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Research report

Consistency of metabolic responses and appetite sensations under postabsorptive and postprandial conditions

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ABSTRACT

The present study aimed to investigate the reliability of metabolic and subjective appetite responses under fasted conditions and following consumption of a cereal-based breakfast. Twelve healthy, physically active males completed two postabsorption (PA) and two postprandial (PP) trials in a randomised order. In PP trials a cereal based breakfast providing 1859 kJ of energy was consumed. Expired gas samples were used to estimate energy expenditure and fat oxidation and 100 mm visual analogue scales were used to determine appetite sensations at baseline and every 30 min for 120 min. Reliability was assessed using limits of agreement, coefficient of variation (CV), intraclass coefficient of correlation and 95% confidence limits of typical error. The limits of agreement and typical error were 292.0 and 105.5 kJ for total energy expenditure, 9.3 and 3.4 g for total fat oxidation and 22.9 and 8.3 mm for time-averaged AUC for hunger sensations, respectively over the 120 min period in the PP trial. The reliability of energy expenditure and appetite in the 2 h response to a cereal-based breakfast would suggest that an intervention requires a 211 kJ and 16.6 mm difference in total postprandial energy expenditure and time-averaged hunger AUC to be meaningful, fat oxidation would require a 6.7 g difference which may not be sensitive to most meal manipulations.

Introduction

Consumption of a meal transiently augments energy expenditure carbohydrate oxidation and feelings of fullness, and suppresses fat oxidation, and feelings of hunger (Miles, Wong, Rumpler, & Conway, 1993; Piers, Soares, Makan, & Shetty, 1992; Stevenson, Astbury, Simpson, Taylor, & Macdonald, 2009; Weststrate et al., 1990). Both metabolic and appetitive responses to meals have implications for energy balance, particularly as in Western societies the majority of the day is spent in the postprandial state (De Castro, 1997). The duration of the postprandial period (the period after eating a meal before which all of the previous meal has been absorbed from the intestine) is dependent upon the energy and macronutrient content of the meal, but typically lasts between 6 and 12 h (Compher, Frankenfield, Keim, & Roth-Yousey, 2006). The stage which follows absorption, but before the effects of prolonged fasting are underway, is known as the postabsorptive state.

The test–retest reproducibility of these measures is pertinent in order to be confident that an intervention or variable is the cause of a difference in a trial and not random variability or systematic bias (Atkinson & Nevill, 1998; Hopkins, 2000). Reliability can be defined as producing the same or similar result when a protocol is repeated a number of times (Atkinson & Nevill, 1998). It has been proposed that reliability should be assessed using a variety of statistical measures (Atkinson & Nevill, 1998) such as Bland and Altman limits of agreement (Bland & Altman, 1986), coefficient of variation (CV), intraclass coefficient of correlation (ICC) and 95% confidence limits of typical error. The inclusion of multiple analyses of reliability allows for interpretation of the components of reliability, comparison with similar studies using different analyses and is further justified due to a current lack of consensus on a primary method to ascertain reliability (Atkinson & Nevill, 2000; Hopkins, 2000).

Research on postprandial thermogenesis have concluded that a high test–retest reliability exists (Segal, Chun, Coronel, Cruz-Noori, & Santos, 1992) with a reliability coefficient of $r = 0.932$ ($P < 0.001$), yet often the meal is in liquid form (Katch, Moorehead, Becque, & Rocchini, 1992; Piers et al., 1992; Segal et al., 1992). Some have investigated the reliability of thermogenesis following solid food consumption exhibiting relatively high CVs of 26–32% (Miles et al., 1993; Weststrate et al., 1990). The reliability of appetite visual analogue scales (VAS) have previously been assessed in response to a solid (Flint, Raben, Blundell, & Astrup, 2000) and liquid (Raben, Tagliabue, & Astrup, 1995) mixed meals. The CVs were shown to vary from 7% to 25%, with prior diet standardisation not improving the consistency. However, in the United Kingdom, around one-third of the population consume cereal-based

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breakfasts (Gibson & Gunn, 2011); recommended for numerous health benefits. To the current author's knowledge, the reliability of energy expenditure and appetite has not been assessed in response to a cereal and milk-based breakfast.

As the physical composition of a meal can influence metabolic and endocrine responses (Peracchi et al., 2000), then the reliability of metabolism is likely to be affected due to additional biological processes arising, each with an inherent variability. Moreover, the number of recent publications using cereal and milk based breakfasts with appetite and/or energy expenditure and fat oxidation as outcomes is considerable (Astbury, Taylor, & Macdonald, 2011; Isaksson et al., 2011; Ping-Delfos & Soares, 2011; Rosen, Ostman, & Bjorck, 2011). Hence clarifying the day to day agreement in metabolic and satiety responses to cereal-based breakfasts is warranted.

The measurement of the thermic effect of food is recommended to be performed over a 400 min period (Levine, 2005). Nonetheless, this may not be possible under complex study designs, particularly those following a more typical daily patterns of food consumption where between meal intervals are between 100 and 300 min (De Castro, 1997). This is particularly apparent in those combining metabolic and appetite measures, as the period of time following a preload can influence the relationship between appetite sensations and energy intake (Blundell et al., 2010). Therefore, studies may wish to abbreviate the postprandial preload period prior to an *ad libitum* meal. It is not known, however to what extent this shortened period would have on the reliability of the measurement of energy expenditure and appetite sensations following meal consumption.

Accordingly, the aim of the present study was to evaluate the reproducibility of whole body energy expenditure and substrate utilisation, along with appetite sensations in response to a typical breakfast.

Methods

Design

Participants attended the laboratory at 0730 h after a 10–14 h fast on four occasions. In a randomised order, each participant completed two postabsorption (PA; after a 10–14 h fast) and two postprandial (PP) trials. Food and fluid intake was matched for 24 h prior to all trials, and vigorous physical activity was prohibited. Following baseline measurements of energy expenditure, substrate metabolism and appetite sensations, a test meal was served (PP) or omitted (PA). Further measures were taken every 30 min for the following 120 min. Fluid intake was recorded on the first trial and replicated for subsequent trials.

Subjects

Twelve healthy, physically active males (age: 23.2 ± 4.3 y, stature: 178 ± 7 cm, mass: 77.2 ± 5.3 kg, BMI: 24.5 ± 2.0 kg/m^2, self-reported activity level: 4024 ± 3018 met-min/wk) were recruited from the student and staff population at Northumbria University and all participants completed the full protocol. Participants who self-reported as physically inactive, defined by less than 30 min of moderate activity, five times a week by the International Physical Activity Questionnaire (Craig et al., 2003) restrained eaters, defined by a score of >11 on the Three Factor Eating Questionnaire (Stunkard & Messick, 1985) or those with any metabolic disorders were omitted. The present study was conducted in accordance with the guidelines stated in the 1964 Declaration of Helsinki. Prior to recruitment, all participants provided informed written consent and the study was approved by the School of Life Sciences Ethics Committee at Northumbria University.

Anthropometric measurements

Body mass was determined to the nearest 0.1 kg using balance scales (Seca, Birmingham, UK) upon arrival to the laboratory, with participants wearing only light clothing. Height was measured to the nearest 0.1 cm using a stadiometer (Seca, Birmingham, UK).

Energy expenditure and substrate oxidation

Energy expenditure was calculated by indirect calorimetry using an online gas analysis system (Metalyzer 3B, Cortex, Germany) calibrated using gases of known concentration and a 3 L syringe. Participants wore a facemask, were sat in an upright position at all times and following a 2 min stabilisation phase, 5 min samples of expired gas were obtained and averaged. Substrate oxidation was calculated with oxygen uptake and carbon dioxide production values using stoichiometric equations assuming protein oxidation to be negligible (Peronnet & Massicotte, 1991). Respiratory exchange ratio (RER) was averaged over the 120 min time-periods.

Appetite sensations

Paper based, 100 mm VAS were completed to determine appetite sensations. Questions asked were used to determine hunger, fullness, satisfaction and prospective food consumption. VAS ratings were double-measured by two researchers and means were taken where discrepancies occurred.

Test meal

The test meal consisted of 72 g quick cook porridge oats (Oatso Simple Golden Syrup, Quaker Oats, Reading, UK) with 360 ml semi-skimmed milk (Tesco, Dundee, UK). The porridge was cooked for 4 min at full power in a 1000 W microwave and was served after 10 min of cooling. The test meal was consumed within 10 min and provided 1859 kJ of energy (17% protein, 60% carbohydrate, 23% fat).

Statistical analysis

All data were calculated as mean ± SD. VAS ratings were calculated as time-averaged area under the curve (AUC) for postprandial and postabsorptive periods. Reliability was assessed using a variety of statistical techniques, with typical error taken as the primary assessment tool. Namely, mean difference, ICC, CV and typical error were employed for all variables (Atkinson & Nevill, 1998; Hopkins, 2000). ICCs were considered to show good reproducibility when ICC $\geqslant$ 0.8, moderate reproducibility when 0.7 $\leqslant$ ICC < 0.8, and acceptable reproducibility when 0.6 $\leqslant$ ICC < 0.7. Energy expenditure, fat oxidation and hunger during the postprandial trials were assessed using Bland–Altman limits of agreement (Bland & Altman, 1986). Data were checked for heteroscedasticity such that the appropriate statistical techniques could be employed. To determine whether either BMI or physical activity levels affected the reliability of the variables, pearson product–moment correlation coefficients were used to determine relationships between CVs of metabolic and appetite responses, and BMI and physical activity level. Paired student's *t* tests were used to detect differences in mean values and CVs. Values were considered significant when $P < 0.05$.