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THE EFFECT OF VARYING FORMS OF CARBOHYDRATE ON SUBSEQUENT CYCLING PERFORMANCE TO EXHAUSTION IN AN ACTIVE FEMALE POPULATION

Table of contents

CHAPTER FIVE

Tables

Table 1: The mean (+SD) values for performance variables within liquid and solid trials.

p. 21

Figures

Acknowlegdements

I would like to say a huge thank you to all my participants, to whom without them this dissertation would not have been possible. To my mum and boyfriend for all the support they have given me through my dissertation and the help I received from my dissertation tutor and the laboratory technicians.

Abstract

This study aimed to investigate the effects of varying forms of carbohydrate on subsequent cycling performance to exhaustion in an active female population. 7 subjects aged 20-21 years, recruited due to their availability, with a maximal oxygen consumption (VO_2 max) 2.62 (+ 0.54) l-min^{-1} took part in this experimental design. Subjects were required to cycle at 55% Wpeak for 25-min, with an increase in intensity to 75% Wpeak until volitional exhaustion on two occasions separated by one week. Each trial was entered following an overnight fast with subjects consuming 2 g per kg of body mass of a liquid carbohydrate (lucozade) 15-min prior to the onset of exercise and solid carbohydrate (pasta) 1.5-hr prior. Results indicated no significant difference in time to exhaustion ($p<0.102$) despite a 406.4-s mean increased time following the ingestion of liquid carbohydrate. Heart rate (HR) was significantly higher within the liquid trial ($p<0.05$). Localised rating of perceived exertion (RPEl) was significantly higher than central RPE (RPEc), with RPEl higher at 75% Wpeak than 55% Wpeak phase ($p<0.05$). VO_2 and VCO_2 (l-min^{-1}) values were similar within both trials. In conclusion varying forms of carbohydrate had no effect on subsequent cycling performance with regards to time to exhaustion. Therefore, the form of carbohydrate (solid vs. liquid) requires further investigation to examine which form is best for performance within an active female population.

CHAPTER I

INTRODUCTION

Chapter I

Introduction

Many physically active individuals devote time, energy and effort striving to optimise their performance, whether it is for endurance based exercise, short high intensity exercise or for personal achievement goals. However, knowledge of the optimum nutrition to provide the foundation for the best physical performance needs to be implemented to reduce sometimes inadequate nutritional practices. Proper nutrition will provide fuel for biologic work as well as chemicals for extracting and using potential energy within fuels (McArdle *et al*., 2007, p.3).

The diet of physically active individuals is said to contain at least 55-60% of calories in the form of carbohydrate (McArdle *et al*., 2001, p.84). Additionally McArdle *et al*. (2001, p.102) states that it is necessary for a pre-competition meal to contain foods (solid or liquid form) high in carbohydrates due to its ability to be readily digested to contribute to the energy (and fluid requirements) of exercise. Carbohydrate digestion and absorption is more rapid than that of protein or lipid, with the rate of transfer of energy from carbohydrate being two times that of lipid and protein (McArdle *et al*., 2007, p.16). This far superior energy transfer rate is due to the advantage of selective carbohydrate metabolism of either muscle glycogen, blood glucose or both.

Carbohydrase enzymes in the gut breakdown complex carbohydrates (starch) into simple sugars (glucose) which then enter the blood stream. This absorption of fuel is enabled by the small intestine being covered in projections called villi which all have a very thin layer of cells with an extensive blood supply (Parsons, 1998, p.22). This enables the walls of the intestine to have an increased surface area for digested food absorption, allowing energy to be transferred into the blood quickly and efficiently. A percentage of the glucose within the bloodstream is used directly for energy around the body, with the remaining being converted to glycogen and stored in the liver and muscles.

During intense exercise an increase in the hormones epinephrine, norepinephrine and glucagon result, with a decrease in insulin release. This accumulatively activates glycogen phosphorylase, so facilitating glycogenolysis in the liver and active muscles (McArdle et al., 2007, p.16). It is an important enzyme because it regulates the concentration of circulating glucose in the bloodstream. As exercise continues the liver markedly increases it's release of glucose so that it is blood-borne, thereby increasing its contribution as a metabolic fuel. Muscle glycogen provides energy without oxygen, and therefore serves as the predominant carbohydrate energy source during the early stages of exercise and when exercise intensity and demand increases (McArdle *et al*., 2006, p.212).

At the point during exercise that compromises liver and muscle glycogen supply, fatigue occurs (McArdle *et al*., 2007, p.17); regardless of whether there is sufficient oxygen availability to the muscle. This in part may be due to skeletal muscle having low levels of phosphatase enzymes, which allows glucose exchange between cells when demands are extreme. Depletion of glycogen coincides with the point of fatigue, but what form of carbohydrate is the best fuel substrate to provide a greater rate of energy transfer to continue exercise for longer therefore prolonging the time to fatigue?

The aims of the present study were to examine the influence of pre-exercise carbohydrate form on subsequent cycling performance in a female population to determine whether performance can be significantly increased depending upon carbohydrate intake. The following hypotheses were proposed:

Alternative hypothesis – The liquid form of carbohydrate will offer participants an increased time to exhaustion compared to that of the solid carbohydrate.

Two-tailed hypothesis – There will be an effect shown on time to exhaustion from consuming pre-exercise carbohydrate.

Null hypothesis – There will be no significant difference in time to exhaustion between either forms of carbohydrate.

CHAPTER III

METHODOLOGY

Chapter III
Methodology

3.1 Subjects

Seven active females were randomly selected at the University of Wales, Institute of Cardiff (UWIC) to take part in this investigation, due to their availability, all studying Sport and Physical Education. The subjects were aged between twenty and twenty-one years, with a mean VO_2 max value of 2.62 litres per minute ($l\text{-}min^{-1}$), standard deviation 0.54 and a mean mass of 66.9 kilograms (kg), standard deviation 8.62. After being fully informed of the purpose, procedures and possible risks that may occur within the testing procedures, each subject signed a consent form. A health/ medical questionnaire was additionally filled in to eliminate any other risks which may become apparent during testing (appendix 3).

Each subject was individually weighed using digital scales (model 770, SECA, Germany), this was done to determine the amount of solid and liquid carbohydrate to be consumed by each individual prior to testing, and measured for height using a stadiometer (Holtain fixed stadiometer, Holtain LTD, Pembs) and results were recorded (appendix 1).

3.2 Equipment

The investigation was carried out in a laboratory setting, lab A1.22, at UWIC Cyncoed Campus, enabling environmental settings to be kept constant.

An ergometer bike (Monark exercise, Sweden) was set up, with a fan and a rack of six douglas bags (Hans, Rudolph Inc., USA) per bike and weights, consisting of 0.5 kilogram (kg) weights to be added per two minute stage. The douglas bags were vacuumed prior to testing procedures, removing any residual air inside, to ensure accuracy of the gas analysis. Subjects wore a heart rate monitor (Polar Electro Oy, Finland) during testing to monitor and record their heart rate throughout the VO_2 max test and individually paced tests. A mouthpiece and valve (Hans Rudolph Inc., USA) were connected to a breathing tube (Hans Rudolph Inc., USA), connected to the douglas bag. Subjects were required to place the mouthpiece into their mouth followed by fitting a nose clip for every last minute of the two minute stages. A stopwatch was used to time the two minute stages. Once testing was complete, to volitional exhaustion, the douglas bags were gas analysed (1440c, Servomex Group Ltd, East Eussex) for carbon dioxide (CO_2) and oxygen (O_2) per bag once the gas analyser was calibrated to ensure accuracy. A stopwatch was again required to time thirty seconds for the first section of the gas analysis procedure, measuring CO_2 and O_2 levels. Air remaining in the bags was then measured in litres. Once collected, results were entered into a gas calc spreadsheet to determine levels of VO_2 and RER. Heart rate data recorded was then obtained via transmitting infra-red signals from the watch to a computer and downloaded, showing values at five second intervals throughout the duration of the test.

3.3 Exercise Protocol

The experiment was carried out over a 12 week period, in the same laboratory conditions. Not all subjects could carry out the VO_2 max test on the same day, nor subsequent individually paced testing due to lack of supervision and time restrictions.

During the VO_2 max test subjects were required to cycle at a constant rate of 75 repetitions per minute (rpm), The weight, increasing resistance and power output, was increased after each two minute stage by 37.5 watts (0.5 kg), starting at a 112 watts (weight of the basket plus 0.5 kg). A heart rate monitor was fitted and tested to ensure it worked correctly (heart rate shown on watch) and recorded throughout the test.

Gas Analysis took place during the last minute of each two minute stage, ensuring a nose clip was on and the valve of the douglas bag was turned downwards to allow gas to enter (and subject to breathe). The test would finish when indicated by the subject in relation to the rate of perceived exertion (RPE) scale. Maximum effort could also be indicated by their heart rate (220 minus age).

Expired air from the douglas bags was analysed in consecutive order according to the stages of collection. 30 seconds was timed on a stopwatch for the analysis of CO_2 and O_2. Values were recorded once they reached a peak with minimum fluctuation. The total amount of air in litres was then vaccumed and recorded once the value reached a peak, adding a litre for expired air lost during the thirty second CO_2 and O_2 analysis. Results were then entered into the gas calc spreadsheet and RER determined.

The inclusion of a pilot study using a subject at random was then implemented to ensure test protocols were adequate for the two subsequent tests. An intensity set at 40% peak power output (Wpeak) was administered for a warm-up, lasting 4 minutes, followed by an increase to 80% Wpeak until exhaustion. The subject was required to cycle at a set 75 rpm. The phase at 80%, however, only lasted for the duration of seven minutes, therefore indicating the intensity set was too advanced and results lacked an element of endurance. Notification of this meant the test protocol needed to be altered and was done so accordingly.

With a minimum of a weeks rest from the incremental VO_2 max test, subjects were asked to refrain from consuming any food on the morning of their day of testing following an overnight fast. A pre-exercise carbohydrate drink (lucozade) was then given to the subjects 15 minutes before exercise measured for every 2 grams (g) of carbohydrate found within the drink to an individual's 1 kg of body mass.
Subjects, 15 minutes later, were equipped with heart rate monitors, fitted and tested, and then required to cycle at 55% of their Wpeak for 25 minutes at 75 rpm. At the end of this period weight was added to the bike to push the subject to 75% of their Wpeak, again maintaining 75 rpm until volitional exhaustion or fatigue defined as the point in which a drop in cycling performance below 65 rpm was observed or a constant inability to stabilise at 75 rpm. Subjects were allowed to consume water at any period during testing and an electric fan was positioned in-front of the subject and on if needed. Heart rate was recorded throughout the procedure, and gas analysis began during the 75% Wpeak stage, taking place during the last minute of each 2 minutes exercised. This meant ensuring a

nose clip was on and the valve of the Douglas bag turned downwards to allow expired air to enter. Rate of perceived exertion (RPE) was additionally measured as a differentiated approach throughout the procedure in relation to localised (muscular fatigue/ pain) and central (breathing, heart rate) factors, from a borg scale of 6 to 20 (ACSM guidelines, 2000) (appendix 4). This occurred at 5 minute intervals throughout the 25 minutes at 55% Wpeak and every two minutes exercised during the 75% Wpeak to exhaustion.
Once testing was complete subjects were required to cool down with no resistance on the bike until heart rate returned to normal and breathing was steady.

A further weeks rest was given to subjects until the final part of testing was to be completed. This entailed subjects repeating the procedure of an overnight fast and refraining from consuming any food on their morning of testing. However, this time subjects would not be receiving a pre-exercise carbohydrate drink but a carbohydrate meal (pasta). Again, 2 g of dry pasta was weighed for every 1 kg of body mass and cooked with half a tin of chopped tomatoes with herbs (increase palatability). This was consumed by each subject an hour and a half prior to exercise, again asked not to consume any further food until after testing.
An hour and a half later, subjects were equipped with heart rate monitors and the 25 minutes at 55% Wpeak was undertaken. Subjects were then required to complete their last stage of testing via completing the individually self-paced intensity to exhaustion at 75% Wpeak. Water was available throughout the test and an electric fan if needed. Heart rate was monitored and recorded throughout, and gas analysis began during the 75% Wpeak stage within the last minute of every 2 minutes exercised. RPE was additionally recorded. The cool down then followed, returning the subject to their pre-exercise state.

3.4 Data Collection

Expired air was collected in every last minute of the 2 minute stages during the incremental VO_2 max test and individually self-paced tests (75% Wpeak stage) for each subject, with heart rate being monitored and recorded throughout the procedures. RPE was additionally recorded for localised and central areas from the 6-20 borg scale. The gas collected was analysed and recorded, putting values into the gas calc spreadsheet to automatically determine levels of VO_2 (ml-kg-min^{-1} and l-min^{-1}) and RER. Heart rate data was transmitted to the computer, off the watch, via infra-red signals and values were shown in five second intervals for the duration of the test. Measurements of height and mass were also taken and recorded.

3.5 Data Analysis

Results are presented as the mean and standard deviation for heart rate, RPE locally (l) and centrally (c), ventilation volume standard temperature and pressure dry (VE stpd), VO_2 (l/min), VCO_2 (l/min), percentage (%) VO_2 peak and test time to exhaustion, due to these parameters being the most significant to the investigation. Paired t-tests were performed to show if any significant differences could be found between these variables. The p-value was decided at <0.05 level of significance. This meant if any results fell below this figure it would be seen as significant, and vice-versa. All graphical data and statistical analysis procedures were conducted using Microsoft excel.

CHAPTER IV

RESULTS

Chapter IV
Results

4.1 Performance variables

Table 1: The mean (+ SD) values for performance variables within liquid and solid trials.

Variable	**Liquid**	**Solid**
VO_2 (l-min^{-1})	2.22 (0.29)	2.15 (0.14)
VCO_2 (l-min^{-1})	2.32 (0.36)	2.20 (0.29)
VE stpd	61.2 (9.0)	56.2 (7.9)
% VO_2 peak	96.0 (5.2)	98.9 (9.8)
Time to exhaustion (s)	2431.4 (670.3)	2025.0 (170.1)

Mean values were found to be consistently similar between VO_2 and VO_2, as well as VCO_2 liquid and VCO_2 solid, therefore indicating intensities set within both trials were alike and attained similarly by subjects. VE stpd values coincided with the amount of VO_2 and VCO_2 l-min^{-1}, with an overall increased amount during the liquid in comparison to solid. % VO_2 peak however was higher than the estimated 75% Wpeak calculated from VO_2 max tests undertaken. Time to exhaustion was longer within the liquid trial, however not significantly different ($p < 0.103$) possibly due to such a high set of standard deviation values present.

4.2 Heart rate

Figure 1 summarises the mean and standard deviation values for liquid and solid carbohydrate trials at both 55% and 75% Wpeak phases.

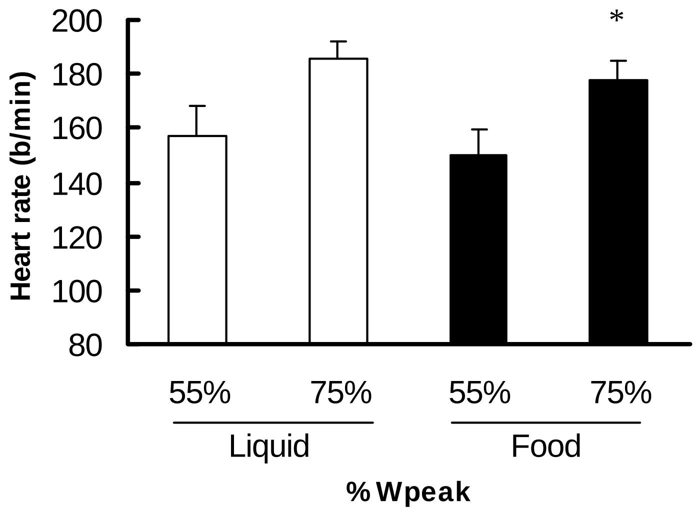

Figure 1. The mean (+SD) values for heart rate during liquid and solid carbohydrate trials at 55% and 75% Wpeak. Values represent the average heart rate attained.

* denotes a difference ($p<0.05$) compared to 75% in liquid trial.

During the 25 minutes at 55% Wpeak, heart rate was found to be significantly higher in the liquid trial compared to that of the solid trial ($p<0.002$). As exercise intensity increased to 75% Wpeak so did that of heart rate, however more pronounced within in the liquid trial (185.6 + 6.2) in contrast to solid (177.6 + 7.0) showing a significant difference of $p<0.007$.

4.3 Ratings of perceived exertion

Figure 2 summarizes the mean central (RPEc) and localized (RPEl) ratings of perceived exertion during the 55% and 75% Wpeak phases from both exercise trials.

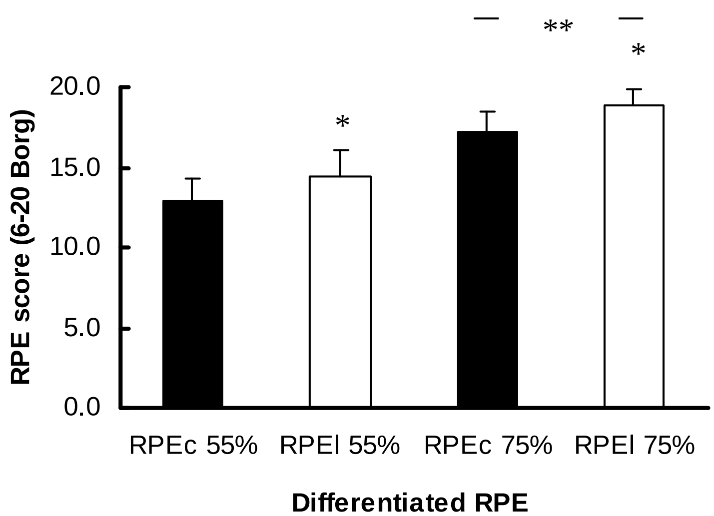

Figure 2. The mean (+SD) values for RPE local (l) and central (c) ratings of perceived exertion. Values represent the average RPE scores reported during both exercise trials.

** denotes RPE at 75% higher (P<0.05) than at 55%

* denotes a difference (P<0.05) between RPEc and RPEl

Rating of perceived exertion was found to be higher within the local areas with regards to muscular fatigue and pain compared to central cardiovascular decline, for example, heart rate and breathing rate within the 55% Wpeak stage. As the exercise intensity increased so did RPE and was significantly greater within localised (p<0.024) compared to central factors.

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Appendix 1

Raw data tables

Subjects	Age (yrs)	Height (cm)	Mass (kg)
1	21	169	73.2
2	20	166.6	70.3
3	20	164.9	58.5
4	21	160.6	58.4
5	21	174.7	81.6
6	20	162.8	65.8
7	21	163	61

Final Gas Sample						
Subjects	Time (s)	VO_2 ($l\text{-}min^{-1}$)	VCO_2 ($l\text{-}min^{-1}$)	VE stpd ($l\text{-}min^{-1}$)	HR ($b\text{-}min^{-1}$)	Peak Power (W)
1	480	2.94	3.42	88.5	192	225
2	480	3.16	3.48	110.1	177	225
3	240	1.83	1.97	48.5	180	150
4	380	2.59	1.85	67.0	195	200
5	483	3.30	2.31	90.2	198	228
6	394	2.12	2.51	48.6	192	209
7	276	2.41	2.36	48.6	172	173

Appendix 2

VO_2 max test results

Subject 1			
Stage	CO_2	O_2	Vol. Bag
1	4.8	15.8	34.4
2	5.1	16.1	43.4
3	4.6	16.6	63.9
4	3.9	17.5	97.4
5			

Subject 2			
Stage	CO_2	O_2	Vol. Bag
1	4.0	16.8	41.5
2	4.2	16.8	51.4
3	4.1	17.1	69.4
4	3.2	18.0	121.1
5			

Subject 3			
Stage	CO_2	O_2	Vol. Bag
1	4.0	16.7	35.6
2	4.1	17.1	53.4
3			
4			
5			

Subject 4			
Stage	CO_2	O_2	Vol. Bag
1	2.8	17.2	43.9
2	3.0	17.0	56.0
3	2.8	17.3	73.7
4			
5			

Subject 5			
Stage	CO_2	O_2	Vol. Bag
1	3.0	16.3	34.6
2	3.6	15.5	35.5
3	3.4	16.2	56.0
4	2.6	17.5	99.2
5			

Subject 6			
Stage	CO_2	O_2	Vol. Bag
1	3.2	17.3	28.8
2	4.9	16.0	36.9
3	5.2	16.4	53.5
4			
5			

Subject 7			
Stage	CO_2	O_2	Vol. Bag
1	4.5	16.0	29.2
2	4.9	16.0	36.2
3			
4			
5			

Appendix 3

Health Questionnaire

Please tick where appropriate:

➢ Do you suffer from asthma	Yes	No
➢ Do you suffer from diabetes	Yes	No
➢ Any food allergies	Yes	No
➢ Can participate in prolonged exercise	Yes	No
➢ Any medical history	Yes	No
➢ Currently on medication	Yes	No
➢ Any current injury/ injuries	Yes	No

If you have ticked yes to any of the above, please state the cause in more detail below:
………………………………………………………………………………………………
………………………………………………………………………………………………
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Appendix 4

Rating of perceived exertion

6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	