HYDRATION STATUS OF HIGH PERFORMANCE NEW
ZEALAND RUGBY UNION PLAYERS IN A MATCH
CONTEXT

Anna Jane Watson

A thesis submitted in partial fulfilment of the
requirements for the degree of

Master of Science
in
Nutritional Science

Massey University, Albany, Auckland,
New Zealand

2005
The changes in body mass and urinary specific gravity of 24 rugby union players in the New Zealand Super12 development championship, were measured during five actual matches. The climatic conditions measured were ambient temperature, relative humidity and wind speed. All subjects participating in this study regardless of playing time showed a loss in body mass after each game. Fluid was available from bottles during formal breaks in play and during the ten-minute break at half time. The mean percentage of drink breaks utilised was only 48%, however this varied between games. The average change in body mass, or fluid deficit, of participants playing 60 minutes of rugby or more was calculated to be 1.87% ± 0.19% (SEM), and the range was 0.10% to 4.61%. Urine analysis for specific gravity supported the fluid deficit data, as the average urine specific gravity for players participating in 60 minutes of rugby was 1.025 and therefore considered to be dehydrated.

Final hydration status is related to the length of time a player is on the field, however even reserve players showed a loss of body mass between the pre-match to the post-match weigh-in.

The level of fluid deficit varied between players and for positional groups between games. However, It was observed that some players were
consistently dehydrated to a high level. This indicates individual fluid ingestion strategies are required to meet the needs of each player in a team.

Given the limited opportunities to replace fluid losses during rugby union, there is potential for heat stress and related illnesses to occur, however serious illness is unlikely. Dehydration can also cause impairment of both physical and mental performance, a reduced exercise capacity and impairment in temperature regulation. Rugby union players in this study were dehydrated to a level where performance may have been impaired, although future research is required to determine the level of fluid deficit at which performance impairment occurs during a rugby union match.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Number</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of figures</td>
<td>v</td>
</tr>
<tr>
<td>List of tables</td>
<td>vii</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>ix</td>
</tr>
<tr>
<td>ABBREVIATIONS</td>
<td>x</td>
</tr>
</tbody>
</table>

## 1 INTRODUCTION

1.1.1 Fatigue, hypohydration and hyperthermia | 1 |
1.1.2 Rugby Union | 2 |
1.1.3 Study aims | 4 |
1.1.4 Study objectives | 4 |

## 2 LITERATURE REVIEW

2.1 SEARCH METHODS | 6 |
2.2 BACKGROUND | 6 |
2.3 TEMPERATURE REGULATION AND FLUID HOMEOSTASIS | 8 |
2.3.1 Exercise and thermoregulation | 9 |
2.3.2 Body water and fluid balance | 12 |
2.3.3 Fluid loss | 16 |
2.3.4 Measurement of fluid loss | 18 |
2.3.5 Fluid intake and absorption | 21 |
2.3.5.1 Gastric emptying of the stomach | 23 |
2.3.5.2 Absorption in the small intestine | 25 |
2.3.5.3 Fluid intake | 27 |
2.3.6 Fluid balance regulation in the kidneys | 28 |
2.3.7 Hyponatremia and physiological function | 31 |

2.4 EFFECTS OF DEHYDRATION AND HYPERThERMIA ON PERFORMANCE | 34 |
2.4.1 Exercise performance and hypohydration | 35 |
2.4.1.1 Physical work capacity | 35 |
2.4.1.2 Aerobic power | 37 |
2.4.1.3 Speed and sprint performance | 38 |
2.4.1.4 Skills related to team sports | 38 |
2.4.1.5 Strength and power | 40 |
2.4.1.6 Physical performance | 40 |
2.4.2 Cognitive function and dehydration | 41 |
2.4.3 Hyperthermia and performance | 43 |

## 2.5 INTERMITTENT EXERCISE | 45 |
4.2.2 Urinary value (UV) ..........................................................95
4.3 VOLUNTARY DRINKING FREQUENCY OF BD > 60 ..........98
4.4 GAME STATISTICS .................................................................101
4.4.1 Hydration status .............................................................103
4.5 DIETARY ASSESSMENT .........................................................106
4.6 DURATION OF PLAYING TIME AND HYDRATION
STATUS ..................................................................................111
4.7 DATA FROM THE NATIONAL PROVISIONAL
CHAMPIONSHIP (NPC) 2003 SEASON .................................112

5 DISCUSSION .............................................................................114
5.1 BODY COMPOSITION ............................................................115
5.2 HYDRATION STATUS ..............................................................117
5.2.1 Player position .................................................................120
5.2.2 Pre-match hydration status ..............................................121
5.2.3 Game variables and environmental conditions .................122
5.3 DRINKING FREQUENCY .........................................................123
5.3.1 First and second half drinking frequency ...........................124
5.3.2 Hydration status ...............................................................125
5.3.3 Exercise intensity ............................................................125
5.3.4 Environmental conditions ...............................................126
5.4 DURATION OF EXERCISE .......................................................127
5.5 PRE-MATCH DIETARY ASSESSMENT .................................128
5.5.1 Carbohydrate .................................................................128
5.5.2 Protein ...............................................................................129
5.5.3 Fat .......................................................................................130
5.5.4 Other nutrients and non-nutrients ..................................130
5.5.5 Fluid intake .................................................................133
5.5.6 Pre-match diet recommendations ..................................135
5.6 LIMITATIONS ........................................................................137
5.6.1 Body mass measurement ................................................139
5.6.2 Fluid intake measurement ..............................................141
5.6.3 Fluid loss and sweat rates ...............................................142
5.6.4 Urinary analysis ...............................................................143
5.6.5 Game variables ...............................................................144
5.6.5.1 Climatic conditions ....................................................144
5.6.5.2 Variability of competition ............................................145
5.6.5.3 Variability of players within a team ...............................145
5.6.6 Dietary analysis ...............................................................146
5.7 RECOMMENDATIONS FOR FUTURE STUDIES .................147
5.7.1 Dietary habits of Rugby players .......................................147
5.7.2 Fluid intake .................................................................148
5.7.3 Factors influencing fluid deficit .......................................149
5.7.4 Dehydration and performance .........................................149
5.8 CONCLUSION .......................................................................150

REFERENCES ..............................................................................154
APPENDICES .................................................. 176

APPENDIX A
   Self-testing program for optimal hydration .................. 177

APPENDIX B
   Sweat rate guidelines for running and cycling ................ 178
   Sweat rate guidelines for a variety of team sports .......... 179

APPENDIX C .............................................................. 180
   Information sheet ................................................... 181
   Consent form ......................................................... 183

APPENDIX D - Schedule of events .................................. 184

APPENDIX E - Combustion® Test® Brochure ..................... 185

APPENDIX F - DATA COLLECTION SHEETS ........................ 186
   Anthropometry data collection .................................... 187
   Player weight & urinary measurements ......................... 188
   Drinking score sheet ............................................... 189

APPENDIX G - Description of somatotypes ....................... 190

APPENDIX H - Beaufort wind scale ................................ 191

APPENDIX I - 24 hr food record booklet .......................... 192

APPENDIX J - RAW DATA ............................................. 195
   Anthropometric data ................................................. 196
   Body mass data ....................................................... 197
   Urinary value data .................................................. 198
   Drinking frequency data .......................................... 199
   24-hr Dietary analysis .............................................. 200
**LIST OF FIGURES**

<table>
<thead>
<tr>
<th>Number</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1-1. Rugby union player numbers (in thousands) of five top rugby playing nations[10]</td>
<td>3</td>
</tr>
<tr>
<td>Figure 2-1. Potential for heat production and dissipation during exercise. Adapted from Maughan and Nadel (2000) [28]</td>
<td>10</td>
</tr>
<tr>
<td>Figure 2-2. Partitioning of body water as reviewed by Sawka and Pandolf</td>
<td>16</td>
</tr>
<tr>
<td>Figure 2-3. Distribution of fluid absorption percentages in the intestine of any given fluid load</td>
<td>26</td>
</tr>
<tr>
<td>Figure 2-4. The regulation of water resorption in the kidneys by antidiuretic hormone ADH</td>
<td>29</td>
</tr>
<tr>
<td>Figure 2-5. Regulation of sodium levels. Low sodium plasma levels activate the mechanisms involved in sodium conservation in the kidneys. Renin increases angiotensin, which increases aldosterone</td>
<td>31</td>
</tr>
<tr>
<td>Figure 2-6. Physiological changes during exercise with and without fluid replacement</td>
<td>33</td>
</tr>
<tr>
<td>Figure 2-7. Pathophysiology of cognitive dysfunction in moderate and severe hypohydration</td>
<td>42</td>
</tr>
<tr>
<td>Figure 2-8. Hydration and beverage recommendations for various durations of exercise. Adapted from Maughan (2000)</td>
<td>64</td>
</tr>
<tr>
<td>Figure 3-1. Likert scale showing assigned Urinary Value (UV) to Urinary specific gravity (Usg) reading</td>
<td>88</td>
</tr>
<tr>
<td>Figure 4-1. Scatterplot of body mass and body fat percentage showing positive correlation between the two measurements</td>
<td>91</td>
</tr>
<tr>
<td>Figure 4-2. Bar chart of absolute and relative BM losses in subjects playing over 60 minutes of rugby (BD &gt; 60) for all matches</td>
<td>93</td>
</tr>
<tr>
<td>Figure 4-3. Relationship between change in BM of the positional groups (FW and BK) and game points differential</td>
<td>94</td>
</tr>
<tr>
<td>Figure 4-4. Distribution of overall ABM results, expressed as a percentage of pre-match weight lost</td>
<td>95</td>
</tr>
<tr>
<td>Figure 4-5. Scatter Plot showing the lack of a relationship between Post-match UV and Pre-match UV</td>
<td>96</td>
</tr>
</tbody>
</table>
Figure 4-6. Scatterplot with linear trendline of weight change (decrease in % of pre-match weight) and change in urinary value, showing a strong positive correlation between the measurements.................................................................97

Figure 4-7. Distribution of overall post-match urinary values.................................98

Figure 4-8. Distribution of drink breaks being utilised in all drinking frequency data collected.................................................................99

Figure 4-9. Correlation between drinking frequency (mean number of drinks taken and game point differential).................................100

Figure 4-10. Correlations between wind speed and urinary values......................104

Figure 4-11. Correlation between the number of drink breaks available during a game and the percentage of players losing over 1.8% of BM .................................................................105

Figure 4-12. Distribution of energy percentage obtained from fat (polyunsaturated, monounsaturated and saturated), protein and carbohydrate in the 24-hour food records submitted by members of the Blues development team 2003 .................................................................107

Figure 4-13. Correlation between pre-match fluid intake and pre-match urine sample.................................................................108

Figure 4-14. Scatter plot with linear trendline showing positive correlation between CHO intake and fluid intake (green) and negative correlation between CHO intake and pre-match UV (purple).................................109

Figure 4-15. Scatter plot with linear trendline showing positive correlation between fat intake and fluid intake (green) and negative correlation between fat intake and pre-match UV (purple) ...............110

Figure 4-16. Correlation between change in body mass and minutes played. For players participating in a full half or more.................................................................112

Figure 4-17. Distribution of ΔBM, % in the North Harbour NPC 2003 team ..................................................................................................................113

Figure 5-1. Relationship between absolute 24-hr pre-match fluid intake and drinking frequency during a match .........................................................134

Figure 5-2. Example of a likert scale for perceived physical effort....................145
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Number</th>
<th>Table 2-1: Comparison of water loss from the body at rest in a cool environment and during prolonged exercise.</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>Table 2-2: Distribution of water in the body</td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>Table 2-3: Major electrolytes and the concentrations in plasma, sweat and muscle</td>
<td></td>
<td>18</td>
</tr>
<tr>
<td>Table 2-4: Types, symptoms and treatment of heat related illnesses</td>
<td></td>
<td>34</td>
</tr>
<tr>
<td>Table 2-5: Average values for rugby union players for body mass, height and somatotype</td>
<td></td>
<td>47</td>
</tr>
<tr>
<td>Table 2-6: Percentage of time the four positional groups spent in three exertion zones, expressed as a percentage of HRmax</td>
<td></td>
<td>48</td>
</tr>
<tr>
<td>Table 2-7: Summary of distance covered for each position group, in each of three classifications of movement</td>
<td></td>
<td>49</td>
</tr>
<tr>
<td>Table 2-8: Comparison of rectal temp, sweat loss and water deficit in the 1981 and 1985 study</td>
<td></td>
<td>51</td>
</tr>
<tr>
<td>Table 2-9: Percentage body water loss in groups with heat related illnesses (HRI) and no heat related illnesses (HRI)</td>
<td></td>
<td>53</td>
</tr>
<tr>
<td>Table 2-10: Advantages and disadvantages of commonly used data collection methods for dietary assessment</td>
<td></td>
<td>74</td>
</tr>
<tr>
<td>Table 2-11: Recommendations for strength athletes competing in moderate duration exercise</td>
<td></td>
<td>77</td>
</tr>
<tr>
<td>Table 3-1: Blues development schedule</td>
<td></td>
<td>80</td>
</tr>
<tr>
<td>Table 4-1: Physical characteristics of the Blues Development team 2003, represented as mean values for body mass (BM), height, body fat and somatotype</td>
<td></td>
<td>90</td>
</tr>
<tr>
<td>Table 4-2: Game number, venue, date, kickoff time, result of game, number of drink breaks available and environmental conditions at the time of game for each match</td>
<td></td>
<td>101</td>
</tr>
</tbody>
</table>
Table 4-3. Individual game values grouped into forwards, backs and entire team (total), for body mass changes, hydration status and voluntary drinking rates ................................................................. 102

Table 4-4. Mean, median and range of macronutrient values for all players completing a self-reported 24-hour food records .................. 106

Table 5-1. Comparison of Blues Development 2003 players and average values for rugby players ..................................................... 116

Table 5-2. UV and ΔBM data collected from subject BD0308 .................. 119

Table 5-3. Average amount of various nutrients consumed in the 24-hr period preceding match 4, comparing to RDI’s for adult males .... 132
ACKNOWLEDGMENTS

I would like to thank the following people for the valuable assistance and support they provided during this research project. Dr Clare Wall for her assistance and knowledge, Jonathan Folland for his enthusiasm, Mark Harvey for his guidance and the players and staff of the Blues Development team 2003, Nicola Hart for the loan of equipment, Jason Blackmore for his valuable assistance with recording data during the initial stages and Alistair Rhodes for his help and patience in the final stages.

I would also like to thank Ken Quarrie and the New Zealand Rugby Union for providing funding for this research project.
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACSM</td>
<td>American College of Sports Medicine</td>
</tr>
<tr>
<td>ADH</td>
<td>Antidiuretic hormone</td>
</tr>
<tr>
<td>BD</td>
<td>Blues development</td>
</tr>
<tr>
<td>BD &lt;60</td>
<td>Group of BD playing less than 60 minutes</td>
</tr>
<tr>
<td>BD &gt; 60</td>
<td>Group of BD playing less than 60 minutes</td>
</tr>
<tr>
<td>BIA</td>
<td>Bioelectrical impedance</td>
</tr>
<tr>
<td>BM</td>
<td>Body mass</td>
</tr>
<tr>
<td>CES</td>
<td>Carbohydrate electrolyte solution</td>
</tr>
<tr>
<td>CRT</td>
<td>Choice reaction time</td>
</tr>
<tr>
<td>ΔBM</td>
<td>Change in body mass</td>
</tr>
<tr>
<td>CHO</td>
<td>Carbohydrate</td>
</tr>
<tr>
<td>GER</td>
<td>Gastric emptying rate</td>
</tr>
<tr>
<td>HRI</td>
<td>Heat related illness</td>
</tr>
<tr>
<td>IRB</td>
<td>International Rugby Board</td>
</tr>
<tr>
<td>MART</td>
<td>Maximal anaerobic running test</td>
</tr>
<tr>
<td>NZRU</td>
<td>New Zealand Rugby Union</td>
</tr>
<tr>
<td>ORS</td>
<td>Oral rehydrating solution</td>
</tr>
<tr>
<td>RDA</td>
<td>Recommended daily allowance</td>
</tr>
<tr>
<td>RDI</td>
<td>Recommended dietary intake</td>
</tr>
<tr>
<td>SD</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>SEM</td>
<td>Standard error of the mean</td>
</tr>
<tr>
<td>Ucol</td>
<td>Urine colour</td>
</tr>
<tr>
<td>Uosm</td>
<td>Urine osmolality</td>
</tr>
<tr>
<td>Usg</td>
<td>Urine specific gravity</td>
</tr>
<tr>
<td>UV</td>
<td>Urinary value</td>
</tr>
</tbody>
</table>
1 INTRODUCTION

Both recreational and elite sportspeople explore ways to achieve their maximal potential, and nutrition can play a major role in improving performance. The science of sports nutrition investigates factors that may limit exercise performance in a variety of sports and attempts to reduce or eliminate this factor via nutrition. As nutritionists are becoming an integral part of the support staff affiliated with elite sports teams, nutritional practices conducive to optimal sporting performance are increasingly considered.

1.1.1 Fatigue, hypohydration and hyperthermia

Metabolic heat is produced during exercise; under warm to hot conditions heat may not be dissipated at the same rate as it is produced resulting in a rise in body core temperature. A very high core body temperature can limit exercise performance \[1,2,3\] and has the potential to be life threatening. Steps must be taken to limit the rise in body temperature and therefore minimise the risk of hyperthermia. Athletes are being advised to acclimatise to hot conditions, pre-cool if possible and ingest fluids during exercise when competing in hot or humid conditions.

Evaporation of sweat is the body’s primary system for regulating temperature particularly when ambient temperatures exceed those of the skin and core. An increase in sweat rate reduces the total body water and if not replaced leads to poor hydration status. The body is then said to be dehydrating, meaning that a body water deficit is occurring \[4\]. When there is an existing body water deficit the body is in a state of hypohydration \[4\]. There is a progressive decline in physical and mental function throughout all levels of fluid deficiency that may begin at a loss of only 1.0% body mass during
competition [5]. Dehydration of 2-3% of body mass occurs frequently in individuals participating in high-intensity intermittent exercise [6]. Even though there have been many studies on the general topic of fluid ingestion and the positive effect it has on exercise performance [7,8,9] the exact mechanisms by which a negative fluid balance can reduce exercise performance are still not clear. Body water deficit does have a significant implication for both cardiovascular and thermoregulatory function.

1.1.2 Rugby Union

A rugby union (15’s) team will have a maximum of 15 players on the field at any one time with seven reserves, who can be substituted on only once during a game. As this study was based on a 15’s team, all practices, laws and regulations mentioned will relate to this form of the game.

Rugby Union is a game similar to other football codes, in that it is a team sport involving intermittent high intensity sprints with periods of jogging and walking, and repeated physical contact. Players exhibit a wide range of anthropometrical attributes due to the positional requirements of the game. Endurance, speed, strength, power, co-ordination and agility are essential physical characteristics for success in this sport. To be effective players may also be required to reason, evaluate, formulate strategy, decision make, and anticipate opposition tactics instantly. Because of the prolonged duration and intermittent high intensity activity pattern of Rugby Union, intake of fluid and perhaps supplementation of carbohydrate (CHO) during training and competition are likely to be beneficial.

As team sports such as Rugby Union often involve international competition, matches can take place in hot locations and/or during summer or transitional months. Teams may have less than a week in the region prior to a match, and players from colder regions will not have time to acclimatise effectively to a hot environment.
Rugby is played internationally (figure 1-1) and in New Zealand rugby union is one of the top five sports on a population participation basis, and at 3.40% participation rate it is one of the highest rates globally [10]

While many professional teams keep their own statistics of individual players in regards to the change in body mass during a match, very few studies exist that investigate the hydration status of Rugby Union players. One South African group in 1981 [11] studied body temperature and change in body mass and found players to be 2.52% dehydrated when fluid was not ingested during play, another group in 1985 [12] found players to be 1.51% dehydrated after ingestion of 751ml (mean volume) of fluid during a match.

*Figure 1-1. Rugby union player numbers (in thousands) of five top rugby playing nations* [10]
Due to the lack of research and limitations of previous studies, there is still a need to establish the level and frequency of dehydration that is occurring in rugby union, and to bring this to the awareness of the individuals involved in the sport. Doing so may aid in the pursuit of increased exercise performance, and more importantly could reduce the risk of the potentially life-threatening consequences of hyperthermia and dehydration. In the U.K a newspaper reported that a 'super fit' 35 year old played a charity game of rugby, drank two pints of beer and then collapsed from dehydration and died shortly after [13]. Severe dehydration during sport can result in injury and death, and does so every year [14,15].

1.1.3 Study aims
This study was designed to determine the change in hydration status of rugby union players during seven games of the New Zealand Super 12 development championship, in a range of environmental conditions. A secondary aim was to determine any factors that may affect post-match hydration status of the players.

1.1.4 Study objectives
To complete these aims the following study objectives were determined:

- To measure the hydration status of each rugby player after each match by determination of the players change in body mass during the match and post-match specific gravity of the urine.

- To record drinking frequency for each of the 15 run-on players, by recording how many times they took a drink during a game.
To record game variables such as environmental conditions (ambient temperature, relative humidity and wind speed), number of drink breaks and final score for each game.

To calculate any statistical correlation, using Pearson's co-efficient equation, between environmental conditions and post-match hydration status.

To calculate any statistical correlation, using Pearson's co-efficient equation, between game variables and post-match hydration status.

To estimate the volume of fluid ingested in the 24-hr period prior to a match and determine if this was related to pre- and post-match hydration status determined by analysis of urinary specific gravity.

To calculate any statistical correlation, using Pearson's coefficient equation, between environmental conditions and frequency of fluid intake of players during a match.

To examine dietary intake of players in the 24 hours prior to a match, determined by the use of self-reported 24-hour food records.