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1 **Title:** The effect of galactose ingestion on affect and perceived exertion in
2 recreationally active females.

3 **Running Title:**

4 **Authors:** Lauren C Duckworth^{a*}, Susan H Backhouse^a, Emma J Stevenson^b

5 **Author affiliations:**

6 ^aCarnegie Faculty, Leeds Metropolitan University, Fairfax Hall, Headingley Campus,
7 Leeds, LS6 3QS, UK.

8 L.Duckworth@leedsmet.ac.uk

9 S.Backhouse@leedsmet.ac.uk

10 ^bSchool of Life Sciences, Northumbria University, Newcastle Upon Tyne, NE1 8ST,
11 UK.

12 e.stevenson@northumbria.ac.uk

13

14 * Corresponding author.

15 Dr Lauren Duckworth

16 E-mail address: L.Duckworth@leedsmet.ac.uk

17 Telephone: (+) 44 113 812 6288

18 Fax: (+) 44 113 812 7575

19

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22

23 Abstract

24 The beneficial effects of acute carbohydrate (CHO) supplementation on exercise
25 performance have been well described. Also reported is the attenuation of perceived
26 exertion and enhancement of affect during prolonged exercise following CHO
27 ingestion. However, no studies to date have assessed the impact of the type of CHO
28 ingested on affective responses during moderate intensity exercise, lasting 60 min or
29 less. Therefore, the aim of the present study was to investigate the effects of
30 consuming a galactose (GAL) CHO drink versus a glucose (GLU) CHO or placebo
31 (PLA) drink before and during exercise on affect and perceived exertion. Nine
32 recreationally active females undertook three trials, each consisting of running for 60
33 min at 65% VO_{2max} followed immediately by a 90 min rest period. Prior to (300 ml)
34 and at every 15 minutes during exercise (150 ml), participants consumed either a
35 GLU or GAL drink each containing 45g of CHO, or an artificially-sweetened PLA
36 drink. Ratings of pleasure-displeasure and perceived activation were measured
37 throughout exercise and the rest period and measures of perceived exertion were
38 measured during exercise. Plasma glucose and serum insulin were significantly
39 greater throughout exercise and rest following the GLU trial compared with the GAL
40 and PLA trials ($P<0.05$). Measures of perceived activation and pleasure-displeasure
41 were not enhanced nor RPE reduced as a result of ingestion of a CHO solution. In
42 conclusion, the GAL beverage elicited a more favourable metabolic profile in the
43 exercising females but this did not translate into an enhanced affective profile.
44 Indeed, CHO ingestion had no noticeable effect on the assessed psychological
45 indices during 60 min of moderate-intensity exercise in females. It is suggested that
46 the maintenance of a positive affective profile may be explained more by the level of
47 hydration as opposed to fuel availability. Therefore, those seeking to use beverages
48 containing CHO to enhance their exercise experience may take note of these
49 findings as this practise appears unjustified.

50 Keywords

51 Carbohydrate, affect, RPE, pleasure-displeasure, females, exercise.

52

53 **Introduction**

54 A well-established evidence base supports the beneficial effects of acute
55 carbohydrate (CHO) supplementation on exercise performance. Such findings have
56 been consistently outlined when CHO is consumed before, during and after,
57 moderate or intense aerobic activity (Carter, Jeukendrup, Mundel, & Jones, 2003;
58 Coggan & Coyle, 1991; Costill, 1988; Coyle, 1991; Ivy, 1999; Jeukendrup, Brouns,
59 Wagenmakers, & Saris, 1997). Mechanisms by which CHO feedings are proposed to
60 improve endurance performance include maintaining blood glucose levels and
61 increased carbohydrate oxidation, the sparing of endogenous glycogen or a central
62 effect (Jeukendrup, 2004). Yet these findings are not necessarily applicable to
63 recreational exercise, and less is known regarding the effects of carbohydrate
64 feedings and exercise in moderately trained individuals. In addition, whilst the
65 evidence base pertaining to the performance, physiological and biochemical effects
66 of CHO ingestion is well established, less is known about the psychological effects.

67 To date, the dominant focus has been on assessing the impact of CHO
68 supplementation and availability on 'what' a person feels, as measured by the Rating
69 of Perceived Exertion (RPE) scale (Burgess, Robertson, Davis, & Norris, 1991;
70 Coggan & Coyle, 1987; Ivy, Costill, Fink, & Lower, 1979; Kang et al., 1996; Utter et
71 al., 1999). Findings demonstrate that increases in circulating blood glucose levels
72 and rates of CHO oxidation attenuate RPE. However, many of these studies have
73 focused only on localised resistance exercise or prolonged cycling protocols using a
74 male population.

75 Whilst there is a strong theoretical basis for the recommendation of CHO ingestion
76 based on its performance benefits as well as attenuations in perceived exertion,
77 there has been much less attention afforded to the potential benefits to constructs
78 such as affect ('how' a person feels). This is somewhat surprising given that whether
79 one feels good or bad during exercise has been linked to an individual's task
80 persistence (Acevedo & Gill, 1996). Of those studies assessing the impact of CHO
81 on cognition and affect, many have focused on the impact of chronic dietary intakes
82 (Achten et al., 2004; Brinkworth, Buckley, Noakes, Clifton, & Wilson, 2009; D'Anci,
83 Watts, Kanarek, & Taylor, 2009; Halyburton et al., 2007), rather than the acute
84 effects accompanying a supplemented exercise bout. Whilst some findings indicate a
85 positive relationship between CHO intake and cognitive behaviour, other studies
86 have found no effects of a CHO rich meal (Christensen & Redig, 1993) or a sucrose-
87 containing beverage on affective states (Reid & Hammersley, 1995) at rest.

88 Recently, O'Neal and colleagues (2013) reported that CHO ingestion consumed by
89 recreational exercisers during 60 min of moderate intensity intermittent cycling did
90 not alter mood or perceived exertion. As with other studies in the field, specific mood
91 states were only assessed before and after exercise using the Profile of Mood States
92 (POMS; (McNair, Lorr, & Droppleman, 1981)). However, in the context of exercise,
93 the POMS has been criticised for its inability to detect acute changes during exercise
94 and its bias towards negative mood state assessment (Backhouse, Ekkekakis, Bidle,
95 Foskett, & Williams, 2007). Thus, Backhouse and colleagues (2007) have called for
96 a shift from an assessment of categorical states before and after exercise to a more
97 encompassing representation of the subjective experience during exercise (Hardy &
98 Rejeski, 1989; Svebak & Murgatroyd, 1985). Using the Feeling Scale (Hardy &
99 Rejeski, 1989) as a dimensional measure of pleasure-displeasure, research has
100 shown that well-trained athletes (Backhouse, Bishop, Biddle, & Williams, 2005) and
101 physically active males (Peacock, Thompson, & Stokes, 2012) 'feel better' as early
102 as 15 min into exercise when they ingest a CHO drink compared to a placebo or ad-
103 libitum water. Moreover, enhanced feelings of pleasure have been noted in the first 5
104 min of a 30 min self-paced run when CHO has been mouth rinsed (Rollo, Williams,
105 Gant, & Nute, 2008).

106 The brain is wholly dependent on circulating blood glucose for fuel and relies on
107 readily digestible forms of carbohydrates within the diet. As such, blood glucose
108 levels are maintained in the range of 3.5 to 5.5 mmol/l. It has been suggested that
109 hypoglycaemia (blood glucose level less than 3.3 mmol/l) can negatively influence
110 indicators of mood including irritability, mental alertness, anxiety and fatigue (Benton,
111 2002). With this in mind, the question arises as to whether acute CHO feedings can
112 play a role in mediating our affective responses. In normal healthy individuals, a true
113 hypoglycaemic response is uncommon. However, a rise and fall in blood glucose
114 levels has been associated with reductions in mood (Benton, 2002). Benton (2002)
115 also noted that males who ingested breakfasts providing a more sustained level of
116 glucose reported better mood and less irritability than those whose blood glucose
117 levels fell more rapidly following a glucose tolerance test (Benton, Kumari, & Brain,
118 1982). Examining the nature of the CHO consumed, in particular whether glucose is
119 slowly or rapidly released into the blood stream compared to other types of CHO, is
120 warranted.

121 The vast majority of research regarding CHO used in sports drinks has focused on
122 the monosaccharide's glucose and fructose, the disaccharide sucrose and the
123 synthetic polymer maltodextrins (glucose polymers) (Coombes & Hamilton, 2000).

124 Sports drinks based on a galactose formulation (GI~20) state that this third primary
125 sugar absorbs into the blood stream quickly and does not stimulate the release of
126 insulin, meaning much like low GI foods, it gives steadier blood sugar levels over
127 time (Gannon, Khan, & Nuttall, 2001). The benefits of using GAL in a sports drink is
128 that it provides CHO at an adequate rate, with a corresponding small insulin
129 response which results in prolonged CHO availability to the muscle as well as a
130 reduced rebound hypoglycaemia (as observed with glucose intake). For the
131 recreational exerciser, the potential to suffer from hypoglycaemia is limited and this
132 lessens the risk of declining affective states owing to rebounding glucose levels
133 (Gold, MacLeod, Frier, & Deary, 1995). Consequently, it is of interest to examine how
134 the type of CHO may impact 'how' one feels during exercise.

135 Given the infancy of this line of research, the suggestion of a mechanistic link
136 between affective states and blood glucose is, at present, only speculative. As
137 suggested by Backhouse and colleagues (2007) it would be of interest to consider
138 the influence of CHO type and dose, as to date only glucose solutions have been
139 considered. Moreover, examining an ecologically valid exercise protocol which is
140 commonly employed by recreationally active females (i.e., a 60 min moderate
141 intensity run on a motorised treadmill) is warranted. Therefore, the aim of the present
142 study was to investigate the effects of consuming a GAL CHO drink versus a GLU
143 CHO drink or PLA drink before and during exercise on affect and perceived exertion.

144 **Material and methods**

145 *Participants*

146 Nine healthy, recreationally active females (mean \pm SD: age 21.8 \pm 3.4 years, height
147 170.0 \pm 0.6 cm, weight 63.3 \pm 7.6 kg and VO_2max 50.7 \pm 7.0 ml/kg/min) were recruited to
148 participate in this study. None of the participants were pregnant or lactating or
149 reported any medical conditions, and had normal resting haemoglobin levels (11.5-
150 16.5 g/dl). All trials were carried out during the follicular phase (days 1-14) of the
151 menstrual cycle. A criterion for inclusion in the study was that participants exercised
152 regularly, scored at least 2 on the International Physical Activity Questionnaire (IPAQ
153 (Craig et al., 2003)) and were able to run for one hour continuously at about 65%
154 VO_2max . Leeds Metropolitan University Faculty Ethics Committee approved the
155 protocol and all participants gave their written informed consent.

156 *Preliminary measurements*

157 Following familiarisation with treadmill running and experimental procedures,
158 participants undertook two preliminary tests in order to determine: 1) the relationship
159 between running speed and oxygen uptake using a 16 min incremental test and 2)
160 their VO_2max using an uphill incremental treadmill test to exhaustion. All preliminary
161 tests were conducted according to procedures previously described (Williams et al.,
162 1990). Based on the results of the two preliminary tests, the running speed
163 equivalent to 65% of each participant's VO_2max was determined.

164 *Experimental Protocol*

165 For 48 hours before the first trial, participants recorded their diet and exercise routine
166 so that it could be repeated before the following trials to minimise differences in
167 pretesting intramuscular substrate concentrations between experimental trials.

168 All participants completed three experimental trials in a randomised crossover design
169 separated by at least 5 days. In two of the trials, participants consumed
170 carbohydrate (CHO) containing beverages providing 45 g of CHO (~0.75 g/min)
171 before and during the trial. Differing in CHO composition, one of these drinks
172 contained glucose (D-Glucose monohydrate, Thornton and Ross, Huddersfield, UK)
173 and the other galactose (D-galactose, Hollandche, Melk & Suiker, Fabrique, The

174 Netherlands). For the remaining trial, the drink consumed was an artificially
175 sweetened placebo. Each drink was identical in flavour and appearance and the
176 participants were unaware of the content of the drinks in each trial.

177 For each main trial, participants were provided with their breakfast to consume at
178 home on the morning of the experiment (at 0800 hours) after an overnight (12 hour)
179 fast. This meal was equivalent to 10% of the individual's daily energy requirement
180 and the proportion of energy from protein, fat and carbohydrate was 14, 14 and 72%
181 respectively. Following this, participants were asked to refrain from eating or drinking
182 (apart from water) until they arrived at the laboratory at 1000 hours. On arrival at the
183 laboratory, participants were asked to void before anthropometric variables and blood
184 pressure was collected and subjective scales were completed.

185 After resting quietly for at least 10 minutes, a resting blood sample was collected
186 from an antecubital vein by cannulation. Immediately following this, participants
187 consumed 300ml of the prescribed drink (either glucose: GLU, galactose: GAL or
188 placebo: PLA) within 5 minutes. Participants then completed a 5-minute warm up at
189 60% VO_2 max on a motorized treadmill (Model ELG 70, Woodway, Weillam Rhein,
190 Germany) after which the speed was increased to that which represented 65% of
191 their VO_2 max for 60 minutes. Heart rate was monitored continuously by a radio
192 telemetry monitor (Polar vantage NV, Kemple, Finland). Samples of expired air were
193 collected continuously using an online automated gas analysis system (Meta-Max
194 3B, Cortex, Leipzig, Germany), and samples were averaged for 5 minute periods at
195 10-15, 25-30, 40-45 and 55-60 minutes during exercise for the determination of VO_2
196 and VCO_2 . Blood samples were collected and subjective scales were recorded at 15
197 minute intervals. After these, participants ingested 150ml of the prescribed drink.

198 At the end of the exercise period, participants removed surface sweat and were
199 weighed in minimal clothing. Participants were then asked to rest in the laboratory
200 lounge for a further 90 minutes and blood and expired air samples were collected at
201 regular intervals. Subjective scales were recorded immediately following blood
202 samples. Participants were instructed not to eat or drink anything other than water
203 throughout this period, which was available *ad-libitum* throughout the first trial, and
204 matched for volume during the following trials.

205 All trials were performed at the same time of day and under similar experimental
206 conditions. The same motorised treadmill was used throughout the study. In order
207 to enable continuous monitoring of expired air, participants were required to wear a

208 mask throughout the exercise trials. During the rest period, participants wore a mask
209 for a 5 minute period before each 5 minute collection sample. Ambient temperature
210 and relative humidity were recorded each morning during the trials. Temperature
211 was maintained between 17°C and 21°C, and humidity was between 42% and 56%.

212 *Subjective scales: measures of affect and perceived exertion*

213 The Rating of Perceived Exertion scale (G. A. Borg, 1982a) was used to assess
214 perceived exertion during exercise, with values recorded every 15 minutes. The 15-
215 point scale ranging from 6-20 with anchors at “very, very light” to “very, very hard”
216 has been found to be a valid and reliable measure of perceived exertion during
217 exercise (G. Borg, 1982b). The Feeling Scale (FS: (Hardy & Rejeski, 1989)) was
218 used as a measure of the affective dimension of pleasure-displeasure. It is an 11-
219 single-item bipolar measure of pleasure-displeasure and was developed especially
220 for use in an exercise setting. The scale ranged from -5 to +5 with anchors provided
221 at the 0 point (“neutral”) and at odd numbered integers, ranging from “very bad” (-5)
222 to “very good” (+5). Participants were asked to rate how they felt at that particular
223 moment. The Felt Arousal Scale (FAS: (Svebak & Murgatroyd, 1985)) is a six-point,
224 single-item measure of perceived activation/arousal and has been used extensively
225 in the context of reversal theory research, including exercise related studies (Hall,
226 Ekkekakis, & Petruzzello, 2002; Kerr & Vlaswinkel, 1993). The scale ranges from 1
227 to 6 with anchors at 1 (“low arousal”) and 6 (“high arousal”). Again, participants were
228 asked to rate how they felt at that particular moment. The FS and FAS have an
229 advantage over most other self-report scales of being easily administered during
230 exercise. During collection periods, the RPE scale was presented first, followed by
231 the FS and then the FAS. RPE was only assessed during the exercise period.

232

233 *Analytical methods*

234 Blood samples were collected into separate EDTA-coated tubes for the assessment
235 of plasma samples, or tubes without anticoagulant for the assessment of serum.
236 Plasma samples were stored on ice until the end of the rest period and analysed
237 within three hours of sampling, and serum samples were left for at least 30 minutes
238 to clot. Whole blood was spun at 3000rpm at 10°C for 10 minutes and plasma/serum
239 was aliquoted into tubes as required for analysis. Aliquots were frozen at -80°C until
240 further analysis. Plasma samples were analysed enzymatically for glucose on a
241 semiautomatic analyser (ILab 2300 stat plus analyser, Instrumentation Laboratories,

242 Warrington, UK). Serum insulin concentrations were transported to the Department
243 of Chemical Pathology at Leeds General Infirmary and analysed by an ADVIA
244 sandwich immunoassay using chemiluminescent technology (Siemens ADIVA
245 Centaur, IL, USA).

246 *Statistical analysis*

247 The PASW software version 17 statistical package was used for all data analysis
248 (IBM SPSS Statistics, Chicago, IL, USA). Descriptive statistics including mean, and
249 the standard errors of the mean (\pm SEM) were calculated for all outcome variables
250 and are reported within the text, tables and figures. Area under the curve (AUC) was
251 calculated using the trapezoid method glucose, insulin and total CHO and fat
252 oxidation between trials. Prior to analysis, data were checked for acceptable values
253 of normality (Kolmogorov-Smirnov test) and homogeneity of variance (Levene's test);
254 the alpha was set to 0.05 for all statistical analysis.

255 Paired samples t-tests were used to check for differences in baseline values for all
256 variables. A repeated measures analysis of variance (ANOVA) was used to
257 determine if there were significant differences between the three treatment conditions
258 (GLU, GAL and PLA) for physiological, metabolic and subjective responses. If
259 significance was found, post hoc analyses were done using a Bonferroni's step-wise
260 test. Separate ANOVA were conducted on the pre- to during-exercise time points
261 (pre, 15, 30, 45, 60 min) and from pre-exercise to rest time points (pre, 15R, 30R,
262 60R, 90R min). This approach allowed for direct comparisons to baseline values.
263 Statistical significance was set at $p < 0.05$

264

265 **Results**

266 *Hydration status and physiological responses to the exercise protocol*

267 Oxygen uptake, heart rate and VO_2max did not differ between the trials
268 demonstrating that the participants were exercising at the same relative intensity
269 during all treatments ($68.8\pm 1.2\%$, $67.4\pm 1.3\%$ and $66.1\pm 0.9\%$ in the GLU, GAL and
270 PLA trials respectively). Heart rate during exercise ranged from 154 to 165
271 beats/min.

272 Body masses before the start of exercise, body mass losses and fluid intakes during
273 the rest period were no different between the three experimental trials (63.3 ± 7.6 kg,
274 and 0.7 ± 0.1 and 366.3 ± 104.9 mls respectively).

275

276 *Blood parameters*

277 There was a significant main trial effect for plasma glucose concentrations ($F(2,$
278 $12)=7.417$, $P=0.022$) which were higher in the GLU trial compared to the GAL
279 ($P=0.032$) and PLA ($P=0.027$) trials (Figure 1A). Values for the GLU trials were
280 significantly greater than both GAL and PLA trials at 30, 60, 15R and 30R min
281 timepoints ($P<0.05$). The incremental area under the curve (IAUC) for plasma
282 glucose was significantly greater throughout the GLU trial (341 ± 29 mmol//hour)
283 compared to the GAL (315 ± 18 mmol//hour) and the PLA trials (304 ± 20 mmol//hour)
284 ($P<0.05$), thus confirming the main trial effect.

285 There was a main trial effect for serum insulin concentrations to be higher throughout
286 the GLU trial ($F(2, 16)=21.045$, $P=0.000$) when compared to GAL ($P=0.030$) and PLA
287 ($P=0.000$) trials (Figure 1B). In addition concentrations were significantly higher
288 throughout the GAL trial compared to the PLA trial ($P=0.013$). The IAUC for serum
289 insulin throughout the trial was greater in the GLU trial (692.9 ± 50.2 mU/L/hour)
290 compared to the GAL (543.2 ± 67.1 mU/L/hour) and PLA (314.0 ± 29.1 mU/L/hour) trials
291 ($P<0.05$) again confirming the main trial effect.

292 After ingestion of the drinks and commencement of exercise, blood lactate
293 concentrations increased in all three trials and peaked at 15 min during exercise.
294 Throughout the exercise and rest period, there were no significant differences
295 between trials and concentrations remained between 0.76 and 1.91 mmol/l. At the

296 end of the rest period, blood lactate had returned to baseline levels or below for all
297 trials (Figure 1C).

298 After consumption of the drinks, serum FFA concentrations increased throughout the
299 exercise period in all three trials (Figure 1D). After 15 minutes of the resting period,
300 values in all conditions decreased but remained elevated above resting values.
301 There was a main trial effect for serum FFA concentrations ($P<0.0001$), such that
302 concentrations in the PLA trial were significantly greater than GLU and GAL trials at
303 several time points ($P<0.05$).

304

305 *Perceived activation (FAS) and pleasure-displeasure (FS)*

306 Compared with baseline, perceived activation was elevated throughout exercise in all
307 three trials ($P<0.05$). This increase in activation appeared more pronounced in the
308 CHO trials but a significant treatment effect was not noted. (Figure 2A). Upon the
309 cessation of exercise, perceived activation rebounded below baseline levels.

310 Feelings of pleasure were maintained throughout exercise and participants reported
311 a positive affective state. However, no significant differences were noted in pleasure
312 ratings between trials and no time effect was observed (Figure 2B).

313

314 *Rating of perceived exertion (RPE)*

315 RPE increased throughout the exercise period ($F(3, 24)=4.293$, $P=0.046$) across all
316 conditions, from average values of 10.4 ± 0.07 at 15 min to 11.2 ± 0.06 at 60 min
317 (Figure 2C). There were no significant differences between trials overall or at any
318 time point assessed.

319 Discussion

320 The aim of the present study was to examine the effects of ingesting a GAL CHO
321 drink, versus a GLU CHO drink or PLA drink on affective responses and perceived
322 exertion during a 60 min bout of moderate intensity exercise. Findings of the study
323 highlighted that feelings of pleasure and perceived activation were maintained and
324 even enhanced during exercise in all trials. This positive affective profile was elicited
325 irrespective of the beverage ingested. These results indicate that the participants
326 found the exercise stimulus to be pleasurable and felt comfortable with the intensity
327 and duration. This is reinforced by ratings of perceived exertion which averaged out
328 at 'fairly light' towards the end of the exercise period. Supporting the subjective
329 findings was the observation that there were no incidences of hypoglycaemia in any
330 of the trials throughout the exercise or rest periods, indicating that euglycaemia
331 would have been maintained without exogenous carbohydrate ingestion. Despite
332 this, ingestion of the GAL drink resulted in a more constant blood glucose level when
333 compared to the GLU drink, a finding which has previously been associated with
334 better mood states (Benton, 2002).

335 It has been proposed that deterioration in psychological indices is related to low
336 levels of blood glucose and elevated brain serotonin (Cox, Gonder-Frederick,
337 Schroeder, Cryer, & Clarke, 1993; Sommerfield, Deary, & Frier, 2004; Utter et al.,
338 1999). Whereas maintenance of higher blood glucose and lower free fatty acid
339 concentrations (and corresponding reductions in free tryptophan) through CHO
340 feedings have been purported to be the mechanisms behind an enhanced activation
341 and central nervous system (CNS) functioning (Backhouse, Ali, et al., 2007;
342 Lieberman, Falco, & Slade, 2002; Welsh, Davis, Burke, & Williams, 2002). Despite
343 this, a rise and fall in blood glucose levels, associated with high glycemic feedings,
344 has been associated with reductions in mood (Benton, 2002). Supporting previous
345 research by Stannard et al. (2009), the present study showed significantly higher
346 blood glucose levels in the GLU, compared to the GAL and PLA trials, throughout the
347 majority of exercise and the first 30 minutes during the rest period. This was followed
348 by a marked reduction in glucose levels towards the end of the 90 minute rest period,
349 whereas after the consumption of galactose, circulating blood glucose levels were
350 more stable. In the study by Stannard et al. (2009), greater FFA levels were reported
351 in the galactose trial after 20 minutes of exercise, a finding not corroborated by the
352 present study. These differences are likely to be due to the participants having
353 arrived in a fasted state in the aforementioned study and thus the slower metabolic
354 processing of galactose, which has been shown to increase plasma FFA levels. This

355 is further supported by studies in which there were no differences in plasma FFA
356 levels between low and high glycemic trials, when participants were fed (Stevenson,
357 Astbury, Simpson, Taylor, & Macdonald, 2009) and improved metabolic profiles when
358 exercising at a moderate intensity in a fed compared to fasted state (Paoli et al.,
359 2011).

360

361 Within the present study, significant increases in blood glucose in the GLU trial
362 compared to the GAL and PLA trials, resulted in no differences in FS or FAS scores.
363 These findings confirm those of O'Neal et al. (2013) who noted that CHO ingestion
364 consumed during a 60 minute moderate exercise session, in a fed state, did not alter
365 post-exercise mood or perceived exertion in recreational exercisers. No metabolic
366 parameters were assessed in the study by O'Neal et al. (2013) so distinct
367 comparisons are difficult to make, yet in the present study it appears that the
368 continuous intake of the drinks and the moderate intensity of the exercise protocol
369 seems to have resulted in a reduction in glucose requirements as the main fuel
370 substrate. O'Hara et al. (2012) corroborates this conclusion as they reported a
371 progressive increase in exogenous carbohydrate oxidation and sparing of liver
372 glycogen stores after pre-exercise consumption of a GAL solution (compared to a
373 GLU solution). However, these differences were only evident after 60 minutes of
374 exercise, which indicates that any potential benefits in performance would only be
375 evident for longer endurance activities. In addition, previous studies report
376 differences in affect in the latter stages of exercise, specifically after 45 min (Welsh et
377 al., 2002) and 60 min (Backhouse, Ali, et al., 2007) of high-intensity intermittent
378 exercise and 10 hours of sustained aerobic activity (Lieberman et al., 2002).
379 Changes in substrate oxidation and mood state therefore are only likely to occur
380 when endogenous glycogen stores are reduced (Bosch, Weltan, Dennis, & Noakes,
381 1996; Leijssen, Saris, Jeukendrup, & Wagenmakers, 1995). Thus, positive affective
382 changes following the consumption of CHO beverages may only be noted in exercise
383 bouts that extend beyond 60 min, and that ask participants to commence the
384 exercise protocol in a fasted state as they place a greater reliance on exogenous
385 carbohydrate as the main substrate. However, the present study employed an
386 ecologically valid protocol which looked to replicate recommended habitual
387 submaximal fixed-duration exercise in females (Kim, Ko, Lee, Lim, & Bang, 2012)
388 and current UK recommendations. Indeed, mood has been shown to improve with
389 moderate-intensity (50–70% VO_{2max}) exercise (Yeung, 1996) and walking-based
390 exercise, and at durations of 10–15 min (Ekkekakis, Hall, VanLanduyt, & Petruzzello,
391 2000). Such an intensity and duration (65% VO_{2max} for 60 minutes) has also been

392 used in previous studies to assess differences in pre-exercise feedings in healthy
393 women (Stevenson et al., 2009; Stevenson, Williams, Nute, Humphrey, & Witard,
394 2007). In addition, participants consumed breakfast prior to the trial, likely to have
395 offset the reliance on exogenous carbohydrate, yet this is common practise among
396 recreational active individuals and has been associated with better mood (Benton,
397 Slater, & Donohoe, 2001).

398

399

400 Enhanced feelings of pleasure have previously been reported in males performing
401 gymnasium-based exercise following ad-libitum ingestion of a low energy 2% CHO
402 solution in a euhydrated state (Peacock et al., 2012) and a dehydrated state
403 (Peacock, Thompson, & Stokes, 2013). In these studies, the positive affective profile
404 may be explained by the stimulation of a greater voluntary fluid intake (i.e., 45%
405 increase; (Peacock et al., 2012)) and more adequate hydration during exercise than
406 an increased delivery of CHO. Indeed, for the recreational exerciser, there is
407 evidence of a greater relative need to supply water over fuel during exercise
408 (Peacock, Stokes, & Thompson, 2011). As such, the findings of the present study
409 suggest that the exercise stimulus was positively perceived by the participants
410 because fluid balance was maintained across all trials and the endogenous supply of
411 CHO energy stores to exercising muscles was not significantly impacted as a result
412 of the exercise task. Based on the findings of this study, CHO supplementation
413 during moderate exercise intensity for 60 min or less appears unjustified and does
414 not elicit a 'feel good' effect.

415

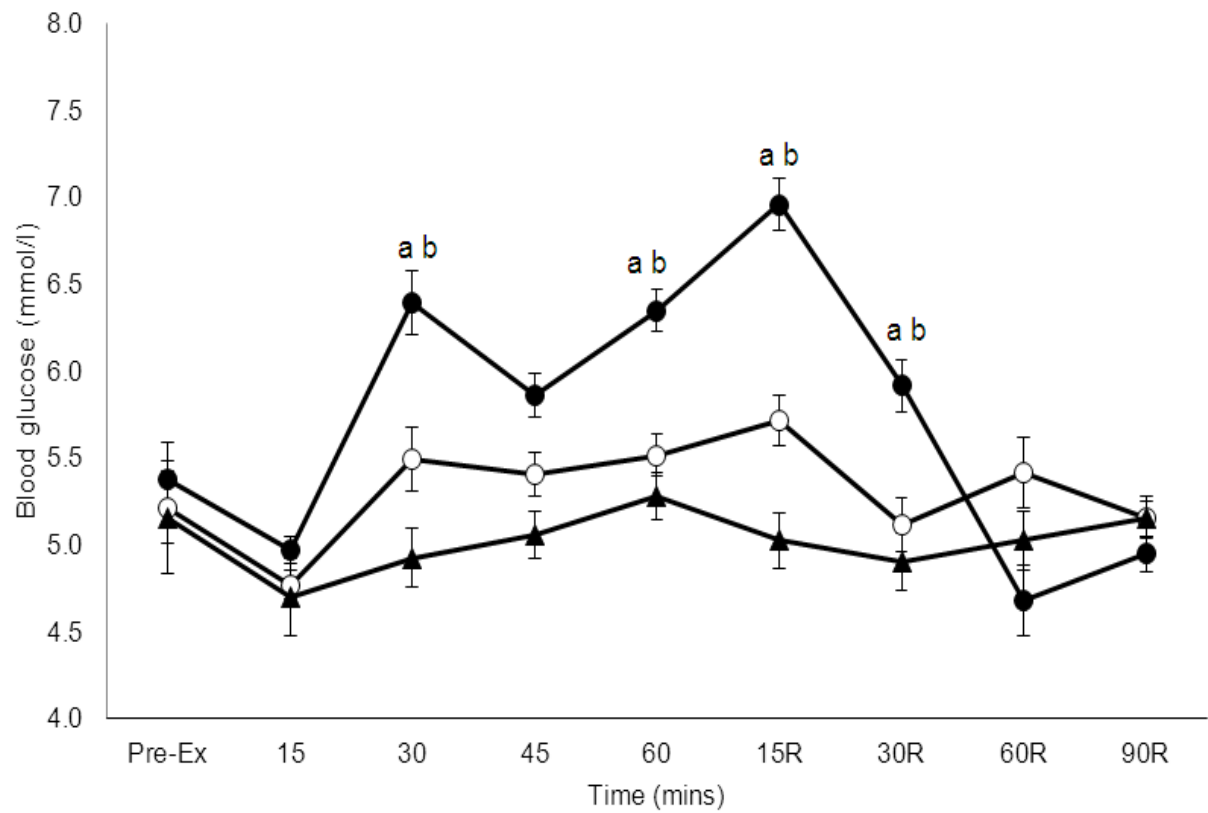
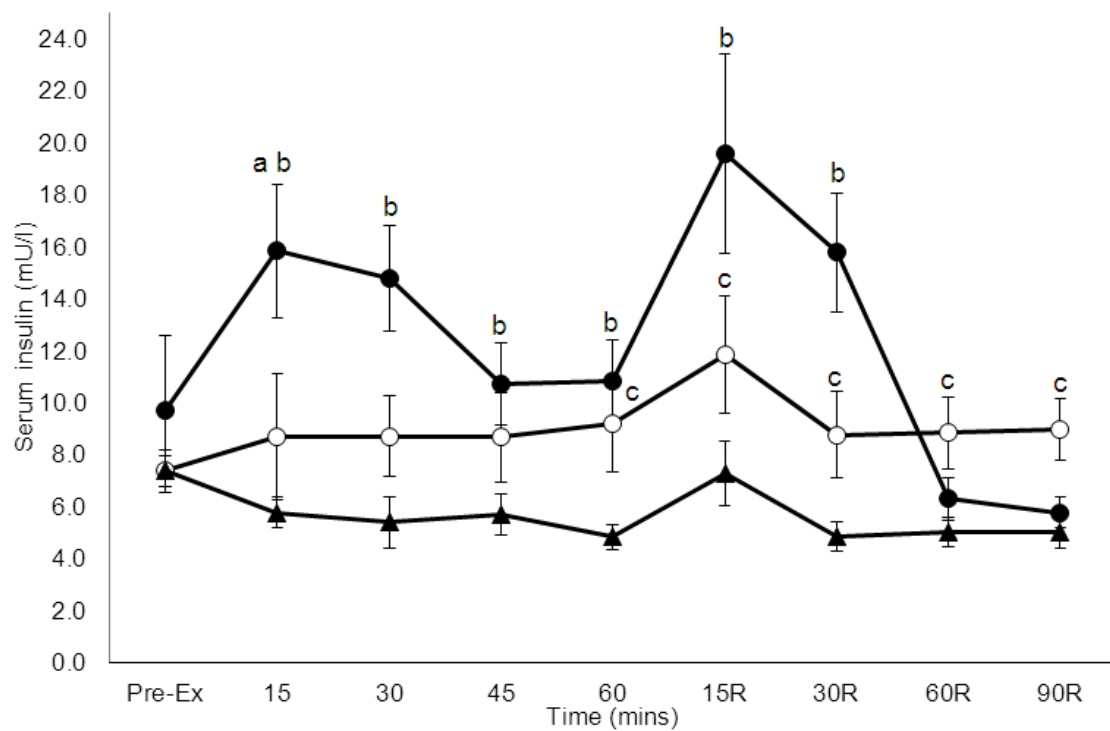
416 As expected, perceptions of exertion increased as the exercise bout continued,
417 attributed to the physiological stress placed on the participant. Despite this, the
418 increases in RPE reported were minimal ranging from 10.4 at to 11.2 ('fairly light')
419 compared to values of between ~15 and ~17 after 120 minutes (Backhouse et al.,
420 2005) and 150 minutes (Utter et al., 1999) of intense exercise. This is supported by
421 relatively stable levels of blood lactate in all trials throughout the exercise period with
422 the highest level of 1.9 mmol/l reported. Furthermore, no differences existed in the
423 central sensory variable of heart rate between trials, which has previously been
424 linked to mediating the perception of effort (Mihevic, 1981). As highlighted
425 previously, the relationship between CHO ingestion and fatigue during prolonged
426 exercise has been well documented (Burgess et al., 1991; Kang et al., 1996; Utter et
427 al., 1999; Welsh et al., 2002), with findings indicating that perceived exertion is
428 attenuated during the latter stages of exercise with CHO ingestion. It has been

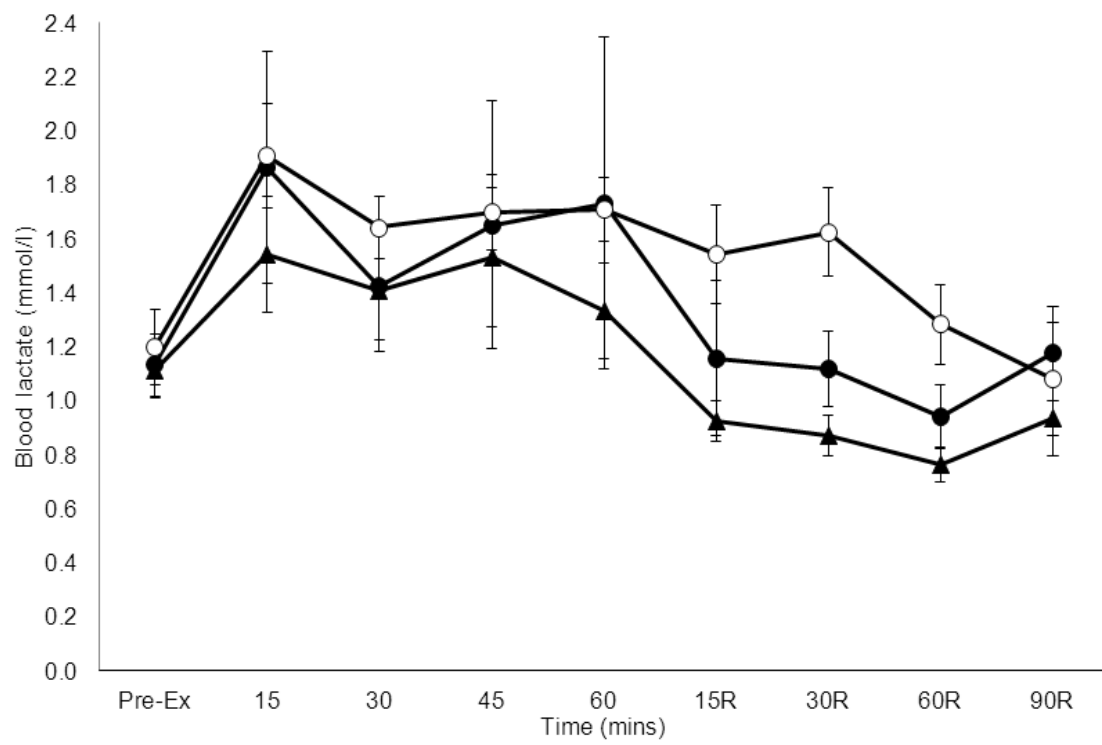
429 proposed that a reduction in CHO availability and associated intensified perceptions
430 of fatigue may be explained by alterations in skeletal muscle contractile properties
431 and neurological function (Utter et al., 1999), such that reductions in blood glucose
432 and muscle glycogen can lead to localised muscle fatigue. Thus, the sustained low
433 levels of subjective perceptions of effort within the present study provide further
434 evidence that the endogenous supply of carbohydrate energy stores to exercising
435 muscles was not significantly impacted as a result of the exercise duration and
436 intensity. Despite this, previous studies have reported similar levels of RPE (10-11)
437 at the lactate threshold (Hetzler et al., 1991; Steed, Gaesser, & Weltman, 1994),
438 defined as the transition from an intensity that can be maintained through aerobic
439 metabolism to an intensity that requires supplementation by anaerobic means, and
440 thus of a defined 'moderate' intensity (Ekkekakis, Hall, & Petruzzello, 2004). As
441 outlined by Marcus et al. (2000), both men and women are more likely to adopt and
442 maintain such moderate intensity activity, therefore further studies examining such
443 ecologically valid protocols are warranted. There were no differences in RPE
444 between trials in agreement with a previous study by Jentjens and Jeukendrup
445 (2003) who found no differences in overall body RPE between glucose, galactose
446 and trehalose solutions. Such findings are encouraging given that blood glucose
447 levels were significantly lower in the GAL trial compared to the GLU trial during
448 exercise, indicating no increases in the perception of effort despite a more sustained
449 carbohydrate delivery.

450

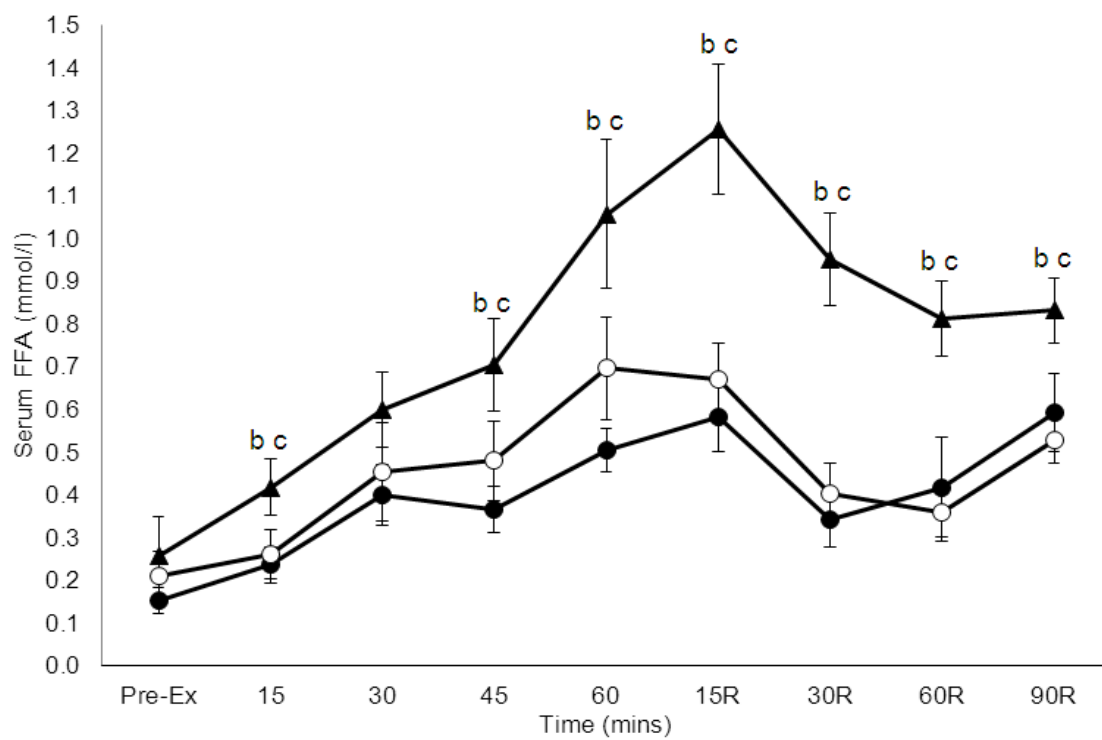
451 In conclusion, this is the first study to examine the effects of different types of CHO
452 ingestion, not only on measures of RPE but also the dimensions of pleasure-
453 displeasure and perceived activation during moderate intensity exercise. Our results
454 suggest that exercise of a moderate intensity does not negatively impact feelings of
455 pleasure and has a positive impact on activation in recreationally active females.
456 Although the consumption of GAL CHO beverage elicited a more favourable
457 metabolic profile in the exercising females, it did not enhance their affective profile.
458 For physically active adults who exercise for health and fitness or for those
459 concerned with achieving weight loss, ingestion of a high-energy sports drink
460 appears unjustified (Peacock et al., 2013) and findings from the present study would
461 discourage CHO supplementation on the basis that a 'feel good' effect was not
462 elicited following ingestion. Instead, the importance of maintaining fluid balance
463 during exercise is reinforced. Future research should continue to explore these
464 constructs and the interventions that may positively impact affective states, given that
465 recent studies carried out in UK populations suggest low physical activity

466 participation levels, whereby only 28% of women achieved the minimum
467 requirements (Information Centre, 2006).

FIGURE 1**A****B**

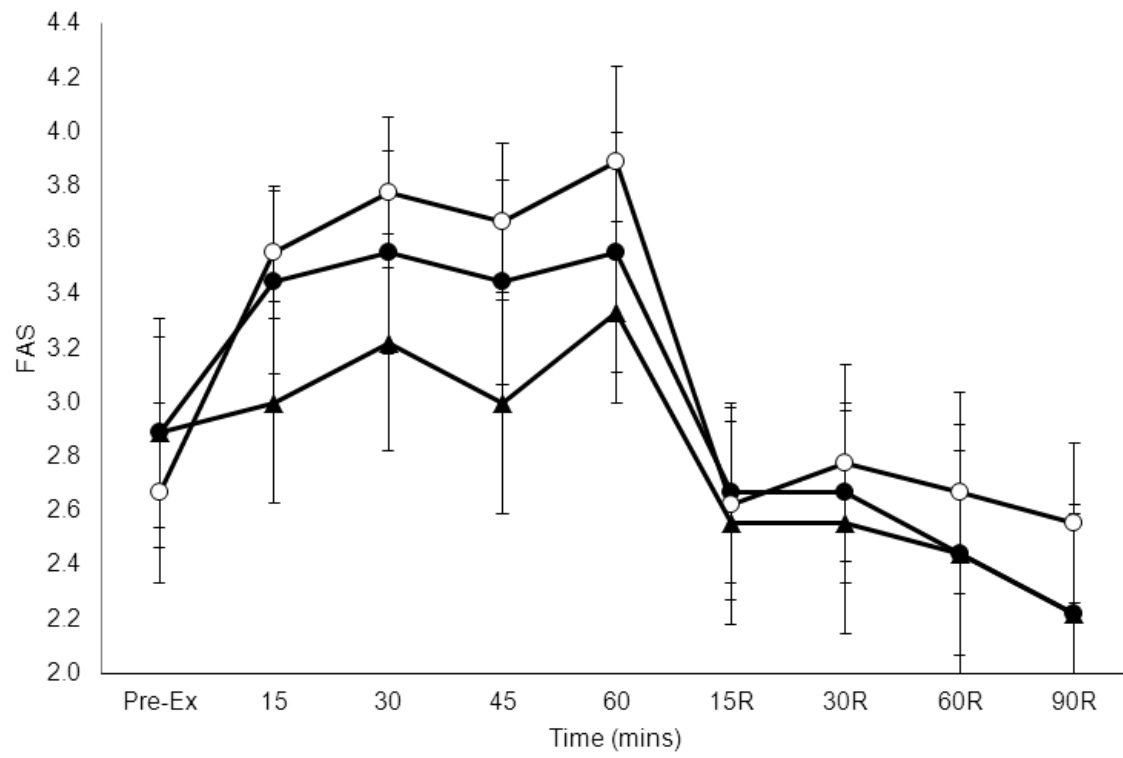


C

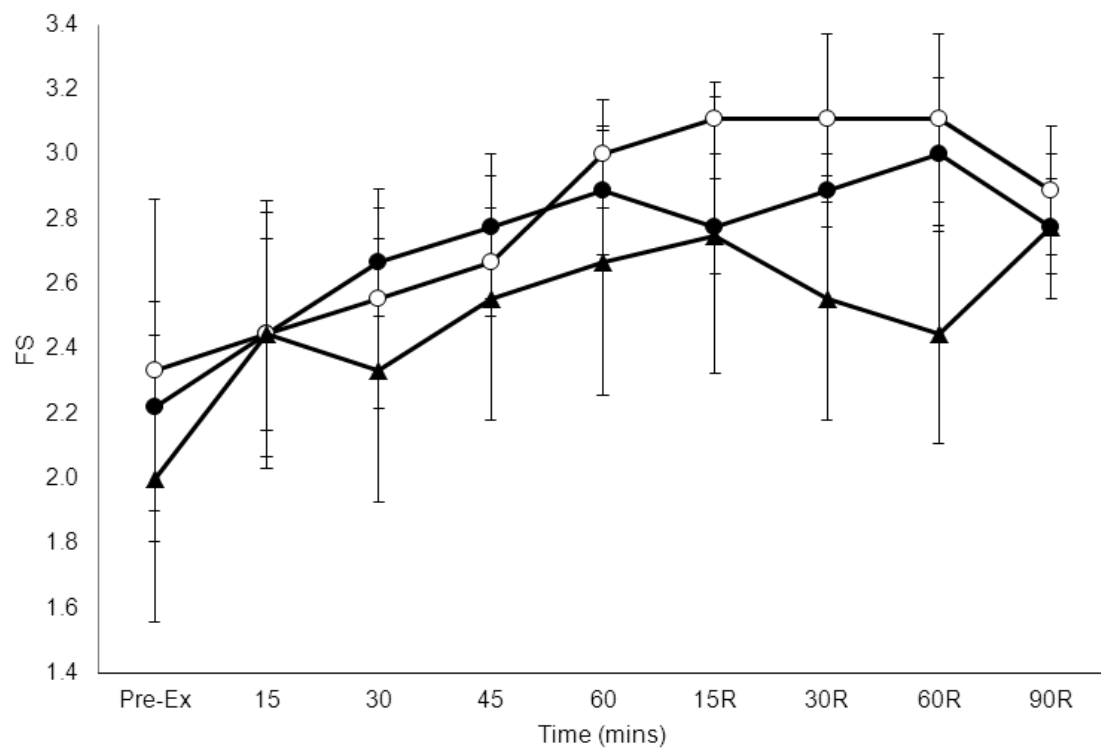


D

FIGURE 2



A



B

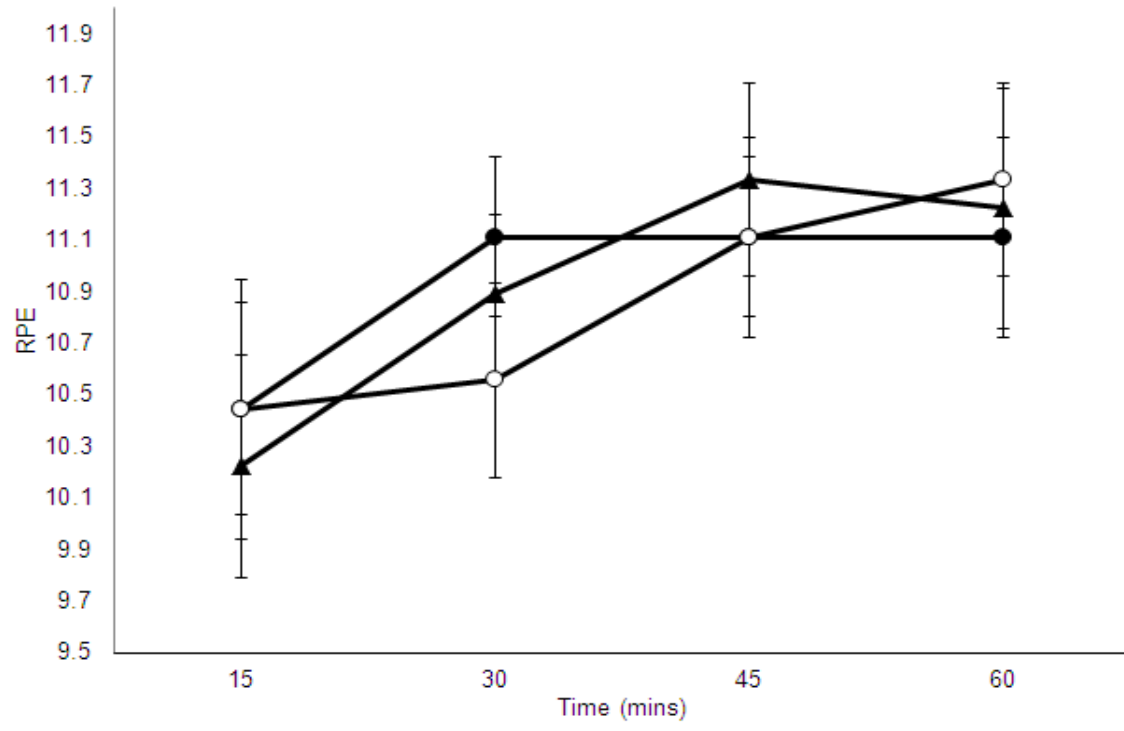
**C**

Figure captions

FIGURE 1 Effects of GLU, GAL and PLA trials on concentrations of blood glucose (A), serum insulin (B), blood lactate (C) and serum FFA (D) during exercise and rest (R). Values are means \pm SEM.

^asignificant difference between GLU and GAL trials ($P<0.05$). ^bsignificant difference between GLU and PLA trials ($P<0.05$). ^csignificant difference between GAL and PLA trials ($P<0.05$).

FIGURE 2 Effects of GLU, GAL and PLA trials on perceived activation (FAS) (A), pleasure-displeasure (FS) (B) and perceived exertion (RPE) (C). Values are means \pm SEM.

Figure legends

- Glucose
- Galactose
- ▲— Placebo

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