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Consistency of metabolic responses and appetite sensations

under postabsorptive and postprandial conditions

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1

17   **Abstract**

18   The present study aimed to investigate the reliability of metabolic and subjective

19   appetite responses under fasted conditions and following consumption of a cereal-based

20   breakfast. Twelve healthy, physically active males completed two postabsorption (PA)

21   and two postprandial (PP) trials in a randomised order. In PP trials a cereal based

22   breakfast providing 1859 kJ of energy was consumed. Expired gas samples were used to

23   estimate energy expenditure and fat oxidation and 100 mm visual analogue scales were

24   used to determine appetite sensations at baseline and every 30 min for 120 min.

25   Reliability was assessed using limits of agreement, coefficient of variation (CV),

26   intraclass coefficient of correlation and 95% confidence limits of typical error. The

27   limits of agreement and typical error were 292.0 and 105.5 kJ for total energy

28   expenditure, 9.3 and 3.4 g for total fat oxidation and 22.9 and 8.3 mm for time-averaged

29   AUC for hunger sensations, respectively over the 120 min period in the PP trial. The

30   reliability of energy expenditure and appetite in the 2 h response to a cereal-based

31   breakfast would suggest that an intervention requires a 211 kJ and 16.6 mm difference

32   in total postprandial energy expenditure and time-averaged hunger AUC to be

33   meaningful, fat oxidation would require a 6.7 g difference which may not be sensitive to

34   most meal manipulations.

35   Key words: reproducibility; breakfast; energy expenditure; hunger, fat oxidation

36

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 hours (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

60 studies using different analyses and is further justified due to a current lack of

61 consensus on a primary method to ascertain reliability (Atkinson & Nevill, 2000;

62 Hopkins, 2000).

63   Research on postprandial thermogenesis have concluded that a high test-retest

64 reliability exists (Segal, Chun, Coronel, Cruz-Noori, & Santos, 1992) with a reliability

65 coefficient of r = 0.932 ($P<0.001$), yet often the meal is in liquid form (Katch,

66 Moorehead, Becque, & Rocchini, 1992; Piers et al., 1992; Segal et al., 1992). Some

67 have investigated the reliability of thermogenesis following solid food consumption

68 exhibiting relatively high CVs of 26-32% (Miles et al., 1993; Weststrate et al., 1990).

69 The reliability of appetite visual analogue scales (VAS) have previously been assessed

70 in response to a solid (Flint, Raben, Blundell, & Astrup, 2000) and liquid (Raben,

71 Tagliabue, & Astrup, 1995) mixed meals. The CVs were shown to vary from 7-25%,

72 with prior diet standardisation not improving the consistency. However, in the United

73 Kingdom, around one-third of the population consume cereal-based breakfasts (Gibson

74 & Gunn, 2011); recommended for numerous health benefits. To the current author's

75 knowledge, the reliability of energy expenditure and appetite has not been assessed in

76 response to a cereal and milk-based breakfast.

77   As the physical composition of a meal can influence metabolic and endocrine

78 responses (Peracchi et al., 2000), then the reliability of metabolism is likely to be

79 affected due to additional biological processes arising, each with an inherent variability.

80 Moreover, the number of recent publications using cereal and milk based breakfasts

81 with appetite and/or energy expenditure and fat oxidation as outcomes is considerable

82 (Astbury, Taylor, & Macdonald, 2011; Isaksson et al., 2011; Ping-Delfos & Soares,

4

83   2011; Rosen, Ostman, & Bjorck, 2011). Hence clarifying the day to day agreement in

84   metabolic and satiety responses to cereal-based breakfasts is warranted.

85   The measurement of the thermic effect of food is recommended to be performed

86   over a 400 min period (Levine, 2005). Nonetheless, this may not be possible under

87   complex study designs, particularly those following a more typical daily patterns of

88   food consumption where between meal intervals are between 100 and 300 min (De

89   Castro, 1997). This is particularly apparent in those combining metabolic and appetite

90   measures, as the period of time following a preload can influence the relationship

91   between appetite sensations and energy intake (Blundell et al., 2010). Therefore, studies

92   may wish to abbreviate the postprandial preload period prior to an *ad libitum* meal. It is

93   not known, however to what extent this shortened period would have on the reliability

94   of the measurement of energy expenditure and appetite sensations following meal

95   consumption.

96   Accordingly, the aim of the present study was to evaluate the reproducibility of

97   whole body energy expenditure and substrate utilisation, along with appetite sensations

98   in response to a typical breakfast.

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100

101   **Methods**

102

103   *Design*

104

105   Participants attended the laboratory at 0730 h after a 10-14 h fast on four

106   occasions. In a randomised order, each participant completed two postabsorption (PA;

107   after a 10-14 h fast) and two postprandial (PP) trials. Food and fluid intake was matched

108   for 24 h prior to all trials, and vigorous physical activity was prohibited. Following

109   baseline measurements of energy expenditure, substrate metabolism and appetite

110   sensations, a test meal was served (PP) or omitted (PA). Further measures were taken

111   every 30 min for the following 120 min. Fluid intake was recorded on the first trial and

112   replicated for subsequent trials.

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114

115   *Subjects*

116

117   Twelve healthy, physically active males (age: 23.2 ± 4.3 y, stature: 178 ± 7 cm,

118   mass: 77.2 ± 5.3 kg, BMI: 24.5 ± 2.0 kg/m^2, self-reported activity level: 4024 ± 3018

119   met-min/wk) were recruited from the student and staff population at Northumbria

120   University and all participants completed the full protocol. Participants who self-

121   reported as physically inactive, defined by less than 30 min of moderate activity, 5

122   times a week by the International Physical Activity Questionnaire (Craig et al., 2003)

123   restrained eaters, defined by a score of >11 on the Three Factor Eating Questionnaire

124   (Stunkard & Messick, 1985) or those with any metabolic disorders were omitted. The

125   present study was conducted in accordance with the guidelines stated in the 1964

126   Declaration of Helsinki. Prior to recruitment, all participants provided informed written

127   consent and the study was approved by the School of Life Sciences Ethics Committee at

128   Northumbria University.

129

Anthropometric measurements

131   Body mass was determined to the nearest 0.1 kg using balance scales (Seca,

132   Birmingham, UK) upon arrival to the laboratory, with participants wearing only light

133   clothing. Height was measured to the nearest 0.1 cm using a stadiometer (Seca,

134   Birmingham, UK).

135

Energy expenditure and substrate oxidation

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138   Energy expenditure was calculated by indirect calorimetry using an online gas

139   analysis system (Metalyzer 3B, Cortex, Germany) calibrated using gases of known

140   concentration and a 3 L syringe. Participants wore a facemask, were sat in an upright

141   position at all times and following a 2 min stabilisation phase, 5 min samples of expired

142   gas were obtained and averaged. Substrate oxidation was calculated with oxygen uptake

143   and carbon dioxide production values using stoichiometric equations assuming protein

144   oxidation to be negligible (Peronnet & Massicotte, 1991). Respiratory exchange ratio

145   (RER) was averaged over the 120 min time-periods.

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Appetite sensations

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149   Paper based, 100 mm VAS were completed to determine appetite sensations.

150   Questions asked were used to determine hunger, fullness, satisfaction and prospective

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151 food consumption. VAS ratings were double-measured by two researchers and means

152 were taken where discrepancies occurred.

153

154 *Test meal*

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156   The test meal consisted of 72 g quick cook porridge oats (Oatso Simple Golden

157 Syrup, Quaker Oats, Reading, UK) with 360 ml semi-skimmed milk (Tesco, Dundee,

158 UK). The porridge was cooked for 4 min at full power in a 1000 W microwave and was

159 served after 10 min of cooling. The test meal was consumed within 10 min and

160 provided 1859 kJ of energy (17% protein, 60% carbohydrate, 23% fat).

161

162 *Statistical analysis*

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164   All data were calculated as mean ± SD. VAS ratings were calculated as time-

165 averaged area under the curve (AUC) for postprandial and postabsorptive periods.

166 Reliability was assessed using a variety of statistical techniques, with typical error taken

167 as the primary assessment tool. Namely, mean difference, ICC, CV and typical error

168 were employed for all variables (Atkinson & Nevill, 1998; Hopkins, 2000). ICCs were

169 considered to show good reproducibility when ICC$\geq$0.8, moderate reproducibility when

170 0.7$\leq$ICC<0.8, and acceptable reproducibility when 0.6$\leq$ICC<0.7. Energy expenditure,

171 fat oxidation and hunger during the postprandial trials were assessed using Bland-

172 Altman limits of agreement (Bland & Altman, 1986). Data were checked for

173 heteroscedasticity such that the appropriate statistical techniques could be employed. To

174 determine whether either BMI or physical activity levels affected the reliability of the

175 variables, pearson product-moment correlation coefficients were used to determine

176 relationships between CVs of metabolic and appetite responses, and BMI and physical

177 activity level. Paired student's t tests were used to detect differences in mean values and

178 CVs. Values were considered significant when $P<0.05$.

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180

181 **Results**

182

183 *Energy expenditure and substrate oxidation*

184

185   Postprandial energy expenditure was higher than postabsorptive energy

186 expenditure, yet CV and typical errors were similar (Table 1). A Bland-Altman plot for

187 postprandial energy expenditure can be seen in Figure 1. Fat oxidation showed greater

188 variation than energy expenditure at baseline and throughout both trials (CVs 20 and

189 8%, respectively). Postprandial fat oxidation is displayed as a Bland-Altman plot in

190 Figure 2. Mean CVs were not significantly different for either energy expenditure or fat

191 oxidation (P=0.80 and P=0.12, respectively) with the postprandial trial compared to the

192 postabsorptive trial (Table 1).

193   Both carbohydrate oxidation and RER revealed similar typical errors and CVs

194 under postabsorptive and postprandial conditions (Table 1).

195   Both postprandial and postabsorptive energy expenditure CVs showed positive

196 relationships with BMI (r = 0.61 and 0.64, respectively; both $P<0.05$), but not with

9

197   physical activity level (r = -0.13 and -0.21, respectively; both *P*>0.05) whereas neither

198   postprandial, nor postabsorptive fat oxidation CVs showed significant relationships with

199   either BMI or physical activity level (all *P*>0.05).

200

201   *Subjective appetite ratings*

202

203   CVs of baseline measures for hunger, fullness, satisfaction and prospective

204   consumption were 21, 42, 43 and 19% respectively. During the postabsorptive trial, all

205   ratings showed an improvement in reliability, yet fullness and satisfaction were less

206   reproducible than hunger and prospective consumption (Table 2). However this was

207   nullified somewhat under postprandial conditions (Table 2). Bland-Altman limits of

208   agreement for the time-averaged, postprandial hunger AUC were ± 22.9 mm (Figure 3).

209   Fullness and satisfaction time-averaged AUC CVs tended to be lower during the

210   postprandial trial compared to the postabsorptive trial (*P*=0.077 and *P*=0.067,

211   respectively). On the other hand, time-averaged AUC for hunger tended to be greater on

212   the postprandial trial (*P*=0.069) and was significantly greater for prospective

213   consumption (*P*=0.016). No significant relationships were determined between any

214   appetite rating CVs and either BMI or physical activity level (all *P*>0.05).

215

216   **Discussion**

217

218   The present study evaluated the consistency of metabolic and appetite responses

219   under postabsorptive conditions and following the consumption of a cereal and milk-

220   based breakfast. Energy expenditure and fat oxidation displayed typical errors of ~100

221   kJ and ~3 g respectively for the postprandial periods. Postprandial typical errors of

222   time-averaged AUC for hunger and fullness were 8.26 and 10.29 mm, respectively.

223   Energy expenditure demonstrated reasonable reproducibility under 2 h of

224   postabsorptive conditions, with an acceptable ICC and a CV of 8.6% (Table 1). Under

225   postprandial conditions, the reliability of EE was slightly improved, with both

226   correlation coefficients increasing and the CV and typical error remaining relatively

227   constant. These correlations are lower than the r=0.932 presented by Segal et al. (1992)

228   after consumption of a liquid meal. It may be that due to the meal in the present study

229   being of a semi-solid consistency, the rate of consumption, gastric emptying and

230   intestinal absorption add further locations where biological variation in the metabolism

231   of the meal can persist. Indeed, the rate of eating can affect the glycaemic response,

232   which is associated with postprandial thermogenesis (Segal et al., 1992). Also, others

233   have demonstrated high variability in the thermic effect of solid meals (Miles et al.,

234   1993). The CV (26%) demonstrated by Miles et al. is higher than that of the present

235   study, which could be due to a less diet and exercise standardisation (12 h vs. 24 h prior

236   to trials). The limits of agreement for EE correspond to 292 kJ (Figure 1), which

237   although may be sensitive enough to detect a difference between groups of individuals,

238   it is of substantial magnitude to question the sensitivity to detect subtle differences in

239   meal composition.

240   The relationship shown between the CVs of EE and BMI suggests that the

241   reliability of EE measurement is reduced as BMI is increased. An explanation for this is

242   not readily available. Although a tentative suggestion is that the higher absolute EE seen

243   with a higher BMI would affect the degree of variance. However, it should be noted that

244   the relatively tight range of BMI in this study may limit the validity of this statistic.

245   When fasted, fat oxidation also displayed strong reproducibility with a good

246   ICC, and reasonable CV (Table 1). However, these values did deteriorate to a degree

247   during the postprandial trial (Table 1), though not to a significant extent with regards to

248   the CV. To the author's best knowledge, this is the first study to exhibit the consistency

249   of the fat oxidation response to a non-liquid meal. It appears that the fat oxidation

250   response is comparable to, yet slightly less reliable than energy expenditure. Bland-

251   Altman limits of agreement for FO were also relatively large at 9.3 g (Figure 2). This

252   may mean that differences in an intervention are difficult to detect with this 2 h

253   postprandial protocol. In a similar fashion to fat oxidation, the typical error for

254   postprandial carbohydrate oxidation was substantial and a 13.9 g difference would be

255   required by an intervention to be considered meaningful (Table 1). RER displayed

256   tighter CVs (Table 1), and the typical error indicates that under both postabsorptive and

257   postprandial conditions, a mean difference of 0.08 would be considered a meaningful

258   difference. The CV for RER under postprandial conditions is similar to the 1.9%

259   previously reported (Piers, Soares, Makan, & Shetty, 1992) during a basal metabolic

260   rate measurement (under postabsorptive conditions).

261   At baseline, hunger and prospective consumption ratings provided a reasonable

262   degree of consistency, in contrast to fullness and satisfaction, as demonstrated by high

263   CVs. A similar pattern emerged during the postabsorptive trials (Table 2), where hunger

264   and prospective consumption were more reliable than fullness and satisfaction, although

265   all showed an improvement. This was probably due to the increase in the number of

266   measures taken. Previous research has also shown reduced coefficients of repeatability

267   (CR = 2 x SD) with mean postprandial measures versus fasting (Flint et al., 2000). It

268   was suggested that as the number of time points increases, the reliability improves as

269 individual outlying data points will be reduced in their impact. The former study had

270 averaged ratings over a 4.5 h period, resulting in 10 data points. The present study

271 demonstrates that the CV is improved after just 2 h (5 data points) to a level comparable

272 to that found previously (Raben et al., 1995). Postabsorptive appetite ratings generally

273 showed improved reliability compared to baseline (although the reliability of

274 prospective consumption ratings weakened). In terms of CV, the pattern was reversed

275 compared to postabsorptive conditions, whereby hunger and prospective consumption

276 displayed higher CVs compared to fullness and satisfaction. A likely explanation for

277 this is that hunger and prospective consumption ratings are high in the fasted state and

278 are reduced following meal consumption. Fullness and satisfaction ratings respond in a

279 converse fashion. Thus, lower values may be more susceptible to a greater variation as a

280 percentage (CV) when absolute variation is similar. The limits of agreement (22.9 mm)

281 for postprandial hunger AUC were similar to those reported previously (Flint et al.,

282 2000) over a 4.5 h period (24 mm). This would suggest that there is no difference in the

283 reliability of hunger ratings between a 2 h period of sampling (5 time points when

284 sampled every 30 min) compared to a 4.5 h sampling epoch.

285 It is unsurprising that appetite ratings are less consistent than metabolic data,

286 particularly in the postprandial state. The physiological processes involved in the

287 consumption of the food are likely to influence appetite ratings, carrying with it the

288 variation in digestion, absorption and metabolism. This adds to the variation in the other

289 factors involved in appetite sensations from environmental and psychological stimuli

290 (Stubbs et al., 2000).

291 Each statistical test of reliability possesses its own inherent limitations. It is

292 beyond the scope of this paper to rigorously critique each statistical method in relation

293   to one another, although it is useful to bear in mind the principle benefits and

294   constraints of each method. The ICC is sensitive to systematic bias but requires

295   heterogenous data and is not recommended as a solitary method (Atkinson & Nevill,

296   1998). The typical error and CVs represent 68% of the variance, yet CV depends on the

297   magnitude of the measured values (Atkinson & Nevill, 1998). Limits of agreement

298   represent 95% of the likely variance between measures in repeat tests. However, unlike

299   typical error these can be influenced by sample size (Hopkins, 2000). This assortment of

300   analyses not only allows for a more resolute picture of global reliability, but also

301   facilitates the comparison with similar studies.

302   The condensed expired gas sampling periods used in the present study could be

303   seen as a limitation, yet 5 min of stable measures have been deemed sufficient for best

304   practise methods for the determination of energy expenditure (Compher et al., 2006). As

305   this study suggests that fat oxidation is less reliable, then considerations may be made

306   that a longer sampling period may be necessary for the determination of postprandial fat

307   oxidation in future studies.

308   It is worthy to note that the participants of both the present study and that of

309   Flint et al. (2000) were young healthy males of normal BMI. An interesting avenue for

310   future research could be to investigate whether the reliability remains at a similar

311   echelon when studying different populations (females, children, overweight and insulin

312   resistant).

313   In conclusion, the reliability of the measurement of energy expenditure in

314   response to a cereal and milk based breakfast is reasonable when taken over a 2 h

315   period. Fat oxidation following breakfast was slightly less consistent and may not be as

316   sensitive to interventions. The reproducibility of appetite sensations over a 2 h

317 postprandial episode were shown to be comparable to those reported previously over a

318 4.5 h period. Thus in physically active males, 2 h is enough time to detect differences in

319 metabolic (namely, energy expenditure and fat oxidation) and appetite responses to

320 breakfast meals within studies requiring a shorter time period of sampling such as pre-

321 load and exercise intervention studies. Typical errors indicate that a 211 kJ, 6.7 g and a

322 16.5 mm difference in postprandial energy expenditure, fat oxidation and AUC for

323 hunger would be a needed for an intervention to be considered meaningful for studies of

324 a similar design.

325

326 **References**

327 Astbury, N. M., Taylor, M. A., & Macdonald, I. A. (2011). Breakfast consumption
328   affects appetite, energy intake, and the metabolic and endocrine responses to
329   foods consumed later in the day in male habitual breakfast eaters. *Journal of*
330   *Nutrition, 141*, 1381-1389.
331 Atkinson, G., & Nevill, A. (2000). Typical error versus limits of agreement. *Sports*
332   *Medicine, 30*, 375-381.
333 Atkinson, G., & Nevill, A. M. (1998). Statistical methods for assessing measurement
334   error (reliability) in variables relevant to sports medicine. *Sports Medicine, 26*,
335   217-238.
336 Bland, J. M., & Altman, D. G. (1986). Statistical methods for assessing agreement
337   between two methods of clinical measurement. *Lancet, 1*, 307-310.
338 Blundell, J., de Graaf, C., Hulshof, T., Jebb, S., Livingstone, B., Lluch, A., Mela, D.,
339   Salah, S., Schuring, E., van der Knaap, H., & Westerterp, M. (2010). Appetite
340   control: methodological aspects of the evaluation of foods. *Obesity Reviews, 11*,
341   251-270.
342 Compher, C., Frankenfield, D., Keim, N., & Roth-Yousey, L. (2006). Best Practice
343   Methods to Apply to Measurement of Resting Metabolic Rate in Adults: A
344   Systematic Review. *Journal of the American Dietetic Association, 106*, 881-903.
345 Craig, C. L., Marshall, A. L., Sjostrom, M., Bauman, A. E., Booth, M. L., Ainsworth, B.
346   E., Pratt, M., Ekelund, U., Yngve, A., Sallis, J. F., & Oja, P. (2003).
347   International physical activity questionnaire: 12-country reliability and validity.
348   *Medicine & Science in Sports & Exercise, 35*, 1381-1395.
349 De Castro, J. M. (1997). Socio-cultural determinants of meal size and frequency. *British*
350   *Journal of Nutrition, 77*, Suppl 1, S39-54; discussion S54-35.
351 Flint, A., Raben, A., Blundell, J. E., & Astrup, A. (2000). Reproducibility, power and
352   validity of visual analogue scales in assessment of appetite sensations in single

353   test meal studies. *International Journal of Obesity and Related Metabolic*
354   *Disorders, 24*, 38-48.
355 Gibson, S. A., & Gunn, P. (2011). What's for breakfast? Nutritional implications of
356   breakfast habits: insights from the NDNS dietary records. *Nutrition Bulletin, 36*,
357   78-86.
358 Hopkins, W. G. (2000). Measures of reliability in sports medicine and science. *Sports*
359   *Medicine, 30*, 1-15.
360 Isaksson, H., Rakha, A., Andersson, R., Fredriksson, H., Olsson, J., & Aman, P. (2011).
361   Rye kernel breakfast increases satiety in the afternoon - an effect of food
362   structure. *Nutrition Journal, 10*, 31.
363 Katch, V. L., Moorehead, C. P., Becque, M. D., & Rocchini, A. P. (1992). Reduced
364   short-term thermic effects of a meal in obese adolescent girls. *European Journal*
365   *of Applied Physiology & Occupational Physiology, 65*(6), 535-540.
366 Levine, J. A. (2005). Measurement of energy expenditure. *Public Health Nutrition, 8*,
367   1123-1132.
368 Miles, C. W., Wong, N. P., Rumpler, W. V., & Conway, J. (1993). Effect of circadian
369   variation in energy expenditure, within-subject variation and weight reduction
370   on thermic effect of food. *European Journal of Clinical Nutrition, 47*, 274-284.
371 Peracchi, M., Santangelo, A., Conte, D., Fraquelli, M., Tagliabue, R., Gebbia, C., &
372   Porrini, M. (2000). The physical state of a meal affects hormone release and
373   postprandial thermogenesis. *British Journal of Nutrition, 83*, 623-628.
374 Peronnet, F., & Massicotte, D. (1991). Table of nonprotein respiratory quotient: an
375   update. *Canadian Journal of Sport Sciences, 16*, 23-29.
376 Piers, L. S., Soares, M. J., Makan, T., & Shetty, P. S. (1992). Thermic effect of a meal.
377   1. Methodology and variation in normal young adults. [Research Support, Non-
378   U.S. Gov't]. *British Journal of Nutrition, 67*, 165-175.
379 Ping-Delfos, W. C., & Soares, M. (2011). Diet induced thermogenesis, fat oxidation and
380   food intake following sequential meals: influence of calcium and vitamin D.
381   *Clinical Nutrition, 30*, 376-383.
382 Raben, A., Tagliabue, A., & Astrup, A. (1995). The reproducibility of subjective
383   appetite scores. *British Journal of Nutrition, 73*, 517-530.
384 Rosen, L. A., Ostman, E. M., & Bjorck, I. M. (2011). Effects of cereal breakfasts on
385   postprandial glucose, appetite regulation and voluntary energy intake at a
386   subsequent standardized lunch; focusing on rye products. *Nutrition Journal, 10*,
387   7.
388 Segal, K. R., Chun, A., Coronel, P., Cruz-Noori, A., & Santos, R. (1992). Reliability of
389   the measurement of postprandial thermogenesis in men of three levels of body
390   fatness. *Metabolism, 41*, 754-762.
391 Stevenson, E. J., Astbury, N. M., Simpson, E. J., Taylor, M. A., & Macdonald, I. A.
392   (2009). Fat oxidation during exercise and satiety during recovery are increased
393   following a low-glycemic index breakfast in sedentary women. *Journal of*
394   *Nutrition, 139*, 890-897.
395 Stubbs, R. J., Hughes, D. A., Johnstone, A. M., Rowley, E., Reid, C., Elia, M., Stratton,
396   R., Delargy, H., King, N., & Blundell, J. E. (2000). The use of visual analogue
397   scales to assess motivation to eat in human subjects: a review of their reliability
398   and validity with an evaluation of new hand-held computerized systems for
399   temporal tracking of appetite ratings. *British Journal of Nutrition, 84*, 405-415.

16

400   Stunkard, A. J., & Messick, S. (1985). The three-factor eating questionnaire to measure
401   dietary restraint, disinhibition and hunger. *Journal of Psychosomatic Research,*
402   *29*, 71-83.
403   Weststrate, J. A., Dekker, J., Stoel, M., Begheijn, L., Deurenberg, P., & Hautvast, J. G.
404   (1990). Resting energy expenditure in women: impact of obesity and body-fat
405   distribution. *Metabolism: Clinical and Experimental, 39*, 11-17.

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408

409   **Table 1.** Reliability of metabolic variables over 120 min postabsorptive and postprandial periods

	Postabsorptive				Postprandial			
	TEE (kJ)	TFO (g)	TCO (g)	RER	TEE (kJ)	TFO (g)	TCO (g)	RER
Trial 1								
Mean	843	15.8	16.4	0.78	943	12.4	26.1	0.84
SD	162	6.0	8.6	0.04	222	5.1	7.8	0.04
Trial 2								
Mean	851	16.6	15.5	0.77	943	13.8	24.8	0.83
SD	155	5.8	6.7	0.06	186	6.1	9.2	0.06
Mean difference	7.9	0.75	-0.89	-0.01	0.13	1.36	1.30	-0.01
95% CI	-78.1, 93.8	-1.53, 3.03	-6.66, 4.88	-0.04, 0.02	-94.93, 94.67	-1.67, 4.39	-6.41, 3.80	-0.04, 0.01
ICC	0.68	0.84	0.18	0.37	0.77	0.68	0.37	0.45
95% CI	0.20, 0.90	0.55, 0.95	-0.37, 0.64	-0.13, 0.72	0.38, 0.93	0.21, 0.90	-0.13, 0.72	-0.03, 0.76
CV (%)	8.6	11.5	27.3	3.9	8.9	20.0	26.3	3.8
Typical error	95.7	2.54	7.04	0.04	105.5	3.37	6.96	0.04
95% CI	67.8, 162.5	1.80, 4.31	5.14, 11.59	0.03, 0.06	74.7, 179.1	2.39, 5.73	5.20, 10.79	0.03, 0.06

410   SD, standard deviation; ICC, intra-class correlation coefficient; CV, coefficient of variation; TEE,
411   total energy expenditure; TFO, total fat oxidation; TCO, total carbohydrate oxidation; RER,
412   respiratory exchange ratio.

413

414 **Table 2**. Reliability of appetite AUC over 120 min postabsorptive and postprandial periods.

	Postabsorptive				Postprandial			
	Hunger	Fullness	Satisfaction	Prospective Consumption	Hunger	Fullness	Satisfaction	Prospective Consumption
Trial 1								
Mean	64.4	22.2	23.5	71.0	31.1	66.3	62.8	36.6
SD	14.2	5.8	6.6	10.5	13.2	11.5	11.9	16.8
Trial 2								
Mean	62.5	24.1	26.9	67.7	31.9	60.8	62.7	40.5
SD	19.3	10.9	11.7	14.7	15.0	15.9	14.4	19.3
Mean difference	-1.93	1.98	3.33	-3.32	0.79	-5.50	-0.03	3.93
95% CI	-8.95, 5.10	-3.34, 7.29	-1.56, 8.23	-9.73, 3.09	-6.63, 8.22	-14.75, 3.75	-8.14, 8.08	-7.39, 15.24
ICC	0.82	0.59	0.71	0.73	0.70	0.49	0.58	0.56
95% CI	0.49, 0.94	0.05, 0.86	0.26, 0.91	0.30, 0.9	0.24, 0.90	-0.08, 0.82	0.03, 0.86	0.01, 0.85
CV (%)	12.8	23.7	21.2	9.5	25.2	14.3	11.3	28.3
Typical error	7.82	5.92	5.45	7.13	8.26	10.29	9.02	12.59
95% CI	5.54, 13.28	4.19, 10.04	3.86, 9.25	5.05, 12.11	5.85, 14.03	7.29, 17.48	6.39, 15.32	8.92, 21.38

415 SD, standard deviation; ICC, intra-class correlation coefficient; CV, coefficient of
416 variation; AUC, area under the curve.

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418 **Figure Legends**

419 **Figure 1.** Bland and Altman plot for difference in energy expenditure over a 120 min
420 period following consumption of a cereal-based breakfast on two occasions.

421 **Figure 2.** Bland and Altman plot for total fat oxidation over a 120 min period following
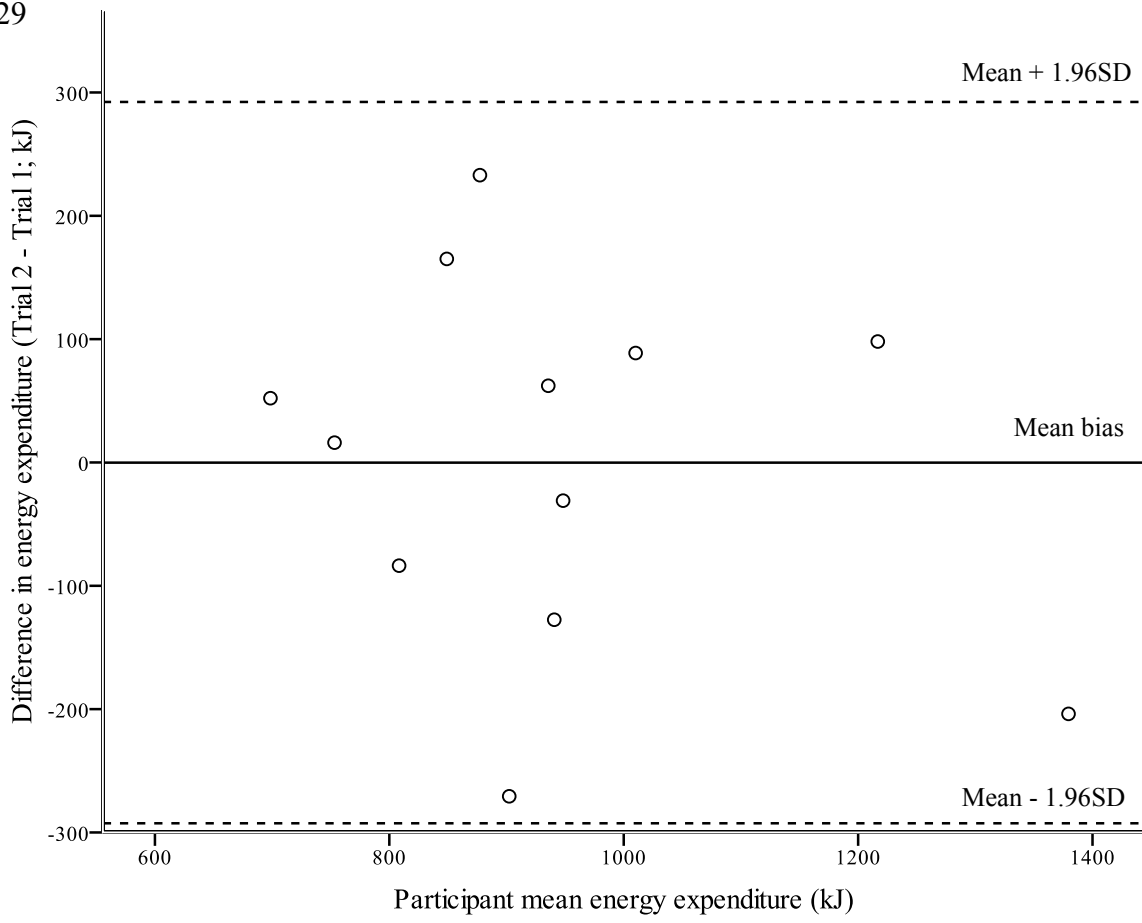422 consumption of a cereal-based breakfast on two occasions.

423 **Figure 3.** Bland and Altman plot for time-averaged AUC for hunger over a 120 min
424 period following consumption of a cereal-based breakfast on two occasions. AUC, area
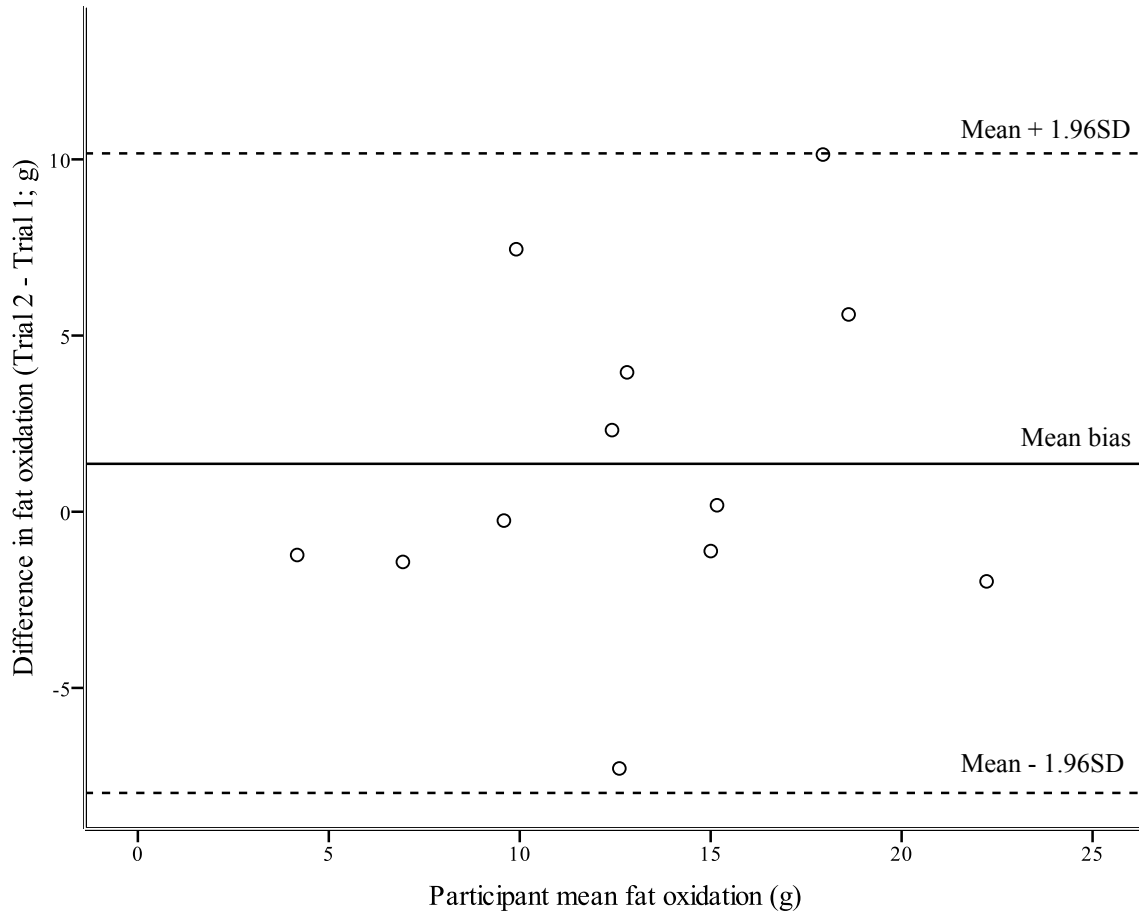425 under the curve.

426

427
428 **Figure 1**

429

430
431   **Figure 2**

432

434

435 **Figure 3**

436