

UNIVERSITI MALAYA

ORIGINAL LITERARY WORK DECLARATION

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Hypohydration during Prolonged Exercise in the Heat

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ABSTRACT

This thesis investigated the effect of hypohydration during prolonged exercise in the heat and the adjustments in the thermoregulatory and cardiovascular control. Four inter-related studies were undertaken. Study One was an observational field study designed to determine the hydration status and practices of elite Kenyan runners (n=11) during competitive distance running events in a tropical environment. Our results show that the elite endurance runners completed their races in warm, very humid climatic conditions with ~3% body weight (BW) loss. They completed their races as the fast finishers in this present study but ran slower than they were capable because of the prevailing heat and humidity. Interestingly, they were able to compensate well by increasing the sweating rate regardless of the amount of fluid ingested or percentage of BW loss in warm conditions. Study Two investigated the effects of hypohydration and simulated hyperhydration on running economy. It was demonstrated that (1) hypohydration did not reduce the oxygen cost of running proportionally with the BW deficit incurred (**D3** and **D4**) and (2) simulated hyperhydration did not increase the oxygen cost of running proportionally with the added gross weight of the runners (**AW3** and **AW4**). Thus despite incurring a decrease in BW, none of the runners in the present study gained any beneficial effect in running economy with hypohydration. The additional oxygen cost was minimised during simulated hyperhydration trials with the added weight evenly distributed around the torso which may be offset by an added contribution from the series and parallel elastic component of muscles and tendons at no additional metabolic cost. In Study Three, the effects of hypohydration on prolonged treadmill running performance in the well controlled hot and cool conditions of a climatic chamber were investigated in 8 male runners. A diuretic (Lasix[®] 1 mg /kg BM) was used to induce ~3% BW deficit. Mild dehydration (~4.5% BW loss) was shown to have a significant effect on endurance performance in hot conditions.

However, this level of dehydration did not adversely affect endurance performance in cool conditions. Study Four addressed the question of whether enhanced heat shock protein (HSP) expression induced via glutamine supplementation is beneficial in offsetting the deleterious effect of hypohydration on exercise performance. The study further investigated whether alanyl glutamine administration offsets the reported prolonged exercise-induced decrease in plasma glutamine concentration. The present study demonstrates alanyl-glutamine ingestion confers protection and enhances plasma HSP 72 expression. Furthermore, ingestion of alanyl-glutamine was associated with an increased time to exhaustion during hot and hypohydrated conditions. In conclusion, this thesis showed that hypohydration (~ 3% BW) placed the circulatory and thermoregulatory systems under considerable physiological strain during prolonged exercise performance in the heat. However, the alanyl-glutamine ingestion conferred protection and enhanced plasma HSP 72 expression which improves thermotolerance in the heat.

ABSTRAK

Tesis ini menyelidik kesan hipohidrasi semasa latihan berpanjangan dalam keadaan panas dan pelarasan kawalan *thermoregulatory* dan kardiovaskular. Empat kajian yang saling berkait telah dijalankan. Kajian Pertama adalah kajian lapangan berbentuk pemerhatian bertujuan untuk menentukan status hidrasi dan amalan pelari elit Kenya (n = 11) semasa pertandingan larian jarak jauh iklim tropika. Keputusan kami menunjukkan bahawa pelari elit menamatkan pertandingan dalam keadaan panas dan kelembapan tinggi dengan kehilangan 3 % berat badan. Mereka memenangi pertandingan dalam kajian ini tetapi berlari lebih perlahan berbanding dengan keupayaan mereka kerana kepanasan dan kelembapan persekitaran. Menariknya, mereka mampu mengimbangi dan meningkatkan kadar berpeluhan tanpa mengambil kira jumlah cecair yang diminum atau peratusan kehilangan berat badan dalam keadaan panas. Kajian Kedua mengkaji hipohidrasi dan simulasi hiperhidrasi terhadap larian ekonomi. Ianya menunjukkan bahawa (1) hipohidrasi tidak mengurangkan kos oksigen larian berkadar dengan defisit berat badan (**D3** dan **D4**), dan (2) simulasi hiperhidrasi tidak meningkatkan kos oksigen larian berkadar dengan tambahan berat badan pada pelari (**AW3** dan **AW4**). Oleh itu, walaupun mengalami penurunan berat badan, tiada pelari dalam kajian ini mendapat manfaat semasa larian ekonomi dengan hipohidrasi. Kos oksigen tambahan telah dikurangkan semasa ujian hiperhidrasi dengan berat badan diagihkan sama rata di sekeliling tubuh yang mungkin diimbangi oleh sumbangan tambahan daripada komponen elastik otot dan tendon yang bersiri dan selari, tanpa mengenakan kos metabolik tambahan. Dalam Kajian Ketiga, kesan hipohidrasi ke atas larian treadmill yang berpanjangan dalam keadaan panas dan sejuk terkawal telah disiasat untuk 8 pelari lelaki. Sejenis diuretik (Lasix[®] 1 mg /kg berat badan) telah digunakan untuk merangsang ~3 % defisit berat badan. Dehidrasi (~ 4.5 % kehilangan berat badan) telah terbukti mempunyai kesan ketara terhadap prestasi ketahanan larian

berpanjangan dalam keadaan panas. Walau bagaimanapun, tahap dehidrasi tidak menjejaskan prestasi ketahanan larian berpanjangan dalam keadaan sejuk. Kajian Keempat memberi perhatian kepada persoalan samada ekspresi *Heat Shock Protein* (HSP) melalui suplemen glutamin bermanfaat dalam mengimbangi kesan berbahaya hipohidrasi terhadap prestasi senaman. Kajian ini selanjutnya menyiasat samada pengambilan alanyl-glutamin ofset penurunan kepekatan glutamin dalam plasma disebabkan oleh senaman berpanjangan. Kajian ini menunjukkan pengambilan alanyl-glutamin memberikan perlindungan dan meningkatkan HSP 72 plasma. Tambahan pula, pengambilan alanyl-glutamin dikaitkan dalam peningkatan tempoh keletihan dalam keadaan panas dan hipohidrasi. Kesimpulannya, tesis ini menunjukkan bahawa hipohidrasi (~ 3 % berat badan) membebankan secara fisiologi sistem peredaran darah dan sistem penyejukan semasa senaman berpanjangan dalam keadaan panas. Walau bagaimanapun, pengambilan alanyl-glutamin memberi perlindungan dan meningkatkan ekspresi HSP 72 plasma yang meningkatkan toleransi termal dalam keadaan panas.

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PREFACE

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TABLE OF CONTENTS

ORIGINAL LITERARY WORK DECLARATION.....	ii
ABSTRACT.....	iii
ABSTRAK.....	v
ACKNOWLEDGEMENTS.....	vii
PREFACE.....	viii
TABLE OF CONTENTS.....	ix
LIST OF FIGURES.....	xxii
LIST OF TABLES.....	xxiii
LIST OF SYMBOLS AND ABBREVIATIONS.....	xxv
CHAPTER 1: INTRODUCTION.....	1
1.1 INTRODUCTION.....	2
CHAPTER 2: LITERATURE REVIEW.....	8
2.1 THE IMPACT OF WEATHER CONDITIONS ON PROLONGED EXERCISE PERFORMANCE.....	9
2.2 RUNNING ECONOMY: EFFECTS OF ACUTE CHANGE IN BODY WEIGHT.....	14
2.3 THERMOREGULATION DURING PROLONGED EXERCISE PERFORMANCE IN THE HEAT.....	20
2.3.1 Core Temperature Measurements.....	20
2.3.2 Evaporative Heat Loss: Sweating.....	24

2.4	HYPOHYDRATION DURING PROLONGED EXERCISE PERFORMANCE IN THE HEAT.....	30
2.4.1	Hydration.....	30
2.4.2	Effects of Hypovolemia and Hyperosmolality on Sweat Rate....	32
2.4.3	Relationship between Hypohydration and Core Temperature....	37
2.4.4	Relationship between Hypohydration and SkinTemperature ...	40
2.4.5	Fluid Replacement during Prolonged Exercise in the Heat.....	42
2.5	CRITICAL CORE TEMPERATURE AND CIRCULATORY STRAIN HYPOTHESES.....	45
2.5.1	Critical Core temperature Hypothesis	45
2.5.2	Circulatory Strain Hypothesis.....	59
2.6	THERMOTOLERANCE, HEAT SHOCK PROTEINS AND GLUTAMINE INGESTION.....	67
2.7	SUMMARY.....	72
	CHAPTER 3: RESEARCH THESIS DESIGN.....	76
3.1	RESEARCH THESIS DESIGN.....	77
	CHAPTER 4: METHODOLOGY.....	81
4.1	ANTHROPOMETRIC MEASUREMENTS.....	82
4.1.1	Height and Weight: Computed Body Mass Index (BMI) and Body Surface Area (A_D).....	82
4.1.2	Skinfold Determination of Thickness: Computed Percentage of Body Fat.....	82
4.2	PRELIMINARY MEASUREMENTS.....	84
4.3.1	Submaximal Exercise Test.....	84

4.2.2	Maximum Oxygen Uptake Test ($\dot{V}O_{2\max}$ Test).....	84
4.3	CARDIORESPIRATORY MEASUREMENTS.....	86
4.3.1	Heart Rate (HR).....	86
4.3.2	Mean Arterial Pressure (MAP).....	86
4.3.3	Oxygen uptake ($\dot{V}O_2$).....	86
4.3.4	Cardiac output (\dot{Q}).....	87
4.3.5	Respiratory Exchange Ratio (RER).....	87
4.4	THERMOREGULATORY MEASUREMENTS.....	89
4.4.1	Skin Temperature (T_{sk}) and Rectal Temperature (T_{re}): Computed Mean Skin Temperature (\bar{T}_{sk}).....	89
4.4.2	Skin Blood Flow (SkBF).....	89
4.5	HYDRATION MEASUREMENTS.....	91
4.5.1	Urine Specific Gravity.....	91
4.5.2	Sweat Loss.....	91
4.6	HAEMATOLOGICAL MEASUREMENTS.....	92
4.6.1	Haemoglobin & Haematocrit: Computed Plasma Volume Changes.....	92
4.6.2	Glucose & Lactate.....	93
4.6.3	Serum Osmolality.....	95
4.6.4	Serum Electrolytes (Na^+ , K^+ , Cl^- , Ca^{2+}).....	95
4.6.5	Plasma Total Protein.....	96
4.6.6	Plasma Viscosity.....	96
4.6.7	Plasma Heat Shock Protein 72.....	97
4.6.8	Plasma Renin.....	97
4.6.9	Plasma Glutamine.....	98

4.7	PERCEPTUAL MEASUREMENTS.....	100
4.7.1	Perceived Thirst Sensation.....	100
4.7.2	Ratings of Perceived Exertion (RPE).....	100
4.7.3	Thermal Comfort Scale.....	100
CHAPTER 5: STUDY ONE.....		101
5.0	HYDRATION STATUS OF ELITE KENYAN DISTANCE RUNNERS COMPETING IN HOT, HUMID CONDITIONS.....	102
5.1	ABSTRACT.....	103
5.2	INTRODUCTION.....	105
5.3	METHODS.....	109
5.3.1	Subjects.....	109
5.3.2	Experimental Procedures.....	109
5.3.3	Statistical Analysis.....	111
5.4	RESULTS.....	112
5.4.1	Environmental Conditions.....	112
5.4.2	Subjects	113
5.4.3	Hydration Level	113
5.4.4	Effect of A_D , Heat Production, Running Speed and Race Time on % BW loss.....	116
5.4.5	Effect of A_D , Heat Production, Running Speed and Race Time on Sweat Rate Responses.....	117
5.5	DISCUSSION.....	118
5.6	REFERENCES.....	128

CHAPTER 6: STUDY TWO.....	133
6.0 THE EFFECTS OF HYPOHYDRATION AND SIMULATED HYPERHYDRATION ON RUNNING ECONOMY.....	134
6.1 ABSTRACT.....	135
6.2 INTRODUCTION.....	136
6.3 METHODS.....	140
6.3.1 Subjects.....	140
6.3.2 Preliminary Testing.....	140
6.3.2.1 Submaximal Exercise Test.....	141
6.3.3 Anthropometric Measurements.....	141
6.3.4 Experimental Design.....	142
6.3.4.1 Experimental Protocol.....	143
6.3.5 Statistical Analysis.....	146
6.4 RESULTS.....	147
6.4.1 Subjects.....	147
6.4.2 Hydration Measurements.....	147
6.4.3 Running Economy.....	149
6.4.5 Cardiorespiratory Responses.....	151
6.4.6 Perceptual Response.....	154
6.5 DISCUSSION.....	155
6.6 REFERENCES.....	165
 CHAPTER 7: STUDY THREE.....	 169
7.0 EFFECT OF DIURETIC-INDUCED DEHYDRATION ON PROLONGED RUNNING PERFORMANCE IN HOT AND COOL CLIMATIC CONDITIONS.....	170

7.1	ABSTRACT.....	171
7.2	INTRODUCTION.....	173
7.3	METHODS.....	175
7.3.1	Subjects.....	175
7.3.2	Anthropometric Measurements.....	176
7.3.3	Preliminary Testing.....	176
7.3.4	Experimental Design.....	177
7.3.4.1	Experimental Protocol.....	178
7.3.4.2	Hydration Measurements.....	181
7.3.4.3	Cardiorespiratory Measurements.....	182
7.3.4.4	Thermoregulatory Measurements.....	183
7.3.4.5	Haematological Measurements.....	184
7.3.4.6	Subjective Reporting.....	185
7.3.5	Statistical Analysis.....	185
7.4	RESULTS.....	186
7.4.1	Time to Exhaustion.....	186
7.4.2	Hydration Status.....	187
7.4.3	Cardiorespiratory Responses.....	189
7.4.4	Thermoregulatory Responses.....	192
7.4.5	Haematological Responses.....	195
7.4.6	Subjective Responses.....	198
7.5	DISCUSSION.....	200
7.6	REFERENCES.....	209

CHAPTER 8: STUDY FOUR.....	212
8.0 EFFECT OF ALANYL-GLUTAMINE INGESTION ON PROLONGED RUNNING PERFORMANCE IN HOT AND HYPOHYDRATED CONDITIONS.....	213
8.1 ABSTRACT.....	214
8.2 INTRODUCTION.....	215
8.3 METHODS.....	219
8.3.1 Subjects.....	219
8.3.2 Anthropometric Measurements.....	219
8.3.3 Preliminary Testing.....	220
8.3.4 Experimental Design.....	220
8.3.4.1 Experimental Protocol.....	221
8.3.4.2 Hydration Measurements.....	224
8.3.4.3 Cardiorespiratory Measurements.....	224
8.3.4.4 Thermoregulatory Measurements.....	225
8.3.4.5 Haematological Measurements.....	225
8.3.4.6 Subjective Reporting.....	227
8.3.5 Statistical Analysis.....	227
8.4 RESULTS	228
8.4.1 Performance Time and Plasma [Glutamine].....	228
8.4.2 Hydration Status.....	229
8.4.3 Cardiorespiratory Responses.....	229
8.4.4 Thermoregulatory Responses.....	232
8.4.5 Haematological Responses.....	233
8.4.6 Subjective Responses.....	238
8.5 DISCUSSION.....	240

8.6	REFERENCES.....	246
CHAPTER 9: KEY FINDINGS & RECOMMENDATIONS.....		250
9.0	KEY FINDINGS.....	251
9.0.1	Hypohydration and Prolonged Exercise Performance (Study One).....	251
9.0.2	Running Economy in a Hypohydrated and Simulated Hyperhydrated State (Study Two).....	251
9.0.3	Hypohydration and Hyperthermia: Circulatory and Thermoregulatory responses (Study Three).....	252
9.0.4	Hypohydration and Thermotolerance (Study Four).....	253
9.1	RECOMMENDATIONS.....	254
REFERENCES (CHAPTER 1, 2, 4).....		255
APPENDICES (Attached CD)		

LIST OF FIGURES

Figure 1.1	Influence of dehydration, as assessed by percent reduction in body weight after 2 hours of exercise, on change in cardiac output, heart rate, stroke volume, forearm blood flow during exercise (Montain & Coyle, 1992b).....	3
Figure 2.1	Nomogram showing the potential performance decrement (y-axis) based on projected marathon finishing time (x-axis) with increasing WBGT (Ely <i>et al.</i> , 2007).....	11
Figure 2.2	The 12 annual races of the Twin Cities Marathon from 1997 to 2008 showing unsuccessful runners per 1000 finishers plotted against start WBGT shows increasing risk with WBGT above 13°C. About 100-120 unsuccessful starters per 1000 finishers is borderline for a mass casualty incident (i.e. an event that produces more patients than available resources, such as ambulances and emergency room beds (Roberts, 2010).....	11
Figure 2.3	The effect of added weight in improving the $\dot{V}O_2$ cost of running in boys (aged 12-13 years). This illustrates that with added vertical load equivalent to 5% and 10% of bodyweight, there is not a proportional increase in $\dot{V}O_2$ that might be expected (Davies, 1980).....	17
Figure 2.4	Rectal and esophageal temperature responses to rest and exercise in the heat (Sawka <i>et al.</i> , 1988).....	22
Figure 2.5	Steady-state values of sweat rate plotted against the corresponding mean skin temperature values (Nielsen, 1969).....	25
Figure 2.6	Influence of a skin cooling paradigm on heart rate with a constant core temperature during light-intensity treadmill walking exercise (Cheuvront <i>et al.</i> , 2003b)	27

Figure 2.7	Schematic diagram showing the idealized effector response, (e.g., sweating rate and SkBF) to increasing T_{ws} using forcing function analysis with linear plots (Gisolfi & Wenger, 1984).....	28
Figure 2.8	The slope of the sweating rate-to- T_{es} relationship was significantly reduced during hypovolemia for one typical subject (Fortney <i>et al.</i> , 1981b).....	34
Figure 2.9	Mean skin temperature (\bar{T}_{sk} , °C), rectal temperature (T_{re} , °C) and sweat loss (g) of 10 well trained subjects during 4h treadmill exercise (Thompson, 1984).....	36
Figure 2.10	Percentage decrement in submaximal aerobic performance from euhydration as a function of skin temperature when hypohydrated by 3-4% of body mass (Sawka <i>et al.</i> , 2012).....	41
Figure 2.11	Esophageal temperature plotted against time. One acclimating subject during ten consecutive days of exercise until exhaustion at 40°C (Nielsen <i>et al.</i> , 1993).....	46
Figure 2.12a	Esophageal temperature (A), mean skin temperature (B), heart rate (C) and skin blood flow (D) during exercise in heat (40°C, 17% rh) during precooling, control, and preheating trials (González-Alonso <i>et al.</i> , 1999b).....	49
Figure 2.12b	Heart rate (A), cardiac output (B), stroke volume (C), skin blood flow (D), and forearm blood flow (E) plotted against core temperature during precooling, control, and preheating trials (González-Alonso <i>et al.</i> , 1999b).....	49
Figure 2.13	Voluntary activation percent (A) and force production (B) during a 20 s maximal voluntary isometric contraction of the knee extensors with superimposed electrical stimulation at 5, 12 and 19 s prior to and	

	following self-paced exercise in hot and cool conditions (Périard <i>et al.</i> , 2011).....	53
Figure 2.14	Individual core temperature response of 18 runners during the half marathon, presented in order of finishing time: (A) 105-111min, N =6; (B) 111-117 min, N=6; (C) 122-146 min, N=6 (Byrne <i>et al.</i> , 2006).....	56
Figure 2.15	New perspective regarding mechanisms for cardiovascular drift during prolonged exercise under conditions of maintained cardiac output and how it is exacerbated by dehydration, which acts primarily by causing hyperthermia (i.e., increased body core temperature) and hypovolemia (i.e., decreased blood volume) (Coyle & González-Alonso, 2001).....	62
Figure 2.16	A redrawn summary of the effects of dehydration and concomitant hyperthermia from González-Alonso <i>et al.</i> (1995) (Coyle & González-Alonso, 2001).....	66
Figure 3.1	Thesis Research Design.....	79
Figure 5.1	Ambient temperature and relative humidity measurements during the Standard Chartered Kuala Lumpur (SCKL) marathon 2009.....	112
Figure 5.2	Relationship between the body surface area (A_D , m^2) and the percentage change of body weight loss in elite (n=11) during different competitive distance running events (Full Marathon and Half Marathon).....	116
Figure 5.3	Relationship between the race time (min) and the sweat rate ($L \cdot hr^{-1}$) in elite Kenyan runners (n=11) during different competitive distance running events (Full Marathon and Half Marathon).....	117
Figure 5.4	Relationship between the change in performance time and ambient temperature during Boston Marathon (1958-1987) (Trapasso & Cooper, 1989) and the present study (Subject 1, 3, 4, 7, 10, 11).....	121
Figure 6.1	Schematic representation of experimental design for AW trials and D trials.....	143

Figure 6.2	$\dot{V}O_2$ (mL.kg ⁻¹ .min ⁻¹ , mL.kg ^{-0.75} .min ⁻¹), caloric unit cost, C_R (kcal.kg ⁻¹ .km ⁻¹) and gross oxygen cost of running (mL.kg ⁻¹ .km ⁻¹) at running velocities that elicit 65, 70, 75 and 80% $\dot{V}O_{2max}$ during D trials (n=8).....	150
Figure 6.3	$\dot{V}O_2$ (mL.kg ⁻¹ .min ⁻¹ , mL.kg ^{-0.75} .min ⁻¹), caloric unit cost, C_R (kcal.kg ⁻¹ .km ⁻¹) and gross oxygen cost of running (mL.kg ⁻¹ .km ⁻¹) at running velocities that elicit 65, 70, 75 and 80% $\dot{V}O_{2max}$ during AW trials (n=8).....	151
Figure 6.4	Heart rate (beats.min ⁻¹), oxygen pulse (mL.beats ⁻¹) and pulmonary ventilation (L.min ⁻¹) at running velocities that elicit 65, 70, 75 and 80% $\dot{V}O_{2max}$ during D trials (n=8).....	152
Figure 6.5	Heart rate (beats.min ⁻¹), oxygen pulse (mL.beats ⁻¹) and pulmonary ventilation (L.min ⁻¹) at running velocities that elicit 65, 70, 75 and 80% $\dot{V}O_{2max}$ during AW trials (n=.....)	153
Figure 6.6	RPE at running velocities that elicit 65, 70, 75 and 80% $\dot{V}O_{2max}$ during D trials (n=8).....	154
Figure 6.7	RPE at running velocities that elicit 65, 70, 75 and 80% $\dot{V}O_{2max}$ during AW trials (n=8).....	154
Figure 6.8	Comparison of the running economy data ($\dot{V}O_2$, mL.kg ⁻¹ .min ⁻¹) in our subjects (AW0 and D0 trials) and with previous research (Spurrs <i>et al.</i> , 2003; Saunders <i>et al.</i> , 2004).....	161
Figure 7.1	Schematic representation of the experimental design and protocols for four experimental trials (E20 , E35 , D35 and D10).....	178
Figure 7.2	Time to exhaustion during four experimental trials (E20 , euhydrated in 20°C; D10 , dehydrated in 10°C; E35 , euhydrated in 35°C; D35 , dehydrated in 35°C).....	186

Figure 7.3	Heart rate, stroke volume and cardiac output responses during PETs...	190
Figure 7.4	Mean arterial pressure (MAP) prior to the diuretic administration (baseline), at 0, 30 and the final point of exhaustion during PETs.....	191
Figure 7.5	Mean oxygen uptake ($\dot{V}O_2$) prior to the diuretic administration (baseline), at 0, 10, 30, 60-min and the final point of exhaustion during PETs.....	191
Figure 7.6	Rectal temperature (A), mean skin temperature (B) and core-to-skin temperature ($T_{re}-T_{sk}$) gradient (C) during PETs.....	193
Figure 7.7	Skin blood flow (SkBF) at 0, 10, 30, 60-min and the final point of exhaustion during PETs.....	194
Figure 7.8	Plasma volume changes prior to the diuretic administration, at 0, 10, 30, 60- min and final point of exhaustion during PETs.....	195
Figure 7.9	Rating of perceived exertion and thermal comfort scale prior to the diuretic administration (baseline), at 10 min intervals during PETs.....	199
Figure 8.1	Schematic representation of the experimental trials protocol.....	223
Figure 8.2	Seven subjects' individual performance time and plasma [Glutamine] mean \pm SD during three experimental trials (CON , euhydrated in 35°C; GLUT , dehydrated in 35°C; PCB , dehydrated in 35°C).....	228
Figure 8.3	Rectal temperature (T_{re}) measurements during exercise in CON , GLUT and PCB trials.....	232
Figure 8.4	Plasma volume changes after the exercise-heat exposure protocol and during exercise in CON , GLUT and PCB	233
Figure 8.5	Percentage changes of plasma heat shock protein (HSP) 72 in CON , GLUT and PCB trials.....	234

Figure 8.6	Rating of perceived exertion (RPE), thirst sensation and thermal comfort scale during exercise in CON , GLUT and PCB	239
Figure 8.7	Relationship between percentage change of plasma HSP and percentage change of plasma [Glutamine] from 0 min to point of exhaustion during exercise in CON , GLUT and PCB trials.....	243

LIST OF TABLES

Table 2.1	Summary of González-Alonso <i>et al.</i> s' studies (1995 and 1997) investigating the effect of dehydration and hyperthermia during prolonged exercise	64
Table 2.2	Cellular locations and proposed functions of mammalian heat shock protein families (Kregel, 2002).....	67
Table 5.1	Environmental conditions during the different competitive distance events.....	112
Table 5.2	General characteristics of the Kenyan distance runners in Standard Chartered Kuala Lumpur (SCKL) Marathon 2009.....	114
Table 5.3	Descriptive data on running performance and hydration level on each individual elite Kenyan runner (n=11) that completed 42.2 km and 21.1 km in SCKL Marathon 2009.....	115
Table 5.4	Comparison between current performance time and the previous best performance time in 7 elite Kenyan runners.....	119
Table 6.1	Four relative running intensities ($\% \dot{V}O_{2\max}$ – ml. kg ⁻¹ . min ⁻¹) which performed by the added weight (AW) and the dehydration (D) groups during the running economy tests.....	142
Table 6.2	Mean \pm SD for physical and physiological characteristics of added weight (AW) and dehydration (D) participant groups.....	147
Table 6.3	Mean \pm SD for hydration measurements prior to each RE test in both Added Weight (AW) and Dehydration (D) trials.....	148
Table 6.4	Relationship between running economy and running velocity during AW (n=8) and D (n=8) trials.....	149

Table 7.1	Mean \pm SD for physical and physiological characteristics of the subjects.....	175
Table 7.2	Hydration status determined by percentage change of body mass, urine specific gravity, sweat rate, and fluid intake during PETS.....	188
Table 7.3	Haematological Responses during PETS.....	197
Table 8.1	Hydration status determined by percentage changes of body mass, urine specific gravity (USG), sweat rate, and fluid intake during CON , GLUT and PCB trials.....	230
Table 8.2	Oxygen uptake and heart rate measurements during CON , GLUT and PCB trials.....	231
Table 8.3	Haematological Responses during PETS.....	236

LIST OF SYMBOLS AND ABBREVIATIONS

a-vO ₂ diff	arteriovenous oxygen differences
ANCOVA	analysis of covariance
ANOVA	analysis of variance
beats.min ⁻¹	beats per minute
BMI	body mass index
BV	blood volume
BW	body weight
Ca ²⁺	calcium
CO ₂	carbon dioxide
°C	degrees Celsius
cm	centimeter
CV	coefficient of variation
CVC	cutaneous vascular conductance
Cl ⁻	Chloride
DBP	diastolic blood pressure
G	gram
GLN	glutamine
GLU	glutamate
Hb	haemoglobin
Hct	haematocrit
HR	heart rate
HR _{max}	maximum heart rate
HSP	heat shock protein
K ⁺	potassium
kg	kilogram

km	kilometer
km.hr ⁻¹	kilometer per hour
LDH	lactate dehydrogenase
L.hr ⁻¹	litre per hour
L.min ⁻¹	litre per minute
m	metre
m ²	square metre
MAP	mean arterial pressure
min	minutes
mL	millilitre
mL.beat ⁻¹	millilitres per beat
mL.kg ⁻¹ .min ⁻¹	millilitres per kilogram per minute
mmHg	millimetres of mercury
mmol	millimoles
μL	microlitre
n	number of subjects
Na ⁺	sodium
NS	statistically non-significant
nm	nanometre
O ₂	oxygen
PET	prolonged exercise testing
PV	plasma volume
%	percent
% HR _{max}	percentage of maximum heart rate
% rh	percent relative humidity
% ΔPV	percentage changes of plasma volume

\dot{Q}	cardiac output
RER	respiratory exchange ratio
rh	relative humidity
RPE	ratings of perceived exertion
s	seconds
SBP	systolic blood pressure
SD	standard deviation
SkBF	skin blood flow
STD	standard
SV	stroke volume
USG	urine specific gravity
T_{core}	core temperature
T_{re}	rectal temperature
\bar{T}_{sk}	mean skin temperature
VE	ventilation
$\dot{V}O_2$	oxygen consumption
$\dot{V}O_{2\text{max}}$	maximal oxygen uptake
WBGT	wet bulb globe temperature
yr	year