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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 hipohydration 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...
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PREFACE

Results culminating from the studies of this thesis which have been presented at scientific conferences:


   *Awarded Young Investigator Award (YIA) Travel Grant*


   *Awarded Young Investigator Award (YIA) Travel Grant*

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<tr>
<td>a-vO$_2$diff</td>
<td>arteriovenous oxygen differences</td>
</tr>
<tr>
<td>ANCOVA</td>
<td>analysis of covariance</td>
</tr>
<tr>
<td>ANOVA</td>
<td>analysis of variance</td>
</tr>
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<td>beats.min$^{-1}$</td>
<td>beats per minute</td>
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<td>GLN</td>
<td>glutamine</td>
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<tr>
<td>GLU</td>
<td>glutamate</td>
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<tr>
<td>Hb</td>
<td>haemoglobin</td>
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<tr>
<td>Hct</td>
<td>haematocrit</td>
</tr>
<tr>
<td>HR</td>
<td>heart rate</td>
</tr>
<tr>
<td>HR$_{max}$</td>
<td>maximum heart rate</td>
</tr>
<tr>
<td>HSP</td>
<td>heat shock protein</td>
</tr>
<tr>
<td>K$^+$</td>
<td>potassium</td>
</tr>
<tr>
<td>kg</td>
<td>kilogram</td>
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</table>
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
m² : 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 : milimetres of mercury
mmoL : milimoles
μL : microlitre
n : number of subjects
Na⁺ : sodium
NS : statistically non-significant
nm : nanometre
O₂ : oxygen
PET : prolonged exercise testing
PV : plasma volume
% : percent
% HRₘₐₓ : percentage of maximum heart rate
% rh : percent relative humidity
% ΔPV : percentage changes of plasma volume
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>$\dot{Q}$</td>
<td>cardiac output</td>
</tr>
<tr>
<td>RER</td>
<td>respiratory exchange ratio</td>
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<tr>
<td>rh</td>
<td>relative humidity</td>
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<tr>
<td>RPE</td>
<td>ratings of perceived exertion</td>
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<tr>
<td>s</td>
<td>seconds</td>
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<tr>
<td>SBP</td>
<td>systolic blood pressure</td>
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<tr>
<td>SD</td>
<td>standard deviation</td>
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<tr>
<td>SkBF</td>
<td>skin blood flow</td>
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<tr>
<td>STD</td>
<td>standard</td>
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<tr>
<td>SV</td>
<td>stroke volume</td>
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<tr>
<td>USG</td>
<td>urine specific gravity</td>
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<td>$T_{\text{core}}$</td>
<td>core temperature</td>
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<td>$T_{\text{re}}$</td>
<td>rectal temperature</td>
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<tr>
<td>$\bar{T}_{\text{sk}}$</td>
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<td>VE</td>
<td>ventilation</td>
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<tr>
<td>$\dot{V}O_2$</td>
<td>oxygen consumption</td>
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<tr>
<td>$\dot{V}O_{2\text{max}}$</td>
<td>maximal oxygen uptake</td>
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<tr>
<td>WBGT</td>
<td>wet bulb globe temperature</td>
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<tr>
<td>yr</td>
<td>year</td>
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