Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.
The effect of mouth rinse and ingestion of carbohydrate solution on short intensive exercise – How can we explain the increase in exercise performance?

A thesis presented for a degree of Master of Science in Sport and Exercise Science at Massey University, Auckland, New Zealand

Catherine Moss
May 16th 2011
Acknowledgements

This thesis would not have been possible without the guidance and the help of several individuals who in one way or another contributed and extended their valuable assistance in the preparation and completion of this study.

Thank you so much to all the athletes who participated in this study. Your time, energy, determination, blood and sweat have written these pages. It has been a pleasure working with all of you and you have motivated me to pick up mountain biking.

I would like to thank all three of my supervisors for taking me on and for initially offering me a scholarship to study at Massey University. This has been a wonderful learning experience.

My utmost gratitude to Dr Ajmol Ali, whose passion for research initially inspired me to further my education. Thank you so much for your wisdom, time, encouragement and more importantly your patience throughout the duration of this study.

Thank you to Dr Bernhard Breier and Dr Michelle Yoo for your continuous guidance and input. I have greatly appreciated your help and opinions.

Thank you to Simon Bennett for not only your help, advice and long hours in the lab but for also supplying a great sense of humour.

Lastly, thank you to Paul and my family for your constant support and encouragement over the years.
The effect of mouth rinse and ingestion of carbohydrate solution on short intensive exercise – How can we explain the increase in exercise performance?

1.0 Abstract

**Background:** Ingestion of carbohydrates during exercise in a fasted state has been shown to improve high-intensity exercise performance. The mechanism responsible for the improvement remains uncertain. Recent studies suggest that rinsing the mouth with a carbohydrate solution improves performance in the latter stages of high-intensity exercise without changes in circulating glucose levels. There has also been an absence of a peripheral metabolic action of exogenous carbohydrates and thus central effects have been postulated to explain this phenomenon. **Aim:** The purpose of the present study was to investigate whether there were individual and/or additive effects of carbohydrate mouth rinse, fluid intake and carbohydrate ingestion on 1-h time trial cycling performance. The project further investigated the response in circulating markers of fuel utilization. **Methods:** Eight recreationally trained cyclists volunteered for this randomised, counterbalanced, double-blind study. After a preliminary familiarisation session, four main trials were performed on an electronically-braked cycle-ergometer with each trial separated by 7 days. Each main trial took place over two days. On Day 1 the participants underwent a 90 min glycogen reducing exercise protocol, immediately followed by a low carbohydrate meal and then a subsequent overnight fast. The following morning a 1-h time trial performance test was conducted. Subjects performed a certain amount of work as fast as possible for the performance test. The main trials included a 15% carbohydrate mouth rinse (CHOR), ingestion of a 7.5% carbohydrate solution (CHOI), a placebo mouth rinse (PLAR) and placebo ingestion (PLAI); solutions were administered every 12.5% of exercise completed. Blood samples and perceptual measures (perceived activation, pleasure-displeasure and ratings of perceived exertion) were taken every 25% of exercise. A profile of mood states questionnaire was also administered prior to the time trial and immediately post exercise. **Results:** There were no significant differences in performance time between treatments (P=0.55). However, there was a main effect of treatment for power output (P=0.002) with higher values in CHOI (231.4 ±9.8 W) relative to other trials (222.1-224.6 W; P<0.05). Plasma glucose was higher in CHOI at 75% (5.4 mmol·L⁻¹) and 100% (5.9 mmol·L⁻¹) of the time trial relative to other trials (3.9-4.7 mmol·L⁻¹; P<0.05). There was a main effect of treatment for insulin (P=0.001) with highest values in CHOI (5.14 mmol·L⁻¹) relative to the other trials (4.2-4.7 mmol·L⁻¹; P<0.05). There were no significant differences reported between treatments for any of the perceptual measures. **Conclusion:** Ingestion of a carbohydrate-electrolyte solution was associated with a decrease in performance time during a 60-min cycling performance time trial in comparison with CHOR, PLAR and PLAI in a glycogen reduced state. This suggests that peripheral and not central effects are largely influenced by the use of a carbohydrate supplement. **Keywords:** fatigue, endurance performance, ergogenic, supplementation, central, peripheral, metabolism, fluid intake
# Table of Contents

Acknowledgements ............................................................................................................................ 22

1.0 Abstract ........................................................................................................................................ 3

Table of Contents .................................................................................................................................. 4

List of Figures ....................................................................................................................................... 6

List of Tables ........................................................................................................................................ 8

2.0 Introduction ...................................................................................................................................... 9

2.1 Hypotheses ..................................................................................................................................... 14

3.0 Literature Review ............................................................................................................................ 15

3.1 Introduction .................................................................................................................................... 15

Key limiting factors of endurance performance ................................................................................ 15

Energy metabolism moderate to high intensity exercise ................................................................ 16

Substrate utilisation ............................................................................................................................ 16

3.2 Fatigue .......................................................................................................................................... 18

Substrate depletion ............................................................................................................................. 19

Central fatigue ................................................................................................................................... 19

Temperature regulation ....................................................................................................................... 20

Dehydration and exercise .................................................................................................................. 21

3.3 Performance .................................................................................................................................. 22

Hydration .......................................................................................................................................... 22

Carbohydrate ingestion and performance ......................................................................................... 22

Endurance capacity ............................................................................................................................ 22

Endurance performance .................................................................................................................... 23

Training with carbohydrate ............................................................................................................... 24

Cognitive ............................................................................................................................................. 25

Carbohydrate ingestion - mechanisms of action .............................................................................. 25

Carbohydrate ingestion perception/mood ......................................................................................... 27

Negative aspects of carbohydrate ingestion ...................................................................................... 30

Taste transduction – process of taste ................................................................................................. 31

Mouth rinsing with carbohydrate ..................................................................................................... 32

Possible mechanisms for ergogenic benefits of mouth rinsing .......................................................... 32

Mouth rinse and performance ............................................................................................................. 33

Conflicting evidence with use of sports mouth rinsing ..................................................................... 35

Application of mouth rinse ................................................................................................................ 37
List of Figures

Figure 4.1: Overview of the experimental protocol

Figure 4.2: Diagrammatic representation of the glycogen reduction exercise protocol

Figure 4.3: Diagrammatic representation of the cycling performance trial

Figure 4.4: Mouth rinse application

Figure 4.5: Blood sampling during performance time trial

Figure 5.1: Mean power output during the performance time trial (mean ±SD; n= 8)

Figure 5.2: Mean performance time (s) of the time trials (mean ±SD; n = 8)

Figure 5.3: Estimated respiratory exchange ratio during exercise. (Mean ±SD; n=8; P=0.39)

Figure 5.4: Plasma glucose concentrations (mmol·L⁻¹) during the cycling time trial for carbohydrate mouth rinse (CHOR), carbohydrate ingestion (CHOI), placebo mouth rinse (PLAR) and placebo ingestion (PLAI) trials (n=8 Mean ± SD). (a = CHOI significantly higher than other time trials at the time point, P<0.05)

Figure 5.5: Plasma insulin concentrations (mU·L⁻¹) during the cycling time trial for carbohydrate mouth rinse (CHOR), carbohydrate ingestion (CHOI), placebo mouth rinse (PLAR) and placebo ingestion (PLAI) trials (n=8 Mean ± SD). (a = CHOI significantly higher than other trials at the time point, P<0.05)

Figure 5.6: C-peptide concentrations (mmol·L⁻¹) during the cycling time trial for carbohydrate mouth rinse (CHOR), carbohydrate ingestion (CHOI), placebo mouth rinse (PLAR) and placebo ingestion (PLAI) trials (n=8 Mean ± SD)

Figure 5.7: Circulating lactate concentrations (mmol·L⁻¹) during the cycling time trial for carbohydrate mouth rinse (CHOR), carbohydrate ingestion (CHOI), placebo mouth rinse (PLAR) and placebo ingestion (PLAI) trials (n=8). (a = CHOI significantly higher than other trials at the time point, P<0.05; Mean ± SD)

Figure 5.8: Free fatty acid (FFA) concentrations (mmol·L⁻¹) during the cycling time trial for carbohydrate mouth rinse (CHOR), carbohydrate ingestion (CHOI), placebo mouth rinse (PLAR) and placebo ingestion (PLAI) trials (n=8 Mean ± SD).

Figure 5.9: Overall profile of mood states (POMS) fatigue subscale results before and immediately post the cycling time trial. Mean (± SD) n=8.
Figure 5.10: Overall profile of mood states (POMS) vigour subscale results before and immediately post the cycling time trial. Mean (± SD) n=8

Figure 5.11: Ratings of perceived exertion (RPE) during trials. Mean (±SD) scores taken every 25% of exercise are shown (n = 8)

Figure 5.12: Change in body mass (%) during trials (mean ±SD; n = 8). (a = significantly different from PLAI and CHOI; P<0.001)

Figure 5.13: Mean (±SD) heart rate (HR) taken every 25% of exercise (n = 8). (Significant time effect of time: a = from rest of exercise to 100%; P<0.05)
List of Tables

Table 3.1: Summary of studies investigating carbohydrate ingestion on exercise performance. (Carbohydrate = CHO; Placebo = PLA)

Table 3.2: Summary of studies investigating carbohydrate mouth rinsing on exercise performance. (Carbohydrate = CHO, Placebo = PLA)

Table 4.1: Typical meal for a subject with a body mass of 70 kg

Table 4.2: Recipes of the trial solutions

Table 5.1: Physiological characteristics of subjects.

Table 5.2: Training activity of the subjects.

Table 5.3: Mean oxygen uptake and relative exercise intensity. Mean (±SD) values of the first 20% to 80% of exercise during the trials are shown (n=8).

Table 5.4: Subjective perceptions of perceived activation (Felt Arousal Scale) and pleasure/displeasure (Feeling Scale) experienced by participants pre exercise and during exercise for each trial (mean ±SD) n = 8.

Table 5.5: The change in plasma volume relative to exercise (mean ±SD; PV data, n=8). (Significant differences: a= from 25% to 100% of exercise; P<0.05; b = from Pre-exercise; c = from ingestion trials; P<0.01)

Table 5.6: Summary of constitutes of the participants’ diet (mean ±SD; data, n=8)