoff frequency of 2 Hz, consistent with [17] using Matlab (The MathWorks Inc., 2013b, Natick, MA), verified using fast-Fourier transform analysis and consistent with the Nyquist sampling theorem.

Table 1
Participant age and anthropomorphic data.

	Normal weight	Overweight	Obese
N	10	10	10
Age (y)	24.4 ± 2.3	24.4 ± 3.0	23.8 ± 6.6
Mass (kg)	61.2 ± 10.0	80.0 ± 9.5	104.2 ± 20.4
Height (cm)	166.5 ± 10.8	167.9 ± 9.3	171.1 ± 11.4
BMI (kg/m^2)	21.9 ± 1.2	28.3 ± 1.5	35.3 ± 3.1
Trunk fat (%)	25.2 ± 5.3	37.2 ± 7.3	42.5 ± 4.2
Total fat (%)	25.3 ± 5.9	31.1 ± 6.6	37.2 ± 4.7

Values are mean ± SD. BMI = body mass index.

2.2.1. Sensory organization test (SOT)

SOT evaluations were performed in order to identify any potential sensory deficits. Participants experienced the six standard testing conditions in three 20 s trials: (1) eyes open with fixed platform, (2) eyes closed with fixed platform, (3) eyes open with sway-referenced vision, (4) eyes open with sway-referenced platform, (5) eyes closed with sway-referenced platform, and (6) eyes open with both sway-referenced vision and sway-referenced platform.

2.2.2. Motor control test (MCT)

The MCT was used to probe how participants responded to dynamic perturbations. Each participant underwent the six default perturbation conditions, applied via constant velocity force-plate translations. Three trials per condition were collected. The amplitude of perturbation was selected as small, medium, or large and the direction of translation included separate anterior and posterior conditions. In a set sequence, participants underwent each condition with eyes open: (1) posterior-small, (2) posterior-medium, (3) posterior-large, (4) anterior-small, (5) anterior-medium, and (6) anterior-large perturbation conditions.

2.3. Quiet stance testing

In the quiet stance condition, participants were instructed to cross their arms in front of their chest and keep their eyes open. Participants underwent three trials, lasting for 30 s each, consistent with the test duration in postural-cognitive evaluation.

2.3.1. Postural-cognitive evaluation

During postural-cognitive testing, participants underwent evaluation of working memory (N-back testing). Cognitive testing was only evaluated in this testing block and during no other evaluations. The N-back test is used to examine a participant's capacity to use short-term memory information in performing one or more tasks simultaneously [18]. The difficulty level of the N-back test is controlled by requiring participants to remember words further back in the presented series [19]. Each participant was assigned three levels of difficulty in auditory N-back tests (easiest to most difficult: 0-, 1-, and 2-back conditions) in a block randomized manner where task difficulty was the blocking factor. Participants were given a series of random words through a headphone-microphone device (Plantronics, Inc., Santa Cruz, CA), instructed to repeat the words, and at the same time maintain upright stance on the platform. Customized Visual C++ software was used to generate random words for this protocol (Microsoft, Corp., Redmond, WA). The rate of correct responses and verbal reaction time (how quickly the participant respond to the stimulus) was recorded by the software and extracted to evaluate cognitive performance.

2.3.2. Body composition assessment

Body composition of each participant was measured via a whole body dual-energy X-ray absorptiometry (DEXA) scanning device (Discovery W, Hologic, Inc., Bedford, MA). Both %Fat_{TOTAL} and %Fat_{TRUNK} were extracted for further analysis.