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THE EFFECT OF VARYING FORMS OF CARBOHYDRATE ON SUBSEQUENT

CYCLING PERFORMANCE TO EXHAUSTION IN AN ACTIVE FEMALE

POPULATION

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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 II

A REVIEW OF LITERATURE

<center>**Chapter II**</center>

<center>**A Review of Literature**</center>

2.1 Introduction

Optimum nutrition for sports performance has been extensively researched, looking into strategies to maintain or enhance carbohydrate availability, such as the ingestion of carbohydrate before, during and after exercise, which is critical to performance, as carbohydrate is a predominant fuel during many types of exercise, such as high-intensity intermittent work and prolonged aerobic exercise. Carbohydrate stores in the human body are not very large (300 – 500 g), therefore the ingestion of various forms of carbohydrate has been systematically studied as a means of extending that fuel supply for a longer period of time (Aragon-Vargas cited in Maughan and Murray, 2001, p.154). This has been done with solid and liquid forms of carbohydrate. However, discrepancies in the results mean outcomes have not been consistent. Jentjens *et al*. (2003) proposed that conflicting results may have been produced within studies investigating the effect of pre-exercise ingestion of carbohydrate on metabolism because of the difference in designs employed within the studies.

The American Dietetic Association (ADA), Dieticians of Canada (DC) and American College of Sports Medicine (ACSM) set up a position statement in the year 2000 on nutrition and performance, stating that optimal nutrition enhances physical activity, athletic performance, and recovery from exercise. This means adequate food and fluid intake before, during and after exercise to help maintain blood glucose, maximise performance and aid recovery.

Hawley and Burke, (1997) stated that the timing and frequency of carbohydrate intake are crucial determinants for optimising fuel availability to enhance exercise capacity. Recent scientific literature suggests that a pre-exercise meal should contain between 150 g to 300 g of carbohydrates (3-5 g per kg body mass) and consumed within 3-4 hours before the onset of exercise (McArdle *et al*., 2007, p.98) to allow for gastric emptying from the stomach and small intestine before the start of exercise. Additionally an

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increase in liver and muscle glycogen enhances subsequent endurance performance (Hargreaves *et al*., 2004). In agreement, Wolinsky and Driskell, (2001), say that all pre-exercise meals should be eaten within one to four hours prior to exercise, with larger solid meals being consumed three to four hours before and smaller liquid meals eaten one to two hours prior.

During prolonged exercise there are many causal factors which may contribute to fatigue, described as the feeling of tiredness and accompanying decrements in muscular fatigue (Wilmore and Costill, 2004, p148), which is detrimental to performance. Carbohydrate depletion in the forms of muscle glycogen and blood glucose seriously limit endurance performance as this is the predominant metabolic fuel. Muscle glycogen is primarily used during the early stages of exercise, however cannot act independently for long periods of time due to its low storage within the body, therefore dependency on blood glucose becomes increased. With time, demand from the working muscles exceeds that of the liver's glucose output, leading to the inability to supply adequate glucose from the blood. Muscles consequently rely solely on their glycogen reserves which rapidly deplete leading to fatigue. In addition to this, dehydration and thermoregulation, if not monitored, could cause early fatigue due to the inability to remove heat generated from the body, increasing internal body temperature.

2.2 Dehydration, thermoregulation and fatigue

Optimal hydration needs to be taken into consideration. Guidelines have been set to consume 400 to 600 ml of fluid, 2-3 hours before exercise to allow enough time for excess fluid to be excreted before the start of exercise, with 150 to 350 ml of fluid to be consumed at 15 to 20 minute intervals throughout exercise (American Dietetic Association, Dieticians of Canada, American College of Sports Medicine, 2000). This is to maintain fluid balance and decrease chances of partial dehydration which may compromise performance, because "even modest levels of dehydration will impair exercise capacity and prevent the athlete from achieving optimum performance" (Maughan cited in Maughan and Murray, 2001, p.5). Sawka *et al*. (1992) investigated the influence of hydration in extreme conditions. Subjects were found to become

exhausted quicker the more dehydrated they were due to the body's allowance of their core body temperature to rise higher than those who were hydrated, as "exercise in the dehydrated state leads to rapid elevation of body temperature" (Maughan cited in Maughan and Murray, 2001, p.10). Maughan *et al*. (1996) also found performance times to be much lower for no water (80.7-min) compared to water (93.1-min), showing performance to be enhanced by the ingestion of water. Walsh *et al*. (1994) also used a test to exhaustion to measure the effects of dehydration, with additional measurements of heart rate, body temperature, respiratory gas exchange, leg muscle power, perceived exertion and plasma anti-diuretic hormone (ADH) concentrations. Subjects were put under two conditions, fluid given before and during exercise and no fluid. High intensity (90% maximal oxygen uptake) cycling time to exhaustion was significantly increased during the fluid trial, therefore supportive of Sawka *et al*. (1992) findings. However there were no measurable differences in body temperature, only the ratings of perceived exertion and concentrations of ADH were increased in the non-fluid trial.

Gonzalez-Alsonso *et al*. (1999) looked at the influence of body temperature on the development of fatigue in prolonged exercise. Findings showed that the time to exhaustion was significantly related to internal body temperature during prolonged exercise in a hot environment. This relates to the findings of Sawka *et al*. (1992) in that body temperature has an overall effect on performance, therefore heat regulation and hydration is extremely important during testing. Additionally with a hot environment the skin is unable to efficiently perspire to reduce heat storage of the body, consequently with optimum hydration (400-600 ml prior, 150-350 ml during) and temperature suitable to exercise, allowing subjects to successfully loose heat to maintain a 37ºC internal body temperature, fatigue and exhaustion will not be premature. Procedures to minimise this include the use of electric fans, (Reznik-Dolins *et al*., 2003) directed towards the subject to allow for cooling, reducing the effect of heat storage.

2.3 Use of placebos

A lot of studies use the use of placebos during testing to deceive their subjects into what liquid they are consuming. Langenfeld *et al*. (1994) used a non-caloric placebo (no energy) or a carbohydrate maltodextrin supplement on fourteen trained cyclists, pedaling at a self-selected pace, three to four hours prior. Finishing times were found to be faster by five percent with the maltodextrin supplement (241.0 ± 2.1) compared to the placebo (253.2 ± 2.1). Strengths are shown within the method by the setting of a control, with each trial being preceded by two days of a prescribed diet, therefore individual diets will not have an affect on the outcome of the investigation, only the variables (maltodextrin and placebo). Similar findings were observed by Coyle *et al*. (1986) where subjects continued exercising at a cycling intensity of 71% VO_2 max for an additional hour (h) before fatiguing when fed a carbohydrate drink (4.02 h) compared to a placebo (3.02 h).

2.4 Overnight fasts and practical applications

Overnight fasts are common in scientific procedures to deplete glycogen stores in the liver and muscles in order to show a true representation of the effects carbohydrates have on performance. Significant depletion has been found to occur in the body's carbohydrate reserves over an eight to twelve hour period without eating (McArdle *et al*., 2006, p.110). Schabort *et al*. (1999) had subjects undergo an overnight fast followed by the consumption of a standardised carbohydrate breakfast (100 g), three hours prior to exercise; or had them enter exercise, without food, following the overnight fast. Cycling times to fatigue were significantly longer (136-min) when the subjects ate the breakfast compared to the overnight fast (106-min). This study consequently proves that depletion does occur within the glycogen stores and to sustain exercise carbohydrate needs to be consumed to replenish stores lost. However, limitations are such that it is an unrealistic practice to undergo exercise in a fasted state.

Exercise following a sixteen hour fast was compared with the ingestion of a high-carbohydrate meal four hours prior to exercise by Coyle *et al*. (1985). Findings showed

there to be no significant difference between subjects who were fed or fasted with regards to blood glucose levels, rate of carbohydrate oxidation or muscle glycogen concentration. This may have been due to findings prior to exercise, whereby levels of plasma insulin and blood glucose, which elevated after the pre-exercise meal, returned to fasting basal levels before the initiation of exercise. However, further results indicated pre-exercise feedings to alter substrate availability during exercise by enabling greater muscle glycogen utilisation within fed subjects, which consequently persisted until the second hour of exercise creating a better performance.

2.5 Digestion, absorption and transport

Entrance into the systemic circulation is a limiting factor via the rate of digestion, absorption and transport of exogenous glucose oxidation, rather than intramuscular factors (Jeukendrup and Jentjens, 2000). This is supported by evidence presented by Jeukendrup *et al*. (1999) using a method of stable isotopes to quantify the appearance of glucose from the gut into the systemic circulation. At low carbohydrate ingestion rates, the rate of appearance of glucose from the gut equaled the rate of ingestion, however when a larger ingestion rate of carbohydrate was investigated, the rate was reduced to only one third (3 g-min^{-1} vs. 0.96 to 1.04 g-min^{-1}). Nevertheless, due to a larger ingestion rate, more carbohydrate is available for absorption, therefore showing higher amounts of glucose in the bloodstream compared to the ingestion of low carbohydrate for utilisation (0.96 to 1.04 g-min^{-1} vs. 0.43 g-min^{-1}). One limitation, however, is due to excess carbohydrate not entering the systemic circulation, leaving the presence of unabsorbed dietary material, gastrointestinal distress may result.

Exercise intensity can have an affect on absorption rates via reduced blood flow to the lining of the small intestine (Brouns and Beckers, 1993). Relatively few studies have investigated the effect of exercise on intestinal absorption because of practical difficulties associated with perfusing the small intestine whilst a subject is exercising. Gisolfi *et al*. (1991) examined the effect of rest and varying exercise intensities (30%, 50% and 70% VO_2 max) on absorption rates of water and a carbohydrate-electrolyte solution. Results indicated no difference in absorption rates between rest and the three

cycling exercise intensities. Findings seen in Brouns and Beckers, (1993) study lead to the conclusion that the effect on absorption rates may only apply to exercise at a very high intensity, therefore, Gisolfi *et al*. (1991) may not have employed a high enough exercise intensity with which to see an affect.

2.6 Timing of carbohydrate ingestion and hypoglycaemia

One effect which may become evident from consumption of carbohydrate closer to the onset of exercise, inside one hour, is hypoglycaemia. This can occur when increases in blood sugar initiate the pancreas to secrete insulin. Insulin consequently lowers blood sugar levels via the promotion of glucose uptake into the cells (Berning and Steen, 1998, p.34). This causes the blood sugar level to decrease and individuals can suffer from symptoms such as dizziness, nausea and confusion, or become exhausted sooner.

Foster *et al*. (1979) reported decreases in performance with the onset of hypoglycaemia where meals or liquid have been consumed within an hour of exercise. On the other hand, some studies found the opposite where either hypoglycaemia did not occur or there is no effect on performance. A 1997 study by El-Sayed *et al*. contradicted the findings of Foster *et al*. (1979). Eight trained male cyclists consumed an 8% carbohydrate solution or a placebo 25 minutes prior to exercise on two separate occasions to compare results of a self-selected maximal pace. The rise in plasma glucose was significantly higher in the carbohydrate trial compared to the placebo 30 minutes into testing, and the power output was significantly greater during the carbohydrate trial with a 44-s improvement, concluding that pre-exercise carbohydrate ingestion significantly increases endurance performance. Foster *et al*. (1979), however, found glucose feedings 30 to 45 minutes prior to endurance exercise, to reduce performance time by 19% compared to the ingestion of water. Mechanisms attributed to this decrease in performance were due to pre-exercise feedings increasing the rate of carbohydrate oxidation which subsequently inhibited the mobilisation of free-fatty acids. Hargreaves *et al.* (2004), in agreement with El-Sayed *et al*. (1997) findings, states "although an increase in plasma insulin following carbohydrate ingestion in the hour before exercise

inhibits lipolysis and liver glucose output…there is no convincing evidence that this is always associated with impaired exercise performance" (Hargreaves *et al*., 2004).

Moseley *et al*. (2003) investigated the effect of different timings of pre-exercise feedings. 75 g of glucose was dissolved in 500 ml of water with subjects commencing exercise either 15, 45 or 75 minutes later. From altering the timing of ingestion, differences in plasma-insulin responses were found to be higher immediately before exercise during the 15 minute conditions compared to the 45 and 75 minute conditions, which disappeared within 10 minutes of exercise to eliminate these differences. As could be expected from this result, hypoglycaemia was evident in some subjects but did not affect performance, producing similar mean powers and ratings of perceived exertion.

2.7 Quantity of carbohydrate ingested

Sherman *et al*. (1991) required subjects to cycle at 70% of maximal oxygen consumption (VO_2 max), the highest rate of oxygen consumption attainable during maximal or exhaustive exercise (Wilmore and Costill, 2004, p.290), for 90 minutes following the ingestion of a placebo or two differing amounts of liquid carbohydrate; either 1.1 or 2.2 grams per kilogram of body mass, one hour prior to exercise. Time trial performance was increased by a significant 12.5% following the liquid carbohydrate compared with the placebo. Jentjens *et al*. (2003), also considered differing amounts of pre-exercise carbohydrate ingestion and had subjects ingesting either 0, 25, 75 or 200 g of glucose in 500 ml of a beverage, 45 minutes prior to a sub-maximal steady-state exercise of 65% maximal power output (Wmax). No difference was found within time trial performances, however this may have been due to exercise only being sub-maximal, therefore the need for carbohydrate as an independent energy source was not required. This suggests that the intensity at which protocols are set as well as the duration in which subjects are required to complete the exercise can have profound affects on substrate usage. This variable can be measured via the volume of expired oxygen and carbon dioxide to determine a respiratory exchange ratio (RER) (Reznik-Dolins *et al*. 2003).

Carbohydrate is essential at moderate and high intensities; however a more pronounced reliability is seen with higher maximal oxygen consumptions (e.g. 85%), due to a decrease in fat oxidation and an increase in plasma glucose uptake and muscle glycogen oxidation in relation to exercise intensity (Aragon-Vargas cited in Maughan and Murray, 2001, p.154).What's more, with an increase in duration of exercise a depletion of muscle glycogen will occur, leading to the dependence of blood glucose as a carbohydrate source for the muscle fibres to continue exercising (Aragon-Vargas cited in Maughan and Murray, 2001, p.154).

A similar study was conducted by Reznik-Dolins *et al*. (2003), which considered the impact of diets providing 8, 5 or 3g of carbohydrate per kilogram of body weight, but required subjects to eat these diets over a six day period with the exercise trial being performed on the seventh day. As previously mentioned a meal of 3 to 5 g per kg of body mass three to four hours prior should be an adequate meal to enhance performance (McArdle et al., 2007, p.98). However no difference was found between either of the amounts given on time to exhaustion. This was also the case for Paul *et al*. (2003), who investigated the effect of different types of pre-exercise meal on performance. Three grams of carbohydrate was given for each kilogram of body weight three and a half hours prior to exercise (optimum). However, this had no effect on carbohydrate oxidisation or time trial performance compared to a placebo meal (and also compared to a fat only meal).

The results of Reznik-Dolins *et al*. (2003) and Paul *et al*. (2003) may be partly explained by Jeukendrup and Jentjens (2000) who found carbohydrate oxidation rates do not exceed 1.0 to 1.1 grams per minute (g-min^{-1}) despite additional carbohydrate being present for use, due to rates of digestion, absorption and transport of glucose located in the intestine or the liver.

Rauch *et al*. (1995) investigated a different performance indicator to that of time to exhaustion, by focusing on distance covered. The protocol was set to working at 75% of peak oxygen consumption with five 60-s sprints at 100% at 20 minute intervals, followed by a 60 minute performance ride. Normal diets of eight endurance trained

cyclists were supplemented with additional carbohydrate for three days prior. Results showed pre-exercise muscle glycogen to be elevated, so implementing an improved power output and extended distance covered in one hour. Therefore additional carbohydrate consumption proved to be a significant effecter of improved cycling performance, possibly due to greater amount of stored muscle glycogen available for utilisation.

2.8 Form of carbohydrate

The type of carbohydrate given may influence the subsequent rate of utilisation during exercise because of a use in different intestinal transporters for absorption (Jeukendrup, 2004). Further, glucose and fructose were shown to result in higher oxidation rates, therefore suggesting that this may be a way to increase exogenous carbohydrate oxidation rates by 20% to 50% (Jeukendrup, 2004). This was tested by Jentjens *et al*. (2004) by giving subjects three different drinks on three separate occasions and cycling for 150 minutes. The purpose was to examine whether a mixture of glucose, sucrose and fructose ingested at a high rate (2.4 g-min⁻¹) would result in even higher exogenous carbohydrate oxidation rates. One drink consisted of water, the second glucose and the third was a mixture of glucose, sucrose and fructose. Results showed high peak exogenous carbohydrate oxidation rates to be 44% higher from the mix solution compared to glucose alone, reaching values of approximately 1.7g-min⁻¹; thus in accord with the statement produced by Jeukendrup, (2004). This supports the formulation of some sports drinks where combinations of carbohydrate forms are integrated into the same solution to enhance performance.

The effect of glucose and fructose on performance was also investigated by Williams *et al*. (1990), with the comparison of water alone acting as a control. A carbohydrate-electrolyte solution contained either additional glucose or fructose (20 g) ingested throughout exercise. Running times however were not significantly different, even compared to the water trial. However, running speed on the final 10-km of a 30-km race was found to significantly decrease with the consumption of water, possibly due to the decrease in blood glucose concentrations compared to the glucose and fructose trials.

Notably, methods did not test the combination of glucose and fructose as a mix solution and therefore cannot be compared to the findings of Jentjens *et al.* (2004). It could be suggested that glucose and fructose is superior for performance trials as consumption individually gave similar results to water alone.

The research of Adopo *et al.* (1994) can be compared to that of Jentjens *et al.* (2004) for within the methods 50 g of glucose and 50 g of fructose were simultaneously ingested within the same drink, and compared to fructose and glucose alone. Fructose was found to be less effective than glucose in improving performance. However when simultaneously ingested, glucose and fructose enhanced exogenous carbohydrate oxidation to 21% above that obtained from 100 g of glucose alone. Reasoning for this may be that absorption and metabolic routes of exogenous glucose and fructose are slightly different, resulting in less competition for oxidation (Adopo *et al.*, 1994).

An understanding of metabolic response is extremely important in relation to carbohydrate ingestion and the effect it may have on performance, and was investigated by Wallis *et al.* (2006) to see whether there are any differences between males and females during exercise. Plasma glucose oxidation contribution to the total energy expenditure was significantly increased with carbohydrate ingestion in both sexes, with similar ratings of muscle glycogen oxidation being unaffected by carbohydrate ingestion. Consequently ingested carbohydrate was oxidised at similar rates in men and women, therefore metabolic responses are largely similar. M'Kaouar *et al.* (2004) came to the same conclusion, that the respective contributions of the oxidation of the various substrates (along with glucose) to the total energy expenditure, during prolonged exercise, are similar in men and women.

2.9 Impact of solid and liquid carbohydrate forms

Liquid meals provide hydration as well as carbohydrate for utilisation by the cells of the body or for glycogen replenishment. They have the ability to be rapidly digested and absorbed, leaving no residue in the intestinal tract, therefore reducing gastrointestinal distress. Many studies use food in the liquid state as a means of consuming carbohydrate

because carbohydrate is digested and transformed into a liquid or semi-liquid state before leaving the stomach (Berning and Steen, 1998, p.25) to provide energy. For example, Hargreaves *et al*. (1987), had subjects ingest either 75 g of glucose or fructose within 350 ml of water. These are types of carbohydrate beverages or sports energy drinks formulated to supply both water and energy to be rapidly absorbed and utilised (Leiper cited in Maughan and Murray, 2001, p.92). However some have gone further to include protein and fat within the drink (Foster *et al*. 1979) to constitute an actual meal, supplying all the nutrients, vitamins and minerals required for normal nutrition.

Most studies have examined either a solid or liquid carbohydrate supplementation on performance, that contain carbohydrate alone. Chryssanthopoulos and Williams (1997) studied the effect of a pre-exercise carbohydrate meal 3-hours prior in conjunction with a carbohydrate-electrolyte solution during exercise, compared to a carbohydrate-electrolyte solution alone. The protocol required ten men to run at 70% VO max to exhaustion. Findings showed the combination of the meal and the solution to further improve performance (147.4-min) compared to the solution alone (125.3-min). This was also true for Febbraio *et al*. (2000) who concluded that pre-exercise ingestion of carbohydrate improves performance only when carbohydrate ingestion is maintained throughout exercise, furthermore Wright *et al*. (1991), found performance to be further improved by combination (feedings before and during), compared to pre-exercise feedings alone (44% versus 18%). However, as previously mentioned, Jeukendrup and Jentjens (2000) found carbohydrate oxidation rates do not exceed 1.0 to 1.1 g-min^{-1} despite additional carbohydrates being present for use, therefore additional carbohydrate may not be the performance enhancer, but the variance of carbohydrate available for utilization, as well as hydration catered for by the carbohydrate-electrolyte solution to reduce fatigue. "Carbohydrates and electrolytes during exercise will provide fuel for the muscles, help maintain blood glucose and the thirst mechanism, and decrease risk of dehydration" (American Dietetic Association, Dieticians of Canada, American College of Sports Medicine, 2000).

2.10 Conclusion

From reviewing previous literature the timing and amount of carbohydrate to be ingested prior to the onset of exercise is still unclear. A specific lack of research exists which has compared solid and liquid forms of carbohydrate alone, prior to exercise, on their effect on performance within a female population. Further, research has been focused predominantly on a male population, and from findings set by Wallis *et al.* (2006) regarding metabolic responses between men and women, no significant differences occurred, therefore a study conducted on women alone can be set as a comparison.

The effect of any consumption of food prior to testing needs to be taken into consideration, and to show true effects of a particular food type (carbohydrate) subjects should be entered into testing following an overnight fast to deplete any existing glycogen stores. Hydration is an additional factor of extreme importance, for this can limit performance capabilities via increasing internal body temperature, leading to early fatigue.

It is evident that relatively few studies have explored how carbohydrate supplementation in the form of solid meals or carbohydrate-containing liquids influence performance. Therefore the specific aim of this present study was to administer pre-exercise carbohydrate feedings of varying carbohydrate forms to explore possible differences in cycling performance within in a female population.

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-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

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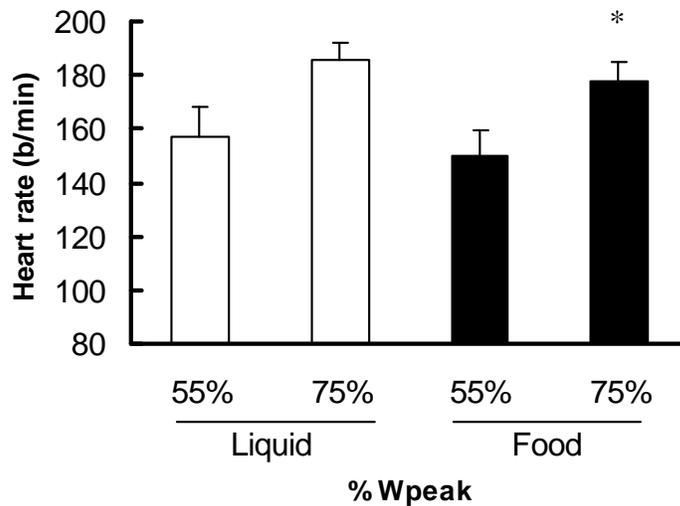
Figure 1. The mean (+SD) values for heart rate during liquid and solid carbohydrate trials at 55% and 75% Wpeak. Values represent the average heart rate attained.

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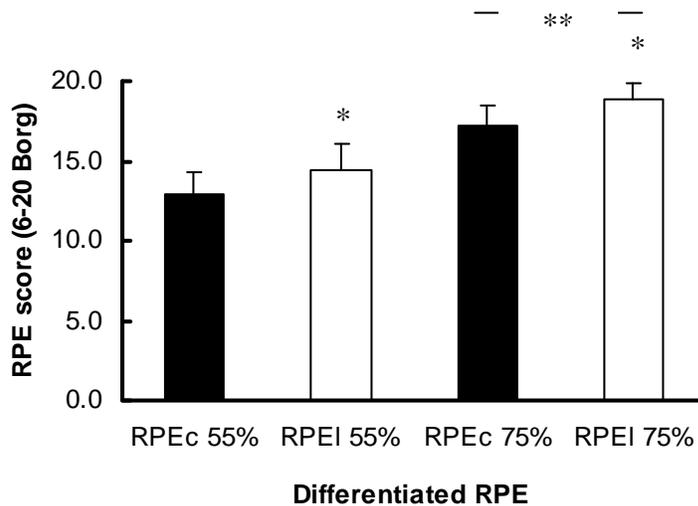
Figure 2. The mean (+SD) values for RPE local (l) and central (c) ratings of perceived exertion. Values represent the average RPE scores reported during both exercise trials.

** 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.

CHAPTER V

DISCUSSION

Chapter V

Discussion

5.1 Explanation of findings

The main significant findings from this study were observed in heart rate and RPE values. In disagreement to previous studies, where demonstration of no effect on heart rate occurred (Reznik-Dolins *et al*., 2003; Walker *et al*., 2000), heart rate was found to increase significantly higher during the liquid trial which subsequently was the longest with regards to time to exhaustion. These findings may have been apparent due to this increased time to exhaustion which allowed for cardiovascular drift to occur. Working at a constant rate (75% Wpeak) enables stroke volume to gradually decrease and heart rate to increase. This results in a progressive increase in cardiac output, permitting additional blood to reach vasodilated areas of the skin to reduce body heat and overall core body temperature. At the same time, priorities to deliver more oxygenated and possibly glucose carrying blood to the muscles to supply increased energy demand is being met, therefore heart rate compensates for the decrease in stroke volume in an effort to maintain cardiac output.

RPE values locally were shown to be the significant limiting factor to an increased time to exhaustion in subjects. However this may not have been the result of decreased carbohydrate stores, and subsequently the oxidation and utilisation of this fuel in order to maintain exercise intensity, because even at 55% Wpeak ratings were still much higher for local rather than central factors (14.5 versus 12.9). The fact that subjects were not trained cyclists, merely active individuals, may have meant that fatigue set in at an earlier stage than would have been expected if trained cyclists were used (El-Sayed *et al*., 1997; Langenfeld *et al*., 1994; Rauch *et al*., 1995). Reznik-Dolins *et al*. (2003) had specific inclusion criteria, whereby only highly endurance trained cyclists were entered as subjects into their study via the completion of a VO_2 max test demonstrating a capacity of 50 ml-kg-min⁻¹ or greater, therefore fatigue of the leg muscles would not be a limiting factor. Centrally, RPE values showed more potential to continue the exercise

in hand (17.2 + 1.2), however subjects were not tested prior to entry of the investigation, purely due to availability. Reasoning for a statistical significance in RPE may also be due to the differentiated approach administered when recording RPE scores, for many studies found there to be no effect of diet on RPE (Lamb *et al*., (1990); Sherman *et al*., (1993).

VO_2 and VCO_2 ($l\text{-}min^{-1}$) values were similar in both the liquid and solid carbohydrate trials, showing consistency of performance set by subjects and methods employed to gather and analyse performance variables. This may be explained via the design of the investigation being an experimental rather than a field study, therefore more controlled. However, the $\%VO_2$ peak achieved by subjects were higher (96 and 98.9%) than the expected 75% Wpeak calculated from the incremental VO_2 max test which commenced prior to the trials. This may have been due to weaknesses in the construction of the incremental VO_2 max test, such as the decision to increase each stage by 37.5 watts (0.5 kg), causing subjects to have fatigued earlier than anticipated. To elicit the highest oxygen consumption increments should have increased via 15-30 watts to allow for a gradual increase in cardiovascular demand (Buchfuhrer *et al*., 1983). In conjunction, a high level of motivation may not have been evident in all participants, therefore maximal peak power output was not attained and the subsequent testing was not a true reflection of their calculated percentage peak power output.

Time to exhaustion was found not to be significant towards either trial (p<0.102) despite the 406.4-s (6.46-min) overall increased time set by the liquid carbohydrate. This may have been a result of such large standard deviation values (670.3 and 170.1) showing huge variation around the average time set by subjects. Interventions to alleviate this problem may be the use of a larger sample group (Palmer *et al.,* 1998; Langenfeld *et al*., 1994). However it is also possible that a test to exhaustion was not sensitive enough to detect differences in performance set by the subjects despite this test being used in many investigations (McConnell *et al*., 2000; Demarco *et al*., 1999; Chryssanthopoulos and Williams, 1997). Jeukendrup *et al*. (1996) suggests a time trial cycling performance, in which subjects are required to cycle a given distance in the fastest time, to be more

reproducible (coefficient of variation 3.35%) than the traditional test to exhaustion, therefore more sensitive (Jeukendrup *et al*., 1997; Rauch *et al*., 1995).

5.2 Practical and theoretical implications

The decision for the experimental protocol to be carried out on a cycle ergometer, despite not having trained cyclists, compared to a treadmill was purely because of the ingestion of pre-exercise carbohydrate, and gastrointestinal distress was found to be further exacerbated by hard exercise involving mechanical factors more common in runners than in cyclists (Brouns cited in Maughan and Murray, 2001). However the use of an electrically braked cycle ergometer would have been superior, thereby providing a constant power output due an electrical conductor that moves through a magnetic or electromagnetic field determining the resistance to pedaling rate (Wilmore and Costill, 2004, p.17). This would have created a more controlled exercise intensity because a resistance increase would be automatic as pedal rate decreases and vice versa.

It is important to notice the timings and amount of carbohydrate given prior to exercise within the methods. A set 2 g per kg of body mass was weighed/ measured for each individual to set as a control. Due to this being lower than the stated 3 to 5 g per kg of body mass optimum, consumed 3 to 4 hours prior (McArdle *et al*., 2007), meant timings of consumption could be estimated and ingested nearer to the onset of exercise. This allowed for closer control of subject's eating, whereby timings were accurate before the onset of exercise, due to the administration of the carbohydrate by the researcher, decreasing subject interference. This however, could have acted as a limitation because the estimated consumption time of the solid food (1.5-hr) prior to exercise may not have been a long enough time period to allow for full gastric emptying before the onset of exercise (Wolinsky and Driskell, 2001). Additionally the liquid carbohydrate (15-min) may have been consumed too near the onset of exercise causing possible hypoglycaemia (Moseley *et al*., 2003). This aspect is based purely upon speculation as a result of the inability to measure plasma glucose concentrations, due to ethical considerations. Therefore possible onset of hypoglycaemia in subjects could not be investigated,

consequently, limiting knowledge of internal performance variables which may have occurred.

The proposition of the inclusion of an overnight fast into the methods was used to deplete glycogen stores to reduce any possible effects of previous dietary consumption on performance, only the carbohydrate consumed prior to testing. However no control was set within the protocol via entering subjects into exercise without pre-ingested carbohydrate (Schabort *et al*., 1999; Coyle *et al*., 1985), due to its un-realistic nature, nor the use of a placebo to deceive subjects into whether they were consuming a carbohydrate drink or non-caloric drink (Langenfeld *et al*., 1994). This methodological involvement would have been necessary to show the effects of either form of carbohydrate on performance, however this study was set to examine the effectiveness of two forms of carbohydrate against one another on performance.

With regards to fatigue of the subjects, a minimum of one week rest between testing was implemented as seen within previous studies (Maughan *et al*., 1996; Backhouse *et al*., 2005). However when investigating active individuals, measures to restrict subjects from exercising on the days between testing would be at a near impossible and more than likely only the night before can be controlled and asked of the subject. To allow for this activity diaries could be completed, therefore acquiring additional information, giving potential explanations to be found if the performance was not at the standard met from previous testing. To measure fatigue at the exhaustive phase, a drop of below 65 rpm or a constant inability to stabilise at 75 rpm was set as the criteria for an automatic ending point of testing. This was similar to Reznik-Dolins *et al*. (2003) who set their criteria to being unable to maintain above 60 rpm.

From highlighting the importance of decreasing levels of dehydration and optimising thermoregulation processes, water was available to all subjects prior, during and post exercise testing to prevent premature fatigue (Maughan *et al*., 1996; Sawka *et al*., 1992). However compulsory intake prior to the initiation of exercise and during exercise was not implemented into the experimental protocol, despite American Dietetic Association,

Dieticians of Canada and American College of Sports Medicine guidelines, (2000). Reasoning for this was due to the consumption of the liquid carbohydrate within the protocol being capable of providing sufficient water to delay dehydration, subsequently additional compulsory water intake would mean too much fluid ingestion. It was up to the subjects discretion to consume water if felt necessary. It's interesting to find that the form of carbohydrate whether solid or liquid is unlikely to be important provided sufficient water is also consumed when ingesting carbohydrate in solid form (Coggan and Swanson, 1992). To aid thermoregulation an electric fan was used (Reznik-Dolin *et al*., 2003), again at the subjects discretion, to avoid un-necessary increases in internal body temperature leading to fatigue (Gonzalez-Alsonso *et al*., 1999).

Wallis *et al*. (2006) and M'Kaouar *et al*. (2004) found no difference in metabolic factors between men and women, therefore showing no reason to refrain from studying either/ or population. However when studying women an aspect that was not investigated and may have had an impact on performance is that of menstrual status, specifically the phase of the menstrual cycle. This was not taken into consideration during this study as it was in another (Reznik-Dolins *et al*., 2003).

Studies (Jenkendrup and Jentjens, 2000; Jenkendrup *et al*., 1999) provide evidence that carbohydrate oxidation rates are limited by the rate of digestion, absorption and transport of glucose into the systemic circulation. Time to exhaustion being longer within the liquid compared to the solid carbohydrate trial supports the theoretical perspective that gastric emptying of liquids is faster than that of solids due to carbohydrate must be in a liquid or semi-liquid state before leaving the stomach to enter the small intestine where absorption takes place (Berning and Steen, 1998, p.25). However, due to evidence supported by Gisolfi *et al*. (1991) and Brouns and Beckers, (1993), exercise intensity above that of 70% needed to be implemented to show any affect on absorption rates from the small intestine. During this study it was not methodologically calculated to require subjects to be exercising above that of 70%, however work rates were shown to be above this percentage, indicating possible implications to gastric emptying and subsequently absorption rates.

5.3 Conclusion

Heart rate and differentiated RPE were found to be the significant variables within this study. Regardless of an increase in the time to exhaustion found within the liquid trial it was still statistically insignificant and the inclusion of a higher subject number may have altered this result by reducing standard deviation values. The use of an experimental design allowed for precision in the gathering and analysing of data, with subjects performing similarly in both trials in retrospect to their VO_2 and VCO_2 ($l\text{-}min^{-1}$) values. Considerations for an accurate method of acquiring a true VO_2 max in order to calculate precisely a subject's % Wpeak would eliminate high % VO_2 peak values observed. Dehydration and thermoregulation must always be of importance, to eradicate these factors as possible determinants to early fatigue, focusing solely on carbohydrate depletion as the only variable to limit performance. In conclusion, due to there being no significant difference in time to exhaustion between either forms of carbohydrate the null hypothesis must be excepted.

5.4 Future research

The form of carbohydrate (solid vs. liquid) still requires further investigation to examine which form is best for performance within an active female population. Inclusion of motivated, highly trained cyclists should be used with their own bike, mounted, to be generalised to real life situations.

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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-min^{-1})	VCO_2 (l-min^{-1})	VE stpd (l-min^{-1})	HR (b-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