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**The Effects of Sago Supplementation for Exercise in a Warm-Humid  
Environment**

A thesis presented in partial fulfilment of the requirements for the degree of Doctor  
of Philosophy

PhD

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## ABSTRACT

Whilst carbohydrate (CHO) ingestion during exercise with heat stress theoretically has some benefits for performance there is a lack of evidence on the effects of complex-CHO on exercise and recovery in warm-humid (tropical) conditions. The aims of this thesis were to investigate the effects of sago feeding on exercise performance, some physiological parameters, substrate metabolism, and thermoregulatory responses in the condition of exercise with thermal stress. The initial experimental study investigated the reliability of two novel laboratory-based cycling protocols in the presence of significant thermal stress. These protocols would then be employed in the second part of this thesis. The data indicate that the 15 min time-trial pre-loaded with 45 min fixed-intensity (**Chapter 5, Study A**) and 15 min time-trial pre-loaded with 15 min incremental warm-up (**Chapter 5, Study B**) were highly reliable when using trained, familiarized males under warm-humid environmental conditions. The second part of this thesis describes experiments which investigated the efficacy of an alternative Malaysian-based CHO, sago, on exercise in conditions which replicate the Malaysian environment (warm and humid). **Chapter 6** describes a study investigating the effect of sago supplementation before and during exercise in a warm-humid environment. The data collected from this study revealed that pre- and during-sago feeding has no differential effects on exercise performance though sago feeding produced a higher glycaemic response during the hour prior to exercise. However, feeding sago before exercise attenuated the rise in core temperature during exercise compared to the control condition, whilst there was a smaller reduction in plasma volume found when consuming sago during steady-state exercise through reduced whole-body sweating, with a concomitant higher plasma sodium concentration. Heart rate was also higher when sago was ingested either before or during exercise compared to control. Then, **Chapter 7** further investigated the utility of sago ingestion as a recovery meal on a

subsequent exercise bout in a warm-humid environment. In terms of performance, sago ingestion during short-term recovery seemed to sustain time-trial performance on the second bout of exercise compared to a control condition (no food) where exercise performance degraded. However, no attenuation of physiological, metabolic and thermoregulatory responses was apparent.

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## LIST OF ABBREVIATIONS

### A

ANOVA Analysis of variance

### B

Bpm Beats per minutes

### C

CBF cerebral blood flow

°C Degrees Celsius

CHO CHO

CO<sub>2</sub> Carbon dioxide

CNS Central nervous system

CV Coefficient of Variation

### D

### E

EMG Electromyogram

E<sub>max</sub> Maximal evaporative capacity of the environment

### G

g Gram

GE Gross energy

g/min Gram per minute

GI Glycaemic index

### H

h Hour

Hb Haemoglobin

HR<sub>max</sub> Maximum heart rate

<b>I</b>	
ICC	Intraclass correlation
<b>K</b>	
Kg	Kilogram
kJ	Kilojoule
km	Kilometre
km/h	Kilometre per hour
<b>L</b>	
L	Litre
L/min	Litre per minute
LF	Linear factor
LOA	Limit of agreement
<b>M</b>	
m	Metre
min	Minute
ml	Millilitre
ml/kg	Millilitre per kilogram
ml/kg/min	Millilitre per kilogram per minute
mmol	Millimole
mmol/L	Millimole per litre
MCA $V_{\text{mean}}$	Middle cerebral artery mean blood velocity
<b>O</b>	
O <sub>2</sub>	Oxygen
<b>R</b>	
r	Correlation coefficient
RPE	Rating of perceived exertion
RPM	Revolutions per minute
<b>S</b>	
SD	Standard deviation

**T**

$T_{\text{bicep}}$	Skin temperature at the bicep
$T_{\text{calf}}$	Skin temperature at the calf
$T_{\text{chest}}$	Skin temperature at the chest
$T_{\text{core}}$	Core temperature
$T_{\text{SK}}$	Mean skin temperature
$T_{\text{skin}}$	Skin temperature
$T_{\text{thigh}}$	Skin temperature at the thigh
TDF	Total dietary fibre

**V**

$V_{\text{CO}_2}$	Volume of carbon dioxide production
$V_{\text{E}}$	Minute ventilation
$VO_2$	Volume of oxygen uptake
$VO_{2\text{max}}$	Maximal oxygen uptake
$VO_{2\text{peak}}$	Peak of oxygen uptake
$\% VO_{2\text{peak}}$	Percentage of the peak rate of oxygen uptake

**W**

W	Watt
WBGT	Wet bulb globe temperature
$W_{\text{max}}$	Watt maximum

**X**

$\bar{x}$	mean
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