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Digital food photography technology improves efficiency and feasibility of dietary intake assessments in large populations eating ad libitum in collective dining facilities

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ABSTRACT

Background: Accurate assessment of dietary intake continues to challenge researchers, especially in field, or non-laboratory settings.
Objective: In this study, digital food photography (DFP) methodology was used to assess nutritional intake (NI) of Soldiers participating in the US Army's Ranger Selection and Assessment Program (RASP).
Methods: During this high-intensity six-week course, Soldiers complete simulated operational missions, perform various military tasks, and importantly, eating time is severely limited. Therefore, this study provided an opportunity to evaluate the utility of DFP methods for accurate assessment of energy balance in conditions where consumption of large numbers of subjects must be completed in a very short periods of time ($\leq$20 min). NI of 131 male, enlisted Soldiers (21 $\pm$ 4 years, 178$\pm$7 cm, and 78$\pm$8 kg) enrolled in the RASP course was assessed in their garrison dining facility using DFP utilizing visual estimation of pre- and post-meal photos of participant meals concurrently with photos of weighed, standardized portions. Total daily energy expenditure (TDEE) was assessed using doubly-labeled water ($^{2}H_{2}^{18}O$) in a sub-group of 19 volunteers.
Results: During the study, data loss (i.e., missing meal photos) was less than 5% per meal, and during the visual estimation process discrepancies in food identification averaged less than 10% per meal, while approximately a third of serving size estimations required a third party adjudication prior to finalization and calculation NI.
Conclusions: We conclude that the use of DFP allows an adequately reliable approach for quantifying NI in real-world scenarios involving large numbers of participants who must be assessed very rapidly, and researchers must have a small footprint.

1. Introduction

Assessing dietary intake of people eating *ad libitum* continues to present researchers with a challenge. The utility of self-reported dietary intake methods such as food record diaries, food frequency questionnaires and 24-hour recall interviews have all been shown to be limited due to misreporting of nutritional intake (NI) by study participants, especially by obese participants (Archer, Hand, & Blair, 2013; Bray, 2008). Furthermore, while dietary assessment by direct observation and visual estimation of portions served and plate waste is accurate (Dubois, 1990; Gittelsohn, Shankar, Pokhrel, & West, 1994), these methods are slow, very labor intensive, and lack historical reference to resolve data collection inconsistencies or errors at a later date (e.g. one time occurrence to capture data). Thus, traditional visual estimation is not ideal for settings where dietary intakes of large numbers of study participants must be assessed while they dine simultaneously in a short

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meal period, without interference by investigators, such as during military group feeding in garrison dining facilities (DFAC) or workplace cafeterias.

The use of digital food photography (DFP) methods have been shown to allow valid and reliable dietary assessment and evaluation of energy and nutrient intake in both children (Martin et al., 2007, 2010; Williamson et al., 2007) and adult (Williamson et al., 2003, 2004) populations, while decreasing participant burden and other problems associated with traditional food data collection. The DFP method of assessing dietary intake is fast, as it only requires only photographs of the participant's food tray, less onsite staff and equipment during data collection, and provides a permanent record (photo) that can be re-examined and re-estimated when an estimate seems in error. Still photographs captured with video cameras allow participants to present their plate for photographing, prior to consumption and again after meal completion. Later, two or more trained technicians, or estimators, view the stored video images of participants' plates to compare the food item images against images of weighed standards of the same foods in appropriate DFAC serving sizes to derive a portion size estimation. Crombie et al (Crombie et al., 2013). used DFP to assess dietary intakes in a military population during the lunchtime meal. Efficient NI of 200 Soldiers per day for five consecutive days in 10 unique DFACs on Fort Bragg, NC (~1000 individual meals) were recorded and assessed.

In the previous study by Crombie et al (Crombie et al., 2013). meal duration was not constrained. Therefore, whether this approach remained useful in settings where diner throughput is very high was not clear. The objective of this study was to evaluate the feasibility of digital photography methods for accurate assessment of energy balance in conditions where consumption of large numbers of subjects must be completed in a very short period of time ($\leq$20 min). We attempted to characterize the energy balance through onsite dietary assessment of a military population eating under severe time limitations in the DFAC environment.

2. Methods

2.1. Participants

Participants were 131 male enlisted Soldiers of the rank of sergeant and below, who were enrolled in Ranger Selection and Assessment Program (RASP) at Fort Benning, GA in October 2012. All Soldiers enrolled in RASP were briefed and interested participants were consented during a report period prior to initializing data collection the first week of this six-week course that selects Soldiers for assignment to the 75th Ranger Regiment. In addition to classroom instruction and daily physical fitness training which included calisthenics and 3–8 mile group runs, RASP participants completed weapons familiarization courses and ranges, land navigation, marches under load, and other military task trainings. The study was reviewed and approved by the US Army Research Institute of Environmental Medicine Human Use Review Committee, and all study investigators adhered to US Army Regulation 70–25 and US Army Medical Research and Material Command regulation 70–25 on the participation of volunteers in research.

2.2. Demographics and anthropometrics

Height was measured to the nearest 0.1 cm using a portable stadiometer, and body weight to the nearest 0.1 kg using a calibrated digital scale with participants wearing shorts and a t-shirt with stocking feet. Mean age, height, weight and body mass index (BMI) was matched between the overall group and a select cohort. A representative sub-group of 19 were asked to participate in the measurement of total daily energy expenditure (TDEE), estimation of body composition using circumference-based equations (abdomen and neck circumferences measured to nearest 0.1 cm) in accordance with Army Regulation 600–9 (U.S. Department of the Army, 2013).

2.3. Total daily energy expenditure

Estimated TDEE was used as a method of comparison for the DFP method (e.g. assumption that energy expenditure equals energy intake in weight-stable individuals) and to characterize the energy requirements of the study population. TDEE was determined in a subgroup of participants using the doubly labeled water (DLW) technique utilized previously in our lab (DeLany et al., 1985; Margolis et al., 2013). Briefly, participants (16 received DLW dose, 3 were controls) were fasted four hours prior to, and eight hours following their consumption of DLW on day one. Baseline urine samples were obtained prior to dosing with DLW (0.23 g $^{2}H_{2}^{18}O$ kg TBW^{-1} and 0.15 g $^{2}H_{2}O$ kg TBW^{-1}) on day one; and second void urine samples were obtained on days two through six to assess the elimination rates of the isotopes. Energy expenditure was calculated by regression analysis using an assumed Respiratory Quotient (RQ) of 0.86 (DeLany et al., 1985).

2.4. Digital food photography

Energy intake was determined using the DFP method described in previous studies (Martin et al., 2007; Williamson et al., 2003, 2004). Briefly, this method captures foods selected and consumed by individuals using a digital video camera pre- and post-meal consumption. After obtaining their tray of food, participants reported to one of three DFP stations (Fig. 1A) to have their tray photographed. Each station contained a video camera (Sony, HandyCam HDR-XR100) and data collector. Participants were able go to any available DFP station for tray photography, regardless of whether it was a pre- or post-tray photo (Fig. 1B). Video cameras were mounted on tripods placed 29 inches (73.7 cm) from the plate (or tray) and angled at approximately 45° and the view adjusted to assure total capture of the participant's tray to standardize the apparent size of all foods and maintain consistency across photographs. Participants were assigned study-specific numbers at the study start and instructed to place the number (e.g. cards were preprinted with study number) on their tray at each photograph opportunity to aid in tracking participants' and in matching pre-with post-meal photos later. Participant's study numbers were visible on the photo capture, enabling the photos, when imported into the Food Photo system, to be imported and organized by participant number. Meal periods were approximately 20 min from arrival to departure of all participants. Due to meal time constraints volunteers that consumed 100% of food selected (pre-meal photo) were instructed to report to assigned data collector for visual confirmation of post-tray consumption (100% consumed). Data collectors then manually logged (written account) of NI recorded at 100% eliminating the need and time taken to photograph an empty tray. When no pre-meal tray photo was taken, data collectors reconstructed the meal using traditional food recall methods (e.g. paper recording) with a participant interview at the time of the post-meal tray return.

Data were collected over five days, three meals per day, with the exception of one field training day when participants consumed the Meal-Ready-to-Eat (MRE) ration and one week day when the DFAC closed early (e.g. no dinner meal was served). During all DFAC meals participants self-selected food items and were provided one of two beverage choices (e.g. water or carbohydrate electrolyte beverage).