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Consistency of a Mobile Body Composition Trailer: A Novel Portable Laboratory Assessment?

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SUMMARY

Objective—The purpose of this investigation was to 1) assess the test-retest reliability and minimum difference (MD) values of air-displacement plethysmography (ADP) and the Siri 3-compartment (3-C) model in a mobile trailer, and 2) identify any environmental fluctuations in the trailer.

Methods—Percent body fat (%BF) was examined in 22 firefighters on two separate days in a climate controlled mobile trailer using ADP. Total body water was examined in a subset of participants (n=12) using bioelectrical impedance spectroscopy (BIS) to determine %BF using Siri's 3-C model.

Results—There were no differences in environmental measures ($P = 0.138$), %BF for ADP ($P = 0.276$), or %BF for the Siri 3-C model ($P = 0.382$) between day 1 and day 2. Intraclass correlation coefficient and standard error of measurement values for ADP and the Siri 3-C model were 0.978 and 1.3% and 0.986 and 0.6%, respectively. The MD values were 3.6% and 1.7%, respectively.

Conclusions—These findings indicate that ADP can reliably determine %BF when transported in a climate controlled mobile trailer. Additional accuracy is achievable with the Siri 3-C model, providing an attractive and promising method to measure body composition in larger scale community-based settings.

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CONFLICT OF INTEREST

The authors declared no conflict of interest.

Keywords

air-displacement plethysmography; ADP; percent body fat; BOD POD®; firefighter; multi-compartment model; obesity

INTRODUCTION

Obesity has become a worldwide public health priority due to the cardiometabolic risk factors associated with the excessive accumulation of body fat (Gomez-Ambrosi et al., 2012). In addition, obese individuals have an increased risk of musculoskeletal injury (Jahnke et al., 2013), cardiovascular events (Smith et al., 2013), perform poorly during job-related tasks (Michaelides et al., 2011), and have higher absenteeism related costs to employers (Poston et al., 2011b). Although body mass index (BMI) is used widely to assess adiposity, it may underestimate obesity when compared to assessments that take into account actual body tissues (Poston et al., 2011a; Gomez-Ambrosi et al., 2012). For larger population-based studies, percent body fat (%BF) assessments are limited to portable body composition devices such as bioelectrical impedance analysis (BIA) (Poston et al., 2011a; Jahnke et al., 2013; Talma et al., 2013). Traditional laboratory assessments of %BF such as air-displacement plethysmography (ADP) have been limited to controlled laboratory settings. However, the Nutrition Obesity Research Center (NORC) recently outfitted a climate controlled mobile trailer that houses ADP equipment to encourage community-based assessments. Previous studies have suggested that ADP is a quick, user-friendly laboratory method that can accommodate various populations making it an attractive portable %BF assessment (Fields et al., 2005; Noreen & Lemon, 2006; Moon et al., 2007; Wingfield et al., 2014). However, given that ADP measurements may be influenced by the environment and air flow (Fields et al., 2005), the reliability of these measures warrants further investigation.

Multi-compartment body composition models are known for their increased precision when evaluating body composition (Wang et al., 1998); however these methods have not been practical for field assessments due to the non-portability (Talma et al., 2013). The Siri 3-compartment (3-C) model is considered a criterion method, and its increased accuracy is recognized because it accounts for variation in participant hydration (Siri, 1961). Previous studies have utilized ADP and bioelectrical impedance spectroscopy (BIS) to determine a 3-C model of %BF (Moon et al., 2007; Smith-Ryan et al., 2014). Given the mobile trailer and additional portability of the BIS, it may be possible to more accurately quantify %BF estimates using a lab-based multi-compartment model in the community setting. Therefore, the purpose of this study was to identify any environmental (i.e. temperature, humidity) fluctuations across testing days in the mobile trailer, and assess the test-retest reliability and minimum difference (MD) values of ADP derived %BF. In addition, to determine the feasibility of the 3-C model assessments, we examined the test-retest reliability and MD values in a subset of the participants.

METHODS

Participants

Twenty-two healthy career firefighters (21 males, 1 female; mean $\pm$ standard deviation (SD): age=35 $\pm$ 8.9 yrs; body mass=94.8 $\pm$ 25.2 kg; stature=178.0 $\pm$ 6.8 cm; BMI=29.8 $\pm$ 7.3 kg/m²) volunteered for this investigation. All participants completed and signed an approved consent form, and a health history and exercise status questionnaire. None of the participants were pregnant, reported any metabolic or neuromuscular diseases, or musculoskeletal injuries sustained within the past three months. This study was approved by the University's Institutional Review Board.

Experimental Design

Prior to testing, the NORC parked a climate controlled mobile trailer at fire station one in Kannapolis, North Carolina. Firefighters performed testing on two separate days in March (separated by 15 $\pm$ 3 days) at the same time of day ($\pm$ 2hrs) to examine test-retest reliability. Participants were asked to avoid strenuous exercise for 24 hours and fast (except water) for at least 4 hours prior to testing. The trailer heater was turned on approximately 1.5 hours preceding testing to ensure the trailer met the recommended operating environmental standards. The trailer had one door that remained closed during testing to avoid changes in air flow, and temperature and relative humidity were recorded (Davis PERCEPTION II, Hayward, CA) to identify environmental fluctuations. Percent body fat was assessed using ADP (BOD POD® version 5.2.0, COSMED Concord, CA, USA; Figure 1). In addition, BIS (SFB7 ImpediMed, Queensland, Australia) was examined in a subset of participants (n=12) to determine %BF using Siri's 3-C model (Siri, 1961).

Body Composition

Stature and body mass (BM) were measured with a calibrated stadiometer (Scale-Tronix Inc. Wheaton, IL, USA) and clinical scale (Model BWB-627-A, Tanita Inc. Arlington Heights, IL, USA), respectively. Body density (BD) was determined using ADP which was calibrated according to instructions provided by the manufacturer before each test (Dempster & Aitkens, 1995). A two point calibration was conducted prior to each participant, with an empty chamber and with a cylinder of a known volume (50.326 L). By utilizing the inverse relationship between air volume and pressure to determine body volume (BV), ADP can ascertain BD. Thoracic gas volume was estimated using the manufacture's software which has been reported to be similar to measured volumes (McCrory et al., 1998). Measurements were taken with participants wearing compression shorts and/or sports bra (females), and after removal of all metal and/or jewelry. Two trials were conducted to determine BV, however if the two measurements were not within 150 ml of each other, a third trial was performed. Total body water (TBW) was determined using BIS, which has been shown to be a valid assessment of TBW (Moon et al., 2008b). Participants laid supine with their arms away from the torso and legs separated while electrodes were applied to the right side of the body on the dorsal surface of the hand and foot, 5 cm apart. Prior to electrode placement, the skin was abraded and then cleaned with alcohol. The ADP %BF values were calculated from internal software using Siri's 2-C model [%BF = ((4.95/BD) - 4.50) $\times$ 100]. For a subset of

participants, %BF was determined using the Siri's 3-C model [$\%BF = ((2.118/BD) - (0.78 \times TBW/BM) - 1.354) \times 100$] (Siri, 1961) using TBW from BIS and BD values from ADP.

Statistical Analysis

Environmental measures (temperature and humidity) across testing days were evaluated with dependent samples t-tests. Separate one-way repeated-measures analysis of variance (ANOVA) were used to detect the systematic variability for ADP and the Siri 3-C model %BF values across the two testing days. Test-retest reliability for %BF was examined for ADP and the Siri 3-C model using procedures described by Weir (Weir, 2005). Model "2,1" intraclass correlation coefficients ($ICC_{2,1}$) (Shrout & Fleiss, 1979), standard error of measurement (SEM), and minimum difference (MD) values were calculated with custom-written software (Microsoft Excel, Microsoft Corporation, Redmond, WA). All other measures were analyzed using SPSS (IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY, USA). A type I error rate of 5% was used to determine statistical significance.

RESULTS

There were no differences ($P = 0.138$) in the environmental measures between day 1 (humidity= $51.4 \pm 7.5\%$; temperature= $22.0 \pm 1.5^\circ\text{C}$) and day 2 (humidity= $46.1 \pm 9.5\%$; temperature= $21.5 \pm 1.6^\circ\text{C}$). Test-retest reliability statistics are provided in Table 1. The %BF values were not different between day 1 (27.2 ± 8.7) and day 2 (26.8 ± 9.0) for ADP ($P = 0.276$) or between day 1 (25.5 ± 5.3) and day 2 (25.8 ± 5.3) for the Siri 3-C model ($P = 0.382$). The $ICC_{2,1}$ and SEM values for ADP and the Siri 3-C model were 0.978 and 1.3% and 0.986 and 0.6%, respectively.

DISCUSSION

The results of the current study did not indicate any systematic error between testing days; relative ($ICC_{2,1} = 0.978$) and absolute ($SEM = 1.3\%$) consistency values were similar ($ICC = 0.97-0.99$; $SEM = 0.47-0.81\%$) to previous studies that have examined test-retest reliability of ADP derived %BF values in laboratory settings on two separate testing days (Moon et al., 2008a; Wingfield et al., 2014). Previous recommendations suggest that the testing room should maintain a constant temperature ($21-32^\circ\text{C}$) with minimal air flow (Fields et al., 2005), which may be a concern with mobile trailers. However, there were no differences ($P = 0.138$) in humidity and temperature between testing days, suggesting the mobile trailer provides suitable environmental conditions for ADP field testing. Field techniques are often limited to skinfold, BIA, or near-infrared interactance which may have high prediction errors and/or result in inaccurate values (Wang et al., 1998; Duren et al., 2008) for populations (e.g. firefighters) who have high rates of overweight and obesity (Poston et al., 2011a). Thus, these data suggest that ADP, a traditional laboratory-based method, can be utilized in a mobile trailer and may provide a novel alternative for measuring %BF in the field, especially considering its consistency, ease of use, and ability to accommodate a wide range of populations (Fields et al., 2005; Noreen & Lemon, 2006).

Clinically, the MD values represent the smallest change in %BF to be considered real as a result of an intervention (i.e. nutritional or exercise), treatment, or condition (Weir, 2005).

Recently, Wingfield et al. (2014) reported a MD of 2.25% for laboratory-based ADP assessments, which is comparable to the 3.6% reported in the current study. Interestingly, the MD values for the Siri 3-C model was 1.7%, suggesting that a change in %BF of less than 2% can be considered real. Thus, although ADP %BF values are consistent, utilizing other portable equipment (i.e. BIS) to calculate a multi-compartment model of %BF would enhance the precision of a field assessment.

In summary, these findings indicate that ADP can reliably determine %BF when transported to a workplace setting in a climate controlled mobile trailer. Although traditionally seen as purely a laboratory method, these data suggest that ADP may be a valuable clinical tool as it offers a user-friendly, accommodating, and time-efficient method to obtain %BF in the field. Furthermore, additional accuracy is achievable with the Siri 3-C model, providing an attractive and promising method to measure body composition in larger scale community-based settings.

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Figure 1.

An image of the outside (A) and inside (B) view of the Nutrition Obesity Research Center (NORC) mobile trailer. The trailer housed air-displacement plethysmography (BOD POD® version 5.2.0, COSMED Concord, CA, USA) equipment.

Table 1

Test-retest reliability statistics for air-displacement plethysmography (ADP) and the Siri 3-C model percent body fat (%BF) values.

ADP		Siri 3-C model	
P-Value	0.276	P-Value	0.382
ICC _{2,1}	0.978	ICC _{2,1}	0.986
SEM (%BF)	1.3	SEM (%BF)	0.6
SEM (% of mean)	4.8	SEM (% of mean)	2.4
MD (%BF)	3.6	MD (%BF)	1.7

P-values represent the type 1 error rate for the one-way repeated-measures ANOVA across the two testing days. ICC_{2,1}, intraclass correlation coefficient, model 2,1 (Shrout & Fleiss, 1979); SEM (%BF), standard error of measurement; SEM (% of mean), standard error of measurement expressed as a percentage of the mean; MD (%BF), minimum difference needed to be considered real. The Siri 3-C model %BF values are derived from a subset (n=12) of participants.