ERGOGENIC AIDS USED BY ULTRA-MARATHON RUNNERS

A DISSERTATION PREPARED BY MICHAEL GWILLIAMS (GWLMIC001) IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE MASTER OF PHILOSOPHY DEGREE IN SPORTS PHYSIOTHERAPY (MPHIL SPORTS PHYSIOTHERAPY) FROM THE UNIVERSITY OF CAPE TOWN

FEBRUARY 2015

University of Cape Town

SUPERVISORS:

DR THERESA BURGESS

PROF MIKE LAMBERT

A/PROF ANDREW BOSCH

DEPARTMENT OF HEALTH AND REHABILITATION SCIENCES

GROOTE SCHUUR HOSPITAL

OBSERVATORY

The copyright of this thesis vests in the author. No quotation from it or information derived from it is to be published without full acknowledgement of the source. The thesis is to be used for private study or non-commercial research purposes only.

Published by the University of Cape Town (UCT) in terms of the non-exclusive license granted to UCT by the author.

University of Cape Town

DECLARATION

I, Michael Gwilliams (GWLMIC001), hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

No part of this dissertation may be reproduced, stored in a retrieval system, or transmitted in any form or means without prior permission in writing from the author or the University of Cape Town.

Michael Gwilliams .

(Signature)

20 May 2015 .

(Date)

ACKNOWLEDGEMENTS

This study would not have been possible without the constant encouragement, support and assistance of certain people without whom this study would not have been possible. I am deeply appreciative and would like to thank them for their time and expertise on both a personal and professional level:

Dr Theresa Burgess, my main supervisor, for her knowledge, expertise, for all the time and dedication into guiding my research, and for the continuous support, encouragement and patience throughout this process.

To Prof Mike Lambert and A/Prof Andrew Bosch, my co-supervisors, for your guidance and expertise in helping to refine my work.

Leoni Klingenberg for your input, time and dedication in the translation of my questionnaire.

To all my participants for volunteering their precious time to my research by completing my questionnaire.

To all the staff with whom I work and my clients for their continued interest, patience, encouragement and understanding.

To my parents, family and friends for their faith in me and unwavering support and encouragement through this entire process.

To Lara-Jayne, my beautiful wife, editor, advisor, research assistant, thank you for your patience, encouragement, love and absolute faith in me.

TABLE OF CONTENTS

DECLARATION i
ACKNOWLEDGEMENTS ii
TABLE OF CONTENTS iii
LIST OF TABLES vi
LIST OF FIGURES ix
LIST OF ABBREVIATIONS AND UNITS x
GLOSSARY OF TERMS xiv
ABSTRACT xv
CHAPTER 1: INTRODUCTION AND SCOPE OF THE THESIS 1
1.1. INTRODUCTION 1
1.2. AIMS AND OBJECTIVES 2
1.2.1. AIMS 2
1.2.2. SPECIFIC OBJECTIVES 2
1.2.3. SIGNIFICANCE OF DISSERTATION 2
1.3. PLAN OF DEVELOPMENT 2
CHAPTER 2: LITERATURE REVIEW: THE USE OF ERGOGENIC AIDS IN ULTRA-MARATHON RUNNERS ... 3
2.1. INTRODUCTION 3
2.2. ENDURANCE RUNNING 4
2.3. EFFECTS OF ENDURANCE TRAINING AND FATIGUE 5
2.3.1. FATIGUE 5
2.3.2. PHYSIOLOGICAL ADAPTATIONS OF ENDURANCE TRAINING 6
2.4. THE RECOVERY PROCESS 7
2.5. ERGOGENICS AIDS 9
2.5.1. DIETARY PRACTICE 9
2.5.2. SUPPLEMENTARY AIDS 19
2.5.3. PHYSIOLOGICAL AIDS 31
2.5.4. PHARMACOLOGICAL AIDS 31
2.6. SUMMARY OF THE LITERATURE 37

CHAPTER 3: ERGOGENIC AIDS USED BY ULTRA-MARATHION RUNNERS 39
3.1. METHODOLOGY 39
3.1.1. STUDY DESIGN AND PARTICIPANTS 40
3.1.2. INCLUSION CRITERIA 40
3.1.3. EXCLUSION CRITERIA 40
3.1.4. SAMPLE SIZE CALCULATION 40
3.1.5. RECRUITMENT OF PARTICIPANTS 41
3.1.6. MEASUREMENT INSTRUMENTATION 43
3.1.7. VALIDITY OF THE ERGOGENIC AIDS QUESTIONNAIRE 44
3.1.8. FEASIBILITY OF THE ERGOGENIC AIDS QUESTIONNAIRE 44
3.1.9. PROCEDURE 45
3.1.10. STATISTICAL ANALYSES 46
3.1.11. ETHICAL CONSIDERATIONS 47
3.1.12. INFORMED CONSENT 47
3.2. RESULTS 49
3.2.1. PARTICIPANTS 49
3.2.2. DESCRIPTIVE, TRAINING, AND RACING CHARACTERISTICS 51
3.2.3. ERGOGENIC AID USE 52
3.2.4. DIETARY PRACTICE 54
3.2.5. SUPPLEMENTARY AIDS 60
3.2.6. PHARMACOLOGICAL AIDS 76
3.2.7. SUMMARY OF ERGOGENIC AID USE 82
3.3. DISCUSSION 88
3.3.1. PARTICIPANTS AND STUDY DESIGN 88
3.3.2. SUMMARY AND RECOMMENDATIONS 99
CHAPTER 4: SUMMARY AND CONCLUSION 107
REFERENCES 110
APPENDIX I: Questionnaire Background and Informed Consent 128
APPENDIX II: Email to Running Clubs and Race Organisers 131
APPENDIX III: Email Advertisement 133
APPENDIX IV: Examples of Reminder Emails 134
APPENDIX V: Word Version of Questionnaire 136

APPENDIX VI: Emails Contacting Validation Panel 214
APPENDIX VII: Letter of Approval for Study 217
APPENDIX VIII: Training and Race Characteristics 218
APPENDIX IX: Detailed Comparison of Ergogenic Aid Use 224
APPENDIX X: Detailed Comparison of the Influential Factors Affecting Ergogenic Aid Intake Strategies. 225
APPENDIX XI: Regression analyses detailed tables. 234
APPENDIX XI: Medication Dosage Patterns 242

LIST OF TABLES

Table 2.1: Recommendations for carbohydrate intake during different endurance events (Table modified from Jeukendrup, AE. 2011 3). 14

Table 2.2: Summary of studies that assessed the ergogenic effects of carbohydrates. 15

Table 2.3: Summary of studies that assessed the ergogenic effects of antioxidants. 21

Table 2.4: Summary of studies that assessed the ergogenic effects of amino acids. 26

Table 2.5: Summary of studies that assessed the ergogenic effects of caffeine. 34

Table 3.1: Dates of initial and reminder recruitment emails sent to participants. 42

Table 3.2: Number of emails sent to the various regions of South Africa. Data are presented as number (n) and percentage (%). 42

Table 3.3: Predictor variables coded for forward stepwise regression analyses. 47

Table 3.4: Descriptive characteristics of the participants ages (n = 266). Data are presented as mean ± standard deviation (SD) and minimum to maximum (min - max). 51

Table 3.5: Race and training characteristics (n = 266). Data are presented as mean ± standard deviation (SD) and minimum to maximum (min - max). 52

Table 3.6: Ergogenic aids used by participants (n = 266). Data are presented as number (n) and percentage (%). 53

Table 3.7: Pattern of use for carbo-loading (n = 117). Data are presented as number (n) and percentage (%). 54

Table 3.8: Perceived ergogenic effects of increased carbohydrate intake (n = 117). Data are presented as number (n) and percentage (%). 55

Table 3.9: Forward stepwise regression analysis of descriptive, race and training factors predicting the use of carbo-loading. 56

Table 3.10: Pattern of use for increased protein intake (n = 46). Data are presented as number (n) and percentage (%). 57

Table 3.11: Perceived ergogenic effects of increased protein intake (n = 46). Data are presented as number (n) and percentage (%). 58

Table 3.12: Forward stepwise regression analysis of the descriptive, race and training factors predicting the use of increased protein intake. 59

Table 3.13: Preferred fluid of choice during training, during and after races (n = 266). Data are presented as number (n) and percentage (%). 60

Table 3.14: Perceived ergogenic effects of fluid intake (n = 266). Data are presented as number (n) and percentage (%). 61

Table 3.15: Forward stepwise regression analysis of the descriptive, training and racing factors predicting use of the use of sports drinks as ergogenic aids. 62

Table 3.16: Pattern of use for the consumption of vitamins (n = 108). Data are presented as number (n) and percentage (%). ... 63

Table 3.17: Perceived ergogenic effects of vitamins (n = 108). Data are presented as number (n) and percentage (%). ... 64

Table 3.18: Forward stepwise regression analysis of the descriptive, race and training factors predicting the use of vitamins. ... 65

Table 3.19: Pattern of use for the consumption of gels (n = 118). Data are presented as number (n) and percentage (%). ... 66

Table 3.20: Consumption strategies of gels during races and training runs (n = 118). Data are presented as number (n) and percentage (%). ... 67

Table 3.21: Perceived ergogenic effects of gels (n = 118). Data are presented as number (n) and percentage (%). ... 68

Table 3.22: Pattern of use for the consumption of electrolytes (n = 89). Data are presented as number (n) and percentage (%). ... 69

Table 3.23: Consumption strategies for electrolytes during races and training runs (n = 85). Data are presented as number (n) and percentage (%). ... 70

Table 3.24: Perceived ergogenic effects of electrolytes (n = 89). Data are presented as number (n) and percentage (%). ... 71

Table 3.25: Pattern of use for the consumption of amino acids (n = 13). Data are presented as number (n) and percentage (%). ... 72

Table 3.26: Perceived ergogenic effects of amino acids (n = 13). Data are presented as number (n) and percentage (%). ... 73

Table 3.27: Pattern of use for the consumption of antioxidants (n = 5). Data are presented as number (n) and percentage (%). ... 74

Table 3.28: Perceived ergogenic effects of antioxidants (n = 5). Data are presented as number (n) and percentage (%). ... 75

Table 3.29: Pattern of use for the consumption of medication. Data are presented as number (n) and percentage (%). ... 77

Table 3.30: Consumption strategies during training and marathons. Data are presented as number (n) and percentage (%). ... 77

Table 3.31: Perceived ergogenic effects of medication. Data are presented as number (n) and percentage (%). ... 78

Table 3.32: Pattern of use for the consumption of caffeine (n = 37). Data are presented as number (n) and percentage (%). ... 80

Table 3.33: Perceived ergogenic effects of caffeine (n = 37). Data are presented as number (n) and percentage (%). ... 81

Table 3.34: Pattern of use for the consumption of the different ergogenic aids. Data are presented as number (n) and percentage (%). ... 84

Table 3.35: Beliefs of ergogenic aid effectiveness. Data are presented as percentage (%). 85

Table 3.36: Summary of the perceived ergogenic effects of different aids. Data are presented as number (n) and percentage (%). 86

Table 3.37: Summary of the incorrect practices observed in this study, the current evidence-based guidelines for use, and practical recommendations for the use of different ergogenic aids. 100

LIST OF FIGURES

Figure 3.1: Summary of the study sample. 50

Figure 3.2: The use of different ergogenic aids by male and female participants. Data are expressed as numbers (n). 82

LIST OF ABBREVIATIONS AND UNITS

URLs	Uniform resource locators
IP	Internet protocol address
min	Minute
h	Hour
US	United States
DOMS	Delayed onset of muscle soreness
EIMD	Exercise-induced muscle damage
IOC	International Olympic Committee
WADA	World Anti-Doping Agency
NSAIDs	Nonsteroidal anti-inflammatory drugs
NAC	N-acetylcysteine
VO_{2max}	Maximum aerobic capacity
RDA	Recommended daily allowance
CNS	Central nervous system
BCAAs	Branched-chain amino acids
FFA	Free fatty acids
CK	Creatine kinase
LDH	Lactate dehydrogenase
g	Grams
kg	Kilograms

mg	Milligrams
PCr	Phosphorylcreatine
EAMC	Exercise associated muscle cramps
CHO	Carbohydrate
MTC	Multiple transportable carbohydrates
GI	Gastrointestinal
GIT	Gastrointestinal tract
RPE	Rate of perceived exertion
MPS	Muscle protein synthesis
EPO	Erythropoietin
n	Number
%	Percentage
SAIDS	South African Institute for Drug-free Sport
ASA	Athletics South Africa
CI	Confidence intervals
HREC	Human Research Ethics Committee
SD	Standard deviation
ACSM	American College of Sports Medicine
LOE	Level of evidence
SGLT1	Sodium-dependent transporter

GLUT5	Sodium-independent transporter
ATP	Adenosine triphosphate
Km	Kilometre
PRO	Protein
AA	Amino acids
CAF	Caffeine
L	Litre
yr	Years
EAH	Exercise-associated hyponatraemia
Min	Minimum
Max	Maximum
SD	Standard deviation
d	Day
wk	Week
n/s	Not significant
$mg.kg^{-1}$	Milligrams per kilogram of body mass
$g.h^{-1}$	Grams per hour
$g.min^{-1}$	Grams per minute
$g.kg^{-1}.h^{-1}$	Grams per kilogram of body weight per hour
$g.kg^{-1}.d^{-1}$	Grams per kilogram of body weight per day
HPT	Hypertension

DM	Diabetes mellitus
$ml.h^{-1}$	Milliliters per hour
$mg.d^{-1}$	Milligrams per day
$g \cdot L^{-1}$	Grams per liter
$Na+$	Sodium
$K+$	Potassium
$L.kg^{-1}$	Liters per kilogram of body weight
UL	Upper limit
na	Not available
N/A	Not applicable
$mg.kg^{-1}$	Milligrams per kilogram of body weight

GLOSSARY OF TERMS

Ergogenic Aids	Broadly defined as a technique or substance used for the purpose of enhancing performance [1].
Marathon	Refers to a footrace run on an open course usually of 42.2 kilometres [2].
Ultra-marathon	A footrace that is of a longer distance than that of a standard marathon (42.2 kilometres) [3].
Carbo-loading	The practice of eating large amounts of carbohydrates for a few days before competing in an athletic event, to provide energy reserves in the form of glycogen [4].
Fatigue	Defined as having sensations of tiredness and associated decrements in muscular performance and function [5].
Central Governor	A central (brain) neural control that regulates performance 'in anticipation' specifically to prevent biological harm [6].
Supercompensated Glycogen Stores	Exercise-diet regimen dramatically elevated or *"supercompensated"* muscle glycogen levels and prolonged sub-maximal exercise time to exhaustion [7].

ABSTRACT

Background

Athletes of all levels and abilities utilise ergogenic aids to enhance sporting performance. However, the extent of ergogenic aid use within the ultra-marathon running community in unknown and there is little available literature documenting characteristics of use among ultra-marathon runners.

Aims and Objectives

The aim of this study is to describe the use of ergogenic aids in ultra-marathon runners. The specific objectives of the study were to: a) To obtain information on the use of ergogenic aids in ultra-marathon runners, with regard to the type of ergogenic aids used, and the pattern of use during training and competition; b) To determine ultra-marathon runner's perceived benefits of the ergogenic aids; c) To determine the factors influencing the intake strategies of ergogenic aids; d) To explore the factors that may predict the use of ergogenic aids, such as age, gender level of competitiveness, training and competition history.

Methods

This study had a descriptive correlational study design. Participants included male and female ultra-marathon runners between 25 and 65 years of age. Participants who did not give informed consent and who failed to meet the defined classifications of being an ultra-marathon runner and medical screening criteria were excluded from the study. Participants were recruited through electronic correspondence, running clubs and running-specific media platforms. A self-developed questionnaire was designed to obtain information on ergogenic aid use in ultra-marathon runners during training and competition, as well as to determine the runners' pattern of use and their perceived effect of ergogenic aids. The questionnaire was available in English and Afrikaans, and explored both legal and illegal ergogenic aid use. A panel of experts reviewed and validated the questionnaire. The online questionnaire was anonymous; with all referring uniform resource locators (URLs) and internet protocol (IP) addresses of respondents hidden to ensure anonymity.

Results

The final sample was comprised of 266 respondents (n=179 males; n=87 females). The mean age of participants was 44 ± 10. The mean number of ergogenic aids used per participant was 5 ± 2.

Dietary practice (47%) was the most common ergogenic intervention, followed by supplementary aids (45%), and pharmacological aids (18%). No participants reported the use of illegal/banned ergogenic aids. The highest self-reported ergogenic aid used was sports drinks (n = 213; 80%) followed by vitamins (n = 181; 68%) and carbo-loading (n = 165; 62%). Participants tended to use ergogenic aids predominantly during competition and less so during training. Seventy-nine percent of participants believed that their chosen ergogenic aid improved their performance, while 9% did not think their performance was improved, and 9% were uncertain. The most frequently perceived benefits of ergogenic aids were 'delayed fatigue' and 'providing an energy boost'. Self-experimentation/personal experience, fellow runners and books/magazines were the highest ranked factors influencing intake strategies of the participants chosen aids. Runners who had more than ten years of ultra-marathon running experience were approximately 50% more likely to consume sports drinks. Females were about two and a half times more likely to utilize vitamins as an ergogenic aid. However, evidence from the general population suggests that females have a significantly higher daily intake of vitamins compared to males; therefore this finding might simply reflect daily supplement use and not be specific to ultra-marathon runners. The use of vitamins was also dependant on the number of ultra-marathons performed; participants completing more than five ultra-marathons were almost twice as likely to use vitamins as those completing less than five ultra-marathons. Recreational runners were approximately one third less likely to undertake the dietary practice of carbo-loading than competitive runners. The number of marathons and the number of ultra-marathons completed conversely affected the use of increased protein. This study was unable to identify any descriptive, race or training characteristics that influenced the use of caffeine, medication, gels or electrolytes as ergogenic aids.

Conclusion

The findings of this study demonstrated that the prevalence of use of legal ergogenic aids is high and often used simultaneously. This study was unable to identify the prevalence of use of illegal ergogenic aids. However, the inappropriate and potentially unsafe use for many legal ergogenic aids was identified. Participants also reported false performance beliefs, potentially indicating poor knowledge or understanding of the effects of ergogenic aids.

A major challenge is the strong influence of personal experience and information from fellow runners on the choice of ergogenic aids. Runners are accessing information through social networking, interactions and possibly social media, rather than scientific resources. Educational initiatives, with a focus on peer-led education, are essential to encourage the safe and effective use of ergogenic aids. This study highlights the importance of collective responsibility of the running community, including regulators, administrators, health care professionals, coaching and support staff, and journalists and authors of books and magazines to ensure that runners are informed about the safe and correct use of legal ergogenic aids.

CHAPTER 1

INTRODUCTION AND SCOPE OF THE THESIS

1.1. INTRODUCTION

Long-distance running is a popular form of physical exercise [8]. Running requires high levels of training and competition, which generate extensive physiological stresses on the body that may be associated with temporary impairments in athletic performance [9,10]. The use of supplements to attain benefits that can improve performance and/or reduce physiological stress may therefore become desirable. There are many different types of ergogenic aids, including legal and illegal aids. Nutritional, pharmacological and physiological ergogenic aids may be used in an attempt to improve performance and maximise training adaptations [11].

Many of the proposed benefits of ergogenic aids are based on anecdotal data and results vary widely across studies [12,13]. Along with the proposed ergogenic effects of numerous supplements, which are often not proven or may be greatly exaggerated, there may also be harmful and potentially fatal side effects [14]. In addition, many athletes have a 'win at all costs' mentality and will choose to use an ergogenic aid regardless of the possible side effects [14]. As a result, ergogenic aids may often be used by athletes without a full understanding of the potential benefits or risks to their performance and health [15]. It is also unclear how athletes obtain information regarding the correct use of ergogenic aids, or whether runners understand the potential benefits and harmful effects of using ergogenic aids during events.

The consumption of ergogenic aids is reportedly common across a number of different sporting disciplines. In professional athletes, the estimated prevalence of use of ergogenic aids is between 57% and 94% [13]. The type of ergogenic aids used and the pattern of use are largely sport-dependent. The highest use tends to occur in individual endurance-type sports, such as athletics and cycling [13]. It is difficult to know the extent of use of illegal ergogenic aids or doping due to the sensitivity of the subject [16]. Unlike other sports, little is known about the use of ergogenic aids in distance running events. In particular, there is a lack of evidence regarding the prevalence and patterns of use of ergogenic aids among ultra-marathon runners. Therefore, the aim of the present investigation was to examine the use of ergogenic aids in ultra-marathon runners during training and competition.

1.2. AIMS AND OBJECTIVES

1.2.1. AIMS

The aim of this study was to describe the use of ergogenic aids in ultra-marathon runners.

1.2.2. SPECIFIC OBJECTIVES

- To obtain information on the use of ergogenic aids in male and female ultra-marathon runners, with regard to the type of ergogenic aids used, and the pattern of use during training and competition;
- To determine ultra-marathon runners' perceived performance benefits of ergogenic aids;
- To determine the sources of information influencing ultra-marathon runners' use of ergogenic aids;
- To explore the factors that may predict the use of ergogenic aids, such as age, gender and training and competition history.

1.2.3. SIGNIFICANCE OF DISSERTATION

There is a lack of evidence on the use of ergogenic aids in ultra-marathon runners. The findings of this study may improve knowledge regarding the prevalence of use of ergogenic aids in ultra-marathon. This study has implications for the practical use of ergogenic aids as it may provide evidence for educational initiatives regarding the future use ergogenic aids, and improve the safe and appropriate use of these aids in ultra-marathon runners.

1.3. PLAN OF DEVELOPMENT

In preparation for the experimental phase of this dissertation, a comprehensive review of the literature on endurance running and the most commonly used ergogenic aids will be presented (Chapter 2). This will be followed by a descriptive correlational study that was designed to investigate the use of ergogenic aids by ultra-marathon runners (Chapter 3). A summary and conclusion section, including recommendations for future research (Chapter 4) will complete this dissertation.

CHAPTER 2

LITERATURE REVIEW: THE USE OF ERGOGENIC AIDS IN ULTRA-MARATHON RUNNERS

2.1. INTRODUCTION

Marathon running is a popular sport worldwide at both recreational and competitive levels. The past twenty years has witnessed a dramatic increase in the number of amateurs runners taking part in endurance and ultra-endurance events [17–19]. This increased participation in endurance running results in a greater level of competition amongst runners and a subsequent desire to enhance sporting performance. The physical demands of the high levels of training associated with modern day sport generate extensive physiological stresses on the body that may be associated with temporary impairments in athletic performance [9,10]. High volumes of training with insufficient recovery periods may lead to symptoms of fatigue and a predisposition to injury [9,20]. Thus athletes tend to use ergogenic aids to prepare their bodies for the demands of training and competition, and to assist them in a speedy recovery.

The purpose of this literature review chapter is to give a brief background of endurance running as a sport, and the effects of training and fatigue on performance and recovery. The different categories of ergogenic aids will be described, and the evidence for commonly used ergogenic aids will be discussed. There is currently equivocal evidence for the efficacy of different ergogenic aids during endurance running. Therefore, literature pertaining to the use of ergogenic aids during different types of endurance activities and sports was included in this review.

The following databases were searched: Google Scholar, PubMed (NCBI) and the Mendeley research catalogue. The following keywords were used: '*ergogenic aids', 'marathon running', 'ultra-marathon', 'endurance', 'recovery', 'training', 'fatigue', 'muscle damage', 'performance', 'performance enhancing', 'blood doping', 'carbohydrates', 'carbo-loading', 'protein', 'amino acids', 'antioxidants', 'vitamins', 'caffeine', 'creatine', 'erythropoietin', 'EPO',* and '*sports nutrition*'. The search was refined by searching for related articles once an article of interest was found.

2.2. ENDURANCE RUNNING

Descriptions of an ultra-endurance event in previous literature vary greatly and range from a minimum of 30 minutes (min) to six hours of continuous racing [21–24] where the distances are not specified. In this review an ultra-marathon is considered to be a footrace that is of a longer distance than that of a standard marathon (42.2 kilometres).

There were 572 marathons held in the United States (US) and Canada in 2010, 639 in 2011, 668 in 2012, and 727 were held in 2013 [25,26]. The estimated number of people finishing a marathon each year in the US has also increased significantly from approximately 440 000 in 2006 to 529 444 in 2012 [25,26]. The highest number of runners taking part in a single event in the US has been recorded in the New York City Marathon, with 44 712 finishers in 2010 and 46 795 finishers in 2011 [25]. In South Africa a similar increase in levels of participation has also been recorded. The Comrades Marathon saw an increase from 1 686 runners in 1975 to attracting a record 24 552 runners in the year 2000 [27], in 2010 the Comrades Marathon made a Guinness World Record for the most runners in an ultra-marathon, with a field of 14 343 runners completing the race within the 12-hour cut-off time [28], 2015 the number of race entries has been capped at 23 000 [29]. The Old Mutual Two Oceans Marathon reported a record field in 2013 of close to 11 089 ultra-marathon runners with as much as 35% of the field being made up first time entrants [30]. Hoffman et al [31], conducted a historical analysis of participation in ultra-marathons in North America and observed that the annual number of races and finishers has increased exponentially over the past three decades. This is attributed to increases in the number of veteran runners (over the age of 40 years), the number of female competitors, and the number of individuals competing in multiple events per annum [31].

The nature of a marathon run demands an adherence to a persistent and intense load training programme. Environmental factors also play a large role on the physical demands of the sport and largely affect performance factors such as dehydration [32]. Other physical stresses associated with ultra-endurance running include glycogen depletion, hydration status, nutritional demands, oxidative damage from free radicals, fatigue, gastrointestinal distress and delayed onset of muscle soreness (DOMS) [19,33–36].

2.3. EFFECTS OF ENDURANCE TRAINING AND FATIGUE

The physical demands associated with ultra-marathon running generate heavy physiological stresses that may be associated with temporary impairments in athletic performance [9,10]. High volumes of training with insufficient recovery periods may lead to fatigue, together with an increased predisposition to injury [9,20]. Fatigue is considered an inevitable consequence of physical activity [37], and there has been much research into its effect on exercise performance [38–40].

2.3.1. FATIGUE

Many definitions of fatigue exist, for the purpose of this review 'fatigue' is defined as *"having sensations of tiredness and associated decrements in muscular performance and function"* [5,37,39–41]. It is important to note that exercise is terminated at the point of exhaustion and not at the point of fatigue [37]. Numerous models have been developed to explain fatigue. These models include: (i) cardiovascular/anaerobic; (ii) energy supply/energy depletion; (iii) neuromuscular fatigue; (iv) muscle trauma; (v) biomechanical; (vi) thermoregulatory; (vii) psychological/motivational; and the (viii) Central Governor [5].

The first seven models are all based around the thought that fatigue is a result of failure. This interprets as a physiological process reaching the point where it is no longer able to continue functioning at the rate at which it is being demanded. Consequently the system slows its functioning down, resulting in the athlete's inability to continue performing at an optimal level. These systems all imply that failure can occur anywhere within a certain system. The 'Central Governor' theory operates differently and can be interpreted as a centrally controlled system whereby the brain is the 'Governor' and it is continuously monitoring all the bodily systems and functions. The theory is based on the notion that the brain is driven towards self-preservation and will not allow harm to itself or any of the vital organs and thus it controls the individual peripheral systems accordingly. The 'Central Governor' theory can therefore be viewed as an anticipatory mechanism that regulates the intensity of effort with the intent of conserving homeostasis. Fatigue is therefore considered to be a safety mechanism aimed at preventing injury or death from occurring during exercise [42].

No model can adequately explain fatigue independently. This is indicative that these models may work better when integrated into a complex systems model of fatigue [5,43]. This challenges scientists and athletes aiming to delay the effects of fatigue and enhance performance through the use of ergogenic aids.

There are many individually proposed intervention strategies that exist claiming to have positive effects on delaying the onset of fatigue and enhancing performance. This review addresses these specific to ultra-endurance events. Please refer to a detailed review by Noakes (2000) [43] as a thorough discussion of the different models of fatigue is beyond the scope of this review.

2.3.2. PHYSIOLOGICAL ADAPTATIONS OF ENDURANCE TRAINING

There is a strong association between running economy and distance running performance, with running economy being a better predictor of performance than VO_{2max} in elite runners who have a similar VO_{2max} [44,45]. Taking body mass into consideration, runners with good running economy use less energy and therefore less oxygen than runners with poor running economy at the same velocity.

Interventions to improve running economy are constantly sought after by athletes, coaches and sport scientists [45]. A number of physiological and biomechanical factors appear to influence running economy in highly trained or elite runners. It is well documented that athletes with a large proportion of slow twitch and fast twitch aerobic skeletal muscle fibre, high metabolic enzyme activities and concentrations, large mitochondria concentration, the ability of the muscles to store and release elastic energy by increasing the stiffness of the muscles, more efficient mechanics leading to less energy wasted on braking forces and excessive vertical oscillation and, of course, the ability to increase the power output generated for a given rate of oxygen consumption and energy expenditure, are generally highly successful distance runners [45–47].

Improvements in running economy have traditionally been achieved through endurance training [44]. Physiological events that occur after exercise may be the stimulus for chronic adaptations to training [48]. Training results in adaptations to occur in many physiological systems [49]. The extent of any adaptation as a result of physical training is directly related to the overall training stimulus [49]. An improvement in exercise capacity is underpinned by the ability of skeletal muscle to adapt to repetitive bouts of exercise training [5,48].

Aerobic and endurance training have been shown to bring about significant adaptations to the skeletal muscle and its inclusions as well as to the delivery system. In particular, enzyme activity levels are readily mutable, mitochondrial concentrations increase, an increase in the number of capillaries in muscles, thereby increasing the amount of oxygen delivered to the muscles to maximise endurance performance, and some evidence suggests that the fibre distribution is changed [46,49].

Highly trained runners and cyclists display more refined patterns of muscle recruitment than their novice counterparts [44,49], showing that neuromuscular adaptations in response to training are also an important contributor to enhancements in running economy [44]. Endurance training is associated with of an increased activity of key enzymes in the mitochondrial electron transport chain and in mitochondrial protein concentration [48]. Along with increased capillary supply, these morphological changes result in a shift in trained muscle to a greater reliance on fat as a fuel, and a reduction in glycolytic flux and tighter control of acid–base status [48]. Taken collectively, these adaptations result in an enhanced performance capacity [48].

As discussed later in *Section 2.5.1.1* 2.5.1.1 *(page 9)*, the depletion of endogenous carbohydrate stores (a major fuel source during exercise) may be linked to fatigue during prolonged cycling (27) [49,50]. All of these training-induced adaptations of skeletal muscle can improve performance capacity; however, all are a result of high-volume, high-intensity training [1]. Please refer to detailed reviews by Hawley and Stepto [49] and Coyle et al [51], as further discussion of training adaptations is beyond the scope of this dissertation.

2.4. THE RECOVERY PROCESS

Recovery is a process whereby the muscles return to their pre-exercise state following exercise [52]. Although recovery is largely a passive process, there are many active interventions and modalities that exist to assist in hastening their recovery period. This becomes increasingly important to competitive athletes who are required to regularly perform at a high standard. The musculoskeletal, nervous, immune and metabolic systems are all stressed to a point where a recovery strategy post-exercise becomes instrumental in preparing the athlete for the next bout of exercise [53]. Adequate recovery decreases fatigue, accelerates the rate of physiological regeneration, facilitates overload and may decrease the risk of injury [54]. Large volumes of intense training can have a negative effect on performance if the body does not recover sufficiently between training sessions [54].

Oxidative damage from free radicals and exercise-induced muscle damage (EIMD) are examples of some of the unavoidable physiological consequences of the intense exercise undertaken during an ultra-marathon. Exercise-induced muscle damage (EIMD) is known to decrease muscle strength and power [55]. Endurance running performance is significant effected by EIMD, this effect seems to be mediated by alterations in the sense of effort [55]. Alterations in muscle sequencing and recruitment patterns may also occur, causing unaccustomed stress to be placed on muscle ligaments and tendons.

These compensatory mechanisms may increase the risk of further injury if a premature return to sport is attempted [20]. Evidence of exercise-induced muscle damage includes morphological changes, delayed onset muscle soreness (DOMS), and impaired muscle function [56–59]. Delayed onset muscle soreness describes the combined sensation of muscle pain, stiffness and tenderness that develops after unaccustomed exercise or after increased exercise intensity or duration [57,60–63]. Delayed onset muscle soreness is particularly evident following lengthening muscle actions or repetitive stretch shortening cycle activity [57,61,63,64] and is classified as a type 1 muscle strain injury [65]. Delayed onset muscle soreness usually presents within eight to 24 hours after the bout of exercise, peaks within 24 to 72 hours and typically dissipates within seven to 10 days after the exercise [58,60,62,66–68]. Delayed onset muscle soreness can affect athletic performance by causing a reduction in joint range of motion, shock attenuation and peak torque. Furthermore, it is known that neuromuscular function is altered for at least 11 days after a 90 km ultra-marathon [69] and despite the absence of pain, signs of regeneration are present in the muscles of runners for up to 12 weeks after a standard marathon [70]. Athletic performance and preparation are typically impaired when an athlete is sore or injured. Thus, any practice that limits the extent of damage or hastens recovery would be of interest and practical value to the coach, trainer, athlete or therapist.

Like fatigue there are many theories that have been proposed for the mechanism of DOMS. An integration of two or more theories is likely to explain DOMS [20]. It is generally accepted that DOMS is associated with muscle or connective tissue damage and may be related to an inflammatory response [56,59,60,62,71]. However, explaining these in full is beyond the scope of this dissertation, refer to reviews by Cheung [20], Connolly [72] and Cleak [57] for further detail on EIMD and DOMS.

A number of strategies have been proposed to help prevent and alleviate the severity of oxidative damage from free radicals and EIMD to restore the maximal function of the muscles. In an attempt to decrease the length of recovery required, many athletes utilise specific ergogenic aids prior to or during exercise with the aim of reducing these and many other negative consequences as a result of exercise. These are discussed in more detail in the relevant ergogenic aids sections that follow.

2.5. ERGOGENICS AIDS

Ergogenic aids may be defined as *"any means of enhancing energy utilization, production, control, & efficiency"* [12]. Ergogenic aids are used to decrease the amount of time required to recover from the physiological stresses placed on the body, and to improve performance [12]. Endurance athletes tend to make use of the ergogenic aids to delay the onset of fatigue [12,73] or reduce muscle damage caused by intense or prolonged exercise [33]. There are numerous categories or methods of grouping ergogenic aids, not all of which are agreed upon. A lack of a standard classification system of ergogenic aids makes comparisons between studies difficult.

This is possibly due to the list of techniques and substances used as ergogenic aids being too extensive for a complete discussion within most articles. This review uses classifications by two different reviews to allow for classification incorporating all the ergogenic aids anticipated to be used by endurance athletes [12,73]. Ergogenic aids have thus been categorised as '*Supplementary Aids'*, '*Dietary Practice'*, '*Physiological Aids'* and '*Pharmacological Aids'* [12,73].

2.5.1. DIETARY PRACTICE

The foods athletes choose will affect their performance through effects on both fitness and health [15]. It has been well established that making both carbohydrate and protein dietary alterations can assist skeletal muscle adaptations to training and potentially influence performance [74–77]. The dietary categories that will be discussed below are increased carbohydrate and protein intake respectively.

2.5.1.1. Increased Carbohydrate Intake

The body oxidises carbohydrates and it is stores as glycogen. Muscle glycogen and blood glucose are the most important substrates for the contracting muscle [78]. Fatigue during prolonged exercise is often associated with muscle glycogen depletion and reduced blood glucose concentrations [79]. Therefore, high pre-exercise muscle and liver glycogen concentrations are believed to be essential for optimal performance. Exercise performance is improved by carbohydrate feedings in prolonged moderate-intensity exercise due to maintenance of blood glucose levels and increased exogenous carbohydrate oxidation [80,81]. There is strong evidence to support the ergogenic effects of beginning endurance exercise with high muscle glycogen concentrations and ingesting carbohydrates during prolonged exercise [81–85].

Colye et al [86] found that ingestion of carbohydrates during exercise delayed the onset and fatigue and improved performance in endurance cyclists. Kruseman et al [77] found that an increased hourly rate of carbohydrate supplementation and overall caloric intake was associated with faster race times [77,87,88]. There seems to be little or no performance benefit of elevating pre-exercise muscle glycogen when the exercise duration is less than 90 min [23]. However, elevated pre-exercise muscle glycogen will postpone fatigue by approximately 20% in endurance events lasting more than 90 min. During this type of exercise, exhaustion usually coincides with critically low muscle glycogen contents. This suggests that the supply of energy from glycogen utilisation cannot be replaced by an increased oxidation of blood glucose.

It is widely accepted that several days of increased carbohydrate intake in association with a reduction in exercise will result in an elevated or *"supercompensated"* glycogen content [82,89–92]. Carbo-loading strategies have evolved over many years, and the glycogen supercompensation protocol derived from earlier studies involved a period of depletion followed by a three day loading phase. More recent studies have demonstrated that supercompensation can be achieved without a depletion phase [93], and with as little as 24 to 36 hours of high carbohydrate intake/rest [94]. It is acknowledged that even without a glycogen-depleting period of exercise, trained athletes can store maximal amounts of muscle glycogen if fed a carbohydrate-rich diet for three days [94].

It is generally accepted that glycogen supercompensation results in improved performance [95], although this is not always shown in the literature [96,97]. Elevating pre-exercise glycogen concentration may improve endurance performance. In such exercise, high carbohydrate diets have been reported to improve performance by 2% to 3% [98]. The amount of dietary carbohydrates needed to promote glycogen loading depends on the duration and intensity of the athlete's daily exercise programme and daily activity. Such requirements can vary from 5 $g.kg^{-1}.d^{-1}$ to 12 $g.kg^{-1}.d^{-1}$. It should be noted that even if a higher carbohydrate intake can achieve higher glycogen stores, this might not always result in better performance [99].

Further, research has investigated the possibility of manipulating the carbohydrate ingestion to gain additional performance benefits. The concept of *"train low, race high"* was developed. *"Train low, race high*" implies periodic training with lowered blood glucose or endogenous glycogen, followed by the repletion of carbohydrates before subsequent training or competition. Hansen [100] tested this theory in untrained participants and showed that training in a state of reduced glycogen stores caused cellular adaptation that result in increased endurance performance.

Two subsequent studies [101,102] investigated whether well-trained athletes would experience similar metabolic outcomes and performance improvements. These studies showed training with lower glycogen stores resulted in greater cellular oxidative adaptations but no difference in performance than training with normal or high glycogen stores [101,102]. Other studies evaluating the effect of decreasing exogenous glucose availability on training adaptation revealed equivocal results [75,103–106]. It would appear that, training in a low-carbohydrate state results in an increase in oxidative enzymes that may be beneficial for ultra-endurance competitions where exercise intensity is usually below 70% VO_{2max} and most of fuel utilization is FFA [78,107]. However, to date no studies have examined ultra-endurance performance after training with low carbohydrates.

In addition, an understanding of multiple transportable carbohydrates (MTC) has also improved the ergogenic effect of carbohydrate diets. Oxidation rates vary due to different transporters for absorption (glucose - SGLT1 and fructose - GLUT5). When glucose was ingested with fructose simultaneously, high oxidation rates of 1.26 $g.min^{-1}$ were observed [108]. Combinations of maltodextrin and fructose, and glucose and fructose or glucose, plus sucrose and fructose produced the most favourable effects. All of these variations supported increased exogenous carbohydrate oxidation with multiple carbohydrate sources compared with a single carbohydrate source or water [109–113].

It has since been recommended that athletes should take between 30 g and 60 g of carbohydrates during endurance exercise lasting longer than one hour [114] or 0.7 $g.kg^{-1}.h^{-1}$ [35]. Recently published recommendations take these findings into account, acknowledging that there may be different carbohydrate needs for different durations of exercise as well as for different levels of athletes [19].

Multiple transportable carbohydrates can be recommended at all durations but are most effective when the exercise is two and a half hours or longer. In these conditions, carbohydrate intakes of up to 90 $g.h^{-1}$ are recommended and these would only be oxidised to any significant degree if they are MTC in which glucose makes up no more than about 60 g [19]. One of the few nutrition studies that evaluated the carbohydrate oxidation rates within the ultra-endurance range, found that a glucose and fructose solution trial resulted in increased exogenous carbohydrate oxidation and increased cycling cadence at end of a time trial, as well as a decreased rate of perceived exertion (RPE) for the workload [115]. It is therefore advised that ultra-endurance athletes fuel with a combination of different carbohydrates to support maximum oxidation. It is important to note that such high oxidation rates can not only be achieved with carbohydrates ingested in a beverage but also as a gel or a low fat, low protein and low fibre energy bar [116].

This then brings about the question surrounding the timing of carbo-loading. Advice ranges from *"ingesting carbohydrates in the hour before exercise*" [117] to *"avoiding carbohydrates in the hour before exercise*" [118]. Early studies outlined the metabolic effects of pre-exercise carbohydrate feeding. These include hyperinsulinaemia and hyperglycaemia before exercise followed by a rapid development of hypoglycaemia, high rates of glycogenolysis and a reduction of lipolysis and fat oxidation during exercise. Although these metabolic perturbations can in theory reduce exercise performance, the results of studies have been varied and only two studies have found reduced performance capacity. The majority of studies have reported no change or an improvement in performance following pre-exercise carbohydrate ingestion [118].

In 2002 and 2003 Jeukendrup et al [119–123] set out to perform a systematic series of studies to investigate the effects of pre-exercise carbohydrate feeding to clarify confounding results surrounding carbohydrate timing. All studies in the series had a similar design and only one variable was changed at a time (e.g. timing of intake or type of carbohydrate). The overall conclusion of these studies was that there is no effect of pre-exercise carbohydrate feeding on performance, even though in some cases hypoglycaemia did develop. Furthermore, there was no relationship between low blood glucose concentrations and performance. There appear to be no performance differences when a smaller or a larger amount of carbohydrate is ingested prior to exercise [121,124,125].

Although research has consistently found clear metabolic differences in response to the timing of pre-exercise carbohydrate ingestion within the hour before exercise, the performance effects have been somewhat vague. With the exception of one study [126], research has shown zero performance effects or an improvement in performance [121–124,127–133]. Based on current research, it would appear there is little evidence to suggest avoiding carbohydrate intake in the hour before exercise as there do not seem to be any detrimental effects on performance. Furthermore, the ingestion of carbohydrates during this period may lead to enhanced performance [19,118].

Most of the earlier studies had methodological issues making it difficult to establish true dose–response relationships between the amount of carbohydrate ingested and performance. Strong evidence of a dose–response relationship between carbohydrate intake and endurance performance is now emerging. In a recent study, endurance performance and fuel selection were assessed during prolonged exercise while ingesting glucose (15, 30, and 60 $g.h^{-1}$ respectively) [134].

The results suggest a relationship between the dose of glucose ingested and improvements in endurance performance [134]. In a large-scale study of the relationship between carbohydrate ingestion rate and cycling time-trial performance, carbohydrate ingestion significantly improved performance in a dose-dependent manner [135].

The authors concluded that an ingestion rate of 60 to 80 $g.h^{-1}$ provided the greatest performance enhancement. Based on the above studies, carbohydrate intake recommendations for more prolonged exercise have been formulated. These guidelines are shown in *Table 2.1*. A summary of experimental studies that assessed the ergogenic effects of dietary intake of carbohydrates is provided in *Table 2.2.*

Table 2.1: Recommendations for carbohydrate intake during different endurance events (Table modified from Jeukendrup, AE. 2011 3).

Exercise duration	CHO required for optimal performance & minimizing negative energy balance	Recommended intake	CHO type	Single CHO (e.g. glucose)	MTC (e.g. glucose : fructose)
< 30 min	None required	-	-	-	-
30 to 75 min	Very small amounts	Mouth rinse	Most forms of CHO	●	●
1 to 2 h	Small amounts	Up to 30 $g.h^{-1}$	Most forms of CHO	●	●
2 to 3 h	Moderate amounts	Up to 60 $g.h^{-1}$	Forms of CHO that are rapidly oxidized (glucose, maltodextrin)	◌	●
>2.5 h	Large amounts	Up to 90 $g.h^{-1}$ (of which glucose must make up no more than 60 g)	Only MTC		●

Note: These guidelines are intended for athletes exercising at a reasonable intensity of 44 $kcal^{-1}.min^{-1}$. If the absolute exercise intensity is below this, the figures for CHO intake should be decreased accordingly

KEY: ●: optimal; ◌: acceptable although not optimal; CHO: carbohydrate; MTC: multiple transportable carbohydrates; h: hour; g: gram; min: minutes.

Table 2.2: Summary of studies that assessed the ergogenic effects of carbohydrates.

Author	Year	Level of evidence	Participants	Intervention	Results	Conclusion
Getzin [18]	2011	Systematic review LOE1	Review focuses on ultra-endurance sports	N/A	Optimal concentrations of GLU & FRU which will not interfere with hydration are usually < 6 %. Begin endurance exercise with a high muscle glycogen load & ingest CHO during prolonged exercise. An increased hourly rate of CHO & overall caloric intake correlated with faster race times. Post training or event repletion, esp. in the 1st h after exercise, when the body has an increased ability to replenish glycogen stores. Evidence suggests there is a role for CHO manipulation in training to maximize CHO oxidative capacity on race day.	We advise ultra-endurance athletes to fuel with a combination of different CHO to maximize oxidation. Athletes should practice their race nutrition during training sessions. Individuals who are having problems fuelling on race day might want to consider rinsing with CHO in an effort to stimulate central drive while their GIT recovers.
Jeukendrup [19]	2011	Systematic review LOE 1	Review focuses on nutrition for endurance sports: marathon, triathlon, & road cycling	N/A	Normal recommend that athletes should take 30 to 60 g of CHO during endurance exercise (>1 h) or 0.7 $g.kg.h^{-1}$. MTC recommended at all durations but are most effective when the exercise is 2.5 h or longer. In those conditions, CHO intakes of up to 90 $g.h^{-1}$ are recommended & these would only be oxidised to any significant degree if they are MTC in which glucose makes up no more than about 60 g.	Individualized nutritional strategies should be developed that aim to deliver CHO at a rate dependent on the exercise intensity and duration. Higher CHO intakes result in better performance. Ingestion of MTC will increase CHO oxidation rates & superior performance.
Ivy et al [85]	2003	Randomised, double-blind, counter balanced design LOE: 1	9 trained male cyclists	1) 7.75 % CHO supplement (200 ml) 2) 7.75 % CHO/1.94 % PRO supplement (200 ml) 3) Sweetened PLA supplement (200 ml) Supplements given before exercise & then every 20 min until 80 % VO_{2max} was reached.	CHO significantly increased TTF (CHO 20 ± 5 min vs. PLA 13 ± 3 min). The PRO enhanced the effect of the CHO supplement by 36 % (CHO - PRO 27 ± 5 min, $p < 0.05$).	The addition of PRO to a CHO supplement enhanced endurance cycling performance above that which occurred with CHO alone.

KEY: PLA: placebo; min: minutes; h: hour; $VO_{2\ max}$: maximal aerobic capacity; TTF: time to fatigue; CHO: carbohydrate; PRO: protein; BW: body weight; g: gram; kg: kilogram; ml: millilitre; TT: time trial; PO: power output; HIE: high intensity exercise; FRU: fructose; GLU: glucose; CHOC: chocolate; IMCL: intramyocellular lipid; esp.: especially.

Table 2.2 (continued): Summary of studies that assessed the ergogenic effects of carbohydrate.

Article	Year	Study design	Participants	Intervention	Results	Conclusion
Van Proeyen et al [105]	2011	Randomised controlled trial LOE 2	20 physically active males	Investigated the effect of consistent training in the fasted state, vs. training in the fed state, on muscle metabolism and substrate selection during fasted exercise.	The training similarly increased V O_{2max} (+ 9 %) & performance in a 60 min simulated time trial (+ 8 %) in both groups ($P < 0.01$). Metabolic measurements were made during a 2 h constant-load exercise bout in the fasted state at ~ 65 % pre-training VO_{2max}. In the fasted state, exercise-induced IMCL breakdown was enhanced in type I fibres ($P < 0.05$) & increased in type IIa fibres ($P < 0.07$). Training did not affect IMCL breakdown in CHO. The fasted state (+ 21%) increased the exercise intensity corresponding to the maximal rate of fat oxidation more than CHO (+ 6%) ($P < 0.05$). Maximal citrate synthase (+ 47 %) & β-hydroxyacyl coenzyme A dehydrogenase (+ 34 %) activity was significantly up- regulated in the fasted state ($P < 0.05$) but not in CHO. Only the fasted state prevented the development exercise-induced drop in blood glucose concentration ($P < 0.05$).	Consistent exercise training in the fasted state stimulates the contribution of IMCL to energy provision during fasting endurance exercise. Fasting training also increases muscular oxidative capacity more than a similar intensity & duration of exercise with ample exogenous CHO supply. Training in the fasted state prevents drop of blood glucose concentration during fasting exercise. Evidence indicates that regular fasted training is a useful strategy to stimulate physiological adaptations in muscle that may eventually contribute to improve endurance exercise performance.
Coyle et al [86]	1983	Randomised, double-blind, cross over design LOE: 1	10 trained cyclists (9 males & 1 female)	Glucose polymer solution vs. PLA solution 50% polycose solution 20 min after the onset of exercise (140 ml) Then 6% polycose solution at 60, 90 & 120 min of exercise (300 ml) PLA group had same volume of flavoured solution	Endurance performance was improved in 7/10 participants. TTF increased from 126 ± 3 min to 159 ± 6 min with CHO ingestion ($p < 0.001$).	CHO feeding during prolonged exercise can postpone the development of fatigue & has an ergogenic effect on endurance cycling performance.

KEY: PLA: placebo; min: minutes; h: hour; $VO_{2\ max}$: maximal aerobic capacity; TTF: time to fatigue; CHO: carbohydrate; PRO: protein; BW: body weight; g: gram; kg: kilogram; ml: millilitre; TT: time trial; PO: power output; HIE: high intensity exercise; FRU: fructose; GLU: glucose; CHOC: chocolate; IMCL: intramyocellular lipid.

Table 2.2 (continued): Summary of studies that assessed the ergogenic effects of carbohydrate.

Article	Year	Study design	Participants	Intervention	Results	Conclusion
Temesi et al [95]	2011	A systematic review with meta-analysis, of single & double-blinded, randomised, placebo-controlled, cross over design studies. LOE: 2	50 studies were included that met the review criteria.	CHO ingestion (not exceeding 8% & between 30 & 80 g/hr during exercise) vs. PLA both ingested at the same rates during exercise.	Mean performance improved 2% with CHO in TT measuring time to complete a distance & distance completed or work done within a set time. Mean performance improvement of 8% with CHO in a submaximal exercise bout followed by a TT. Mean performance improvement of 15% with CHO in TTF measured at a predetermined exercise intensity, speed, or PO. A mean performance improvement of 54% with CHO in a submaximal exercise bout immediately followed by TTF.	The ingestion of CHO during endurance exercise (> 1 h) improves TT performance, TTF, submaximal + TT as well as submaximal + TTF performance.
Burke et al [97]	2000	Randomised, placebo-controlled, cross over design. LOE: 2	7 male endurance trained cyclists & triathletes.	Individualised meal plans based on BW given 72 h before the trial. CHO-loading trial (9 $g.kg.BW^{-1}$ vs. PLA controlled moderate-CHO diet (6 $g.kg.^{-1}$).	Time to complete the TTs or the average PO during the TTs did not differ between the trials.	CHO-loading did not provide an ergogenic effect on endurance cycling performance.

KEY: PLA: placebo; min: minutes; h: hour; $VO_{2\ max}$: maximal aerobic capacity; TTF: time to fatigue; CHO: carbohydrate; PRO: protein; BW: body weight; g: gram; kg: kilogram; ml: millilitre; TT: time trial; PO: power output; HIE: high intensity exercise; FRU: fructose; GLU: glucose; CHOC: chocolate; IMCL: intramyocellular lipid.

2.5.1.2. Increased Protein Intake

Proteins have recently shown to be effective for the maintenance, repair and muscle protein synthesis in response to training [136], thus assisting in the recovery processes. High-protein diets have a long history in sports nutrition and were reportedly popular with athletes in the Olympics of ancient Greece. Protein requirements are increased by hard training [137]. It is generally accepted that athletes have a greater daily protein requirement than their sedentary counterparts (0.8 $g.kg^{-1}.d^{-1}$ to 0.9 $g.kg^{-1}.d^{-1}$) [138]. Burke [139] stated that *"An increase in protein oxidation during endurance exercise, coupled with nitrogen balance studies, provides the basis for recommending increased protein intakes for recovery from intense endurance training*", and that *"Nitrogen balance studies suggest that dietary protein intake necessary in endurance athletes ranges from 1.2 $g.kg^{-1}.d^{-1}$ to 1.4 $g.kg^{-1}.d^{-1}$"* and for ultra-endurance athletes this should be slightly higher [139]. It is possible to achieve very high protein intakes by choosing appropriate foods, however many high protein foods have a high fat content. Protein supplements offer athletes the possibility of achieving their desired protein intake without an unacceptable increase in fat intake [137]. Despite the immense popularity of protein supplementation there is little evidence to support additional consumption of protein as an ergogenic aid [140]. However, increased dietary intake of protein may enhance the post-exercise recovery process [141,142].

Ingestion of additional protein during endurance exercise does not improve performance, reduce proxy markers of muscle damage or hasten the recovery of muscle function [143]. The effectiveness of post-exercise protein ingestion for potentiating muscle protein synthesis is unequivocal [136]. Protein ingestion also potentiates the acute muscle protein synthetic response to endurance exercise [144]. Thus, protein ingestion may assist in maintaining muscle structural integrity and power-generating capacity, rather than influencing muscle aerobic capacity [138]. High-quality proteins such as whey, casein or soy have recently shown to be effective for the maintenance, repair and synthesis of muscle protein in response to training [145]. Protein consumed prior to or post strength and endurance exercise can enhance the maintenance of and net gains in mass of skeletal muscle [145,146]. There is no clear consensus as to whether protein ingestion before, during or after exercise promotes the greatest adaptive response [138]. Although the timing of protein consumption is debated, it is generally recommended that *"the sooner athletes consume protein after exercise the better"* [138]. Relatively frequent protein ingestion (i.e. every 3 to 4 hours) over the 24 hours after exercise is also recommended to sustain the elevation in muscle protein synthesis [138].

2.5.2. SUPPLEMENTARY AIDS

Supplementary aids are oral products taken in additional supplementation to one's normal diet designed to augment the effects of training [147]. According to this definition supplementary aids may include antioxidants, vitamins, amino acids, electrolytes and creatine. Although it is important to recognise that many ergogenic aids may fall under this category, such as pyruvate, carnitine, and calcium, this review will focus on antioxidants, vitamins, amino acids, electrolytes and creatine, as it has shown that these are the supplementary aids shown to have the greatest potential for ergogenic effects in endurance athletes.

2.5.2.1. Antioxidants

Antioxidants are believed to delay human muscle fatigue during prolonged sub-maximal exercise in endurance-trained individuals [148,149]. Antioxidants may also enhance the recovery process following strenuous exercise. Dietary antioxidants include ascorbic acid (vitamin C), α-tocopherol (vitamin E), carotenoids (mainly β-carotene - precursor to vitamin A), polyphenols (e.g. flavonoids), selenium, glutathione, N-acetylcysteine (NAC) and coenzyme Q10 [150]. The most popular antioxidants used are vitamin C, vitamin E, coenzyme Q10 and β-carotene [151].

It is well established that physical exercise results in a significant increase in oxygen uptake by body tissues, particularly in the active skeletal muscles that leads to the production of free radicals [152]. Free radicals are highly reactive molecules that can cause damage to proteins, lipids and DNA. This radical-mediated damage is referred to as *"oxidative damage"* [153], and may contribute to muscular fatigue during prolonged exercise[33,153]. Evidence suggests that free radicals may mediate EIMD and DOMS [154]. Literature suggests that in theory, antioxidants may attenuate the oxidative damage, thereby preventing EIMD and enhancing the recovery process [154]. However, a large dose of vitamin C (400 mg daily) for two weeks did not improve DOMS, EIMD, or lipid pre-oxidation in active male runners [155]. Furthermore, there is no evidence that exercise-induced free radical production in skeletal muscle is detrimental to human health. Regular exercise training promotes increased enzymatic and non-enzymatic antioxidants in muscle fibres therefore resulting in improved endogenous protection against exercise-induced oxidative damage [151]. However, trained athletes who received antioxidant supplements showed evidence of reduced oxidative stress [151].

Neilson et al [156] used a double-blind crossover design to investigate a combination of three antioxidants (Vitamin C, E and coenzyme Q10) rather than relying on just one antioxidant. No change was noted in maximal oxygen update, muscle energy metabolism and muscle fatigue, all of which involve aerobic activity [156]. Coenzyme Q10 supplementation for 28 days did not affect VO_{2max}, heart rate, blood pressure or anaerobic respiratory threshold in male cyclists and triathletes [157]. In another study, vitamin E supplementation did not enhance performance in a marathon run [158]. It must be noted that most of these studies involve short-term supplementation and the results may differ with long-term supplementation. Further research into antioxidants with larger sample sizes or crossover designs would help clarify the role of antioxidants in aerobic activity [73].

A growing number of studies suggest that acute administration of NAC delays muscle fatigue during prolonged sub-maximal exercise in endurance-trained individuals [148,149,159,160]. N-acetylcysteine however does not retard muscle fatigue during exercise close to aerobic capacity (VO_{2max}) [148,149]. There is little evidence that other more commonly used antioxidant supplements can improve exercise performance [161]. The general consensus from the literature is that antioxidants have not been shown to be an effective ergogenic aid for aerobic or anaerobic activity and thus do not improve performance [151]. However, antioxidant supplementation remains popular among endurance athletes. The possible reason for this is there is a belief that antioxidants may enhance the recovery process following strenuous exercise, and that many athletes may take vitamin supplements *"just in case"* [137]. *Table 2.3* provides a summary of the relevant experimental studies that assessed the relevant ergogenic effects of antioxidants.

Table 2.3: Summary of studies that assessed the ergogenic effects of antioxidants.

Author	Year	Level of evidence	Participants	Ergogenic aid under investigation	Recommended dosage and timing	Conclusion
Thompson et al [155]	2001	Placebo-controlled cross-over trial. LOE 2	9 habitually active males.	Vitamin C	1 g dose of vitamin C 2 h before exercise, and on another occasion consumed an identical placebo.	Acute supplementation with vitamin C had no beneficial effects although it is possible that such short-term vitamin C supplementation was ineffective because it occurred at an inappropriate time.
Nielsen et al [156]	1999	A double-blind placebo-controlled cross-over trial. LOE 1	7 male triathletes.	Antioxidant supplementation in capsule form including 100 mg coenzyme Q10, 600 mg ascorbic acid & 270 mg alpha-tocopherol.	N/A	The results demonstrate no effect of antioxidative vit supplementation on VO_{2max}, muscle energy metabolism or muscle fatigue in triathletes.
Weston et al [157]	1997	A double blinded controlled trial. LOE 1	18 endurance athletes – road cyclists & triathletes.	Coenzyme Q10.	1 $mg.kg^{-1}.d^{-1}$ for 28 days.	No significant effect on oxygen uptake, anaerobic & respiratory comparison thresholds, blood lactate, glucose & triglyceride kinetics, heart rate, & blood pressure during & after graded cycling exhaustion.
Buchman et al [158]	1999	A randomised double blinded controlled trial. LOE 1	40 marathon runners.	Vit E.	Vit E (1000 IU daily) or placebo (soya lecithin) for 2 weeks before the race.	Prerace supplementation with the antioxidant vit E had no effect on performance, intestinal injury, occult bleeding, or the severity of post-race gastrointestinal complaints. Vit E supplementation was associated with a decreased incidence of these complaints but had no effect on their severity.

KEY: N/A: not applicable; LOE: level of evidence; vit: vitamin; mg: milligrams; kg: kilogram; h: hour; min: minute; NAC: N-acetylcysteine; vs.: versus; VO_{2max}: maximal oxygen uptake.

Table 2.3 (continued): Summary of studies that assessed the ergogenic effects of antioxidants.

Author	Year	Level of evidence	Participants	Ergogenic aid under investigation	Recommended dosage and timing	Conclusion
Medved et al [148]	2004	Double-blind, crossover study. LOE 1	8 endurance trained males, completing either in running or cycling activity, 4 to 5 times per week for 1 to 2 h, for a minimum of 2 years.	NAC	NAC was intravenously infused at 125 $mg.kg^{-1}.h^{-1}$ for 15 min & then at 25 $mg.kg^{-1}.h^{-1}$ for 20 min before & throughout exercise.	NAC infusion during prolonged, submaximal exercise increased muscle NAC & skeletal muscle cysteine, cystine, & glutathione availability during exercise & that it substantially enhanced performance in well trained individuals.
McKenna et al [149]	2006	Double-blind, randomised, cross over design. LOE 1	8 endurance trained males, completing either in running or cycling activity, 4 to 5 times per week for 1 to 2 h, for a minimum of 2 years.	NAC	NAC was intravenously infused throughout exercise until fatigue. Initial loading dose of 125 $mg.kg^{-1}.h^{-1}$ for 15 min, followed by a constant infusion of 25 $mg.kg^{-1}.h^{-1}$, with exercise commencing after 20 min of constant infusion.	Results confirm that the antioxidant NAC attenuates muscle fatigue, in part via improved K+ regulation, & point to a role for reactive oxygen species in muscle fatigue.
Medved et al [160]	2004	Double-blind, randomised, cross over design. LOE 1	8 male volunteers, 4 recreationally active team sports participants who trained or competed 1 to 2 times per week and 4 endurance-trained cyclists who trained 4 to 5 times per week.	NAC	NAC was intravenously infused throughout exercise until fatigue. Initial loading dose of 125 $mg.kg^{-1}.h^{-1}$ for 15 min, followed by a constant infusion of 25 $mg.kg^{-1}.h^{-1}$, with exercise commencing after 20 min of constant infusion.	NAC infusion effects on fatigue during prolonged cycling exercise may be dependent on VO_{2max}. Furthermore, NAC improved K+ regulation as evidenced by a decreased rise in plasma [K+].
Matuszczak et al	2005	Placebo-controlled trial. LOE 2	18 volunteers (8 females & 10 males).	NAC	NAC was given orally, dissolved in 100 ml of 0.9% saline. Total NAC intake differed between males (12 mg ± 0.5) and females (10 mg ± 0.7) according to body weight.	NAC or NAC-derived compounds have the potential to improve exercise performance during selected endurance tasks.

KEY: N/A: not applicable; LOE: level of evidence; vit: vitamin; mg: milligrams; kg: kilogram; h: hour; min: minute; NAC: N-acetylcysteine; vs.: versus; VO_{2max}: maximal oxygen uptake; K+: potassium.

2.5.2.2. Vitamins

Vitamins along with minerals are commonly referred to as micronutrients. Rodriguez [35] states that, "*These play an important role in energy production, haemoglobin synthesis, the maintenance of bone health, adequate immune function and protection of the body against oxidative damage*" (page 715). Exercise stresses many of the metabolic pathways where micronutrients are required and may also result in muscle adaptations that increase micronutrient needs [162]. Micronutrients assist with synthesis and repair of muscle tissue during recovery from exercise and injury [35]. Thus a higher micronutrient intake may be required to cover increased needs for building, repair and maintenance in athletes [35].

The most common vitamins found to be deficient in athletes' diets are vitamin D, the B group vitamins, as well as some antioxidants such as vitamins C and E, A-carotene and selenium [12,161–164]. It has long been common practice of athletes to take vitamin supplements usually without any thought as to the vitamin status of the individual concerned. Athletes who restrict energy intake, who have severe weight-loss practices, who eliminate one or more of the food groups from their diet, or who consume unbalanced and low micronutrient-dense diets are at the great risk for poor micronutrient status [35]. Rodriguez [35] suggests that "*These athletes may benefit from a daily multivitamin-and-mineral supplement*". In general, most athletes who eat well-balanced meals and have no dietary restrictions do not benefit from vitamin supplementation [162–166].

To ensure optimum energy production and the building and repair of muscle tissue an adequate intake of B vitamins is important [164,167]. The B-complex vitamins major functions which are directly related to exercise are: protein synthesis, tissue repair and maintenance including the central nervous system (CNS), energy production during exercise [162,167] and the production of red blood cells [35]. Some data suggest that exercise may increase the need for these B vitamins as much as twice the current RDA [164]. However, this increased need can generally be met with higher dietary intakes. Short-term marginal deficiencies of B vitamins does not impact performance but severe deficiency of vitamin B12 and/or folate may result in anaemia and reduced endurance performance [162,163,168]. It is therefore for athletes to consume these micronutrients in adequate amounts to ensure optimal performance and health [35].

Vitamin D regulates the development and homeostasis of the nervous system and skeletal muscle [169,171,172] and also plays a major role in bone health by helping to maintain skeletal calcium balance in bone tissue [169,170]. Stress fractures, chronic musculoskeletal pain, viral respiratory tract infections and several chronic diseases are associated with vitamin D deficiency [171,173,174]. Good sources of vitamin D include liver, cod liver oil, fatty fish and egg yolks [169].

Vitamin D is also synthesised in the skin with exposure to sunlight [175]. Surprisingly even in a sport where sun exposure is common, cyclists training 16 hours per week were found to have had low levels of vitamin D [176]. These athletes would benefit from supplementation with vitamin D at the RDA of 5 $\mu g.d^{-1}$ for ages 19 to 49 years [172,177–181]. A growing number of experts advocate that the RDA for vitamin D is not adequate [171,174,182]. Existing evidence suggests that adequate treatment of vitamin D-deficient athletes may improve their athletic performance [183]. However, further research is needed to develop evidence-based guidelines for supplementation.

Buchman [158] investigated short-term vitamin E supplementation before a marathon and showed that supplementation did not prevent ischemia/reperfusion injury of the GIT or muscle injury in long-distance runners, and there was also no change in performance [158]. However, the use of prophylactic vitamin E supplements may be associated with a reduction in the frequency of running-associated GIT complaints [158].

As strenuous and prolonged exercise has been shown to increase the need for vitamin C, physical performance can be compromised with marginal or deficient vitamin C status. Athletes who participate in habitual prolonged, strenuous exercise should consume 100 to 1000 mg of vitamin C daily [163,184]. Vitamin C supplements do not seem to have an ergogenic effect if the diet provides adequate amounts of this nutrient [35]. Bryant [185] reported that neither vitamin E nor vitamin C (alone or taken together) improve exercise performance.

2.5.2.3. Amino Acids

Amino acids are commonly described as the building blocks of protein. The majority of amino acids ingested are in a combined form as dietary proteins from both animal and vegetable sources. There are 20 amino acids, nine of which are essential amino acids and 11 non-essentials. The nine essential amino acids must be obtained through the diet, as the body lacks the ability to synthesize them in sufficient quantities. The general consensus is that adults need 0.8 to 0.9 $g.kg^{-1}.d^{-1}$ of protein to meet their amino acid requirements [138]. It has been advised that endurance athletes adjust their protein intake to 1.2 to 1.4 $g.kg^{-1}.d^{-1}$ to offset significant protein breakdown during exercise [35].

The human body can, however, synthesize the remaining 11 non-essential amino acids. Three of the essential amino acids, leucine, isoleucine, and valine, are collectively referred to as the (BCAAs) [186]. The BCAAs have been the focus of much research in amino acid supplementation in athletes [187,188]. Therefore the BCAAs have been discussed in more detail throughout this section. Branched-chain amino acids are believed to attenuate post exercise protein synthesis and decrease protein degradation, causing a net anabolic effect on muscle metabolism [189]. Supplementation with BCAA has been shown to reverse the reduction in serum glutamine concentration observed after prolonged intense exercise. The decrease in plasma glutamine concentration is paralleled by an increased incidence of symptoms of infections. Thus BCAA and/or glutamine supplementation may also assist the body against infections [190].

The central fatigue theory suggests that prolonged exercise lowers BCAA plasma concentrations, but more importantly, increases plasma concentrations of free fatty acids (FFA). As FFA concentrations increase, free tryptophan levels increase. Higher tryptophan concentrations in the brain results in a sedative effect of the CNS and a resultant compromise in athletic performance [187,188]. Supplementation of BCAA during sustained physical activity has shown positive effects on cognitive performance and perceived exertion [191,192]. Under certain conditions, BCAA supplementation may improve physical performance [193]. However, the majority of studies however have found no effect of BCAA on performance when supplied together with carbohydrates [193]. The amount of BCAA recommended is 0.03 to 0.05 $g.kg^{-1}.h^{-1}$ or 2 to 4 $g.h^{-1}$ ingested repeatedly during exercise and recovery, preferably taken as a drink. Large doses (30 $g.d^{-1}$) are well tolerated, however they may be detrimental to performance due to increased production of ammonia by the exercising muscle [186].

In addition, BCAA supplementation may attenuate post exercise synthesis and decreases degradation of protein, causing a net anabolic effect on muscle metabolism [189]. Supplementation of BCAA during exercise recovery showed a significant decrease in serum creatine kinase concentrations and lactate dehydrogenase values after exercise (from hours up to five days) [194]. Further, Kingsburg [195] found athletes with acute heavy fatigue had a marked although temporary change in amino acid levels. Athletes with chronic fatigue and a higher incidence of infection symptoms also showed persistent decreases in amino acid levels, mainly glutamine [195]. Another study of BCAA supplementation and infection found similar results [196]. These findings suggest that BCAAs may assist in reducing the risk of infection in fatigued athletes; however more research is needed. *Table 2.4* provides a summary of the experimental studies that assessed the ergogenic effects of amino acids.

Table 2.4: Summary of studies that assessed the ergogenic effects of amino acids.

Author	Year	Level of evidence	Participants	Ergogenic aid under investigation	Recommended dosage and timing	Conclusion
Kingsbury et al [195]	1998	Randomised controlled trial. LOE 2	52 elite Olympic athletes 39 field & track athletes 12 Judo competitors 1 rower	Glutamine.	N/A	Decreased plasma AA patterns are directly correlated to infections & chronic fatigue.
Bassit et al [196]	2000	Prospective comparative study. LOE 2	12 male elite triathletes.	BCAA.	Participants received BCAA or placebo for 30 d before the competition & 1 week after the event. BCAA was given twice daily, after each training session (6 g: 60 % L-leucine, 20 % L-valine, & 20 % L-isoleucine) during the first 30 d, & a single dose of 3 g 30 min before the triathlon, as well as a single dose (3 g) daily, in the morning, in the first week after the test were administered.	The data showed that BCAA supplementation can reverse the reduction in serum [glutamine] observed after prolonged intense exercise. The prevention of the lowering of plasma [glutamine] allows an increased response of lymphocytes to ConA & LPS, as well as an increased production of IL-1 & 2, TNF-α , & IFN- γ, possibly linked to the lower incidence of symptoms of infection (33.84 %) reported by the supplemented athletes.
Castell et al [190]	1996	Randomised, double blinded controlled trial LOE 1	201 marathon & ultra-marathon runners as well as rowers.	Glutamine.	5 g L-glutamine dissolved in 330 ml of mineral water was taken immediately after & another 2 h after exercise.	Reduced the self-reported incidence of illness in endurance athletes was significantly lower in the athletes consuming glutamine compared to the control group.
Marwood & Bowtell [197]	2008	Case-control Study. LOE 3	8 cyclists.	Glutamine.	N/A	Glutamine has no effect on performance during high-intensity exercise.
Meeusen et al [193]	2006	Systematic review. LOE 1	N/A	BCAA, tryptophan & CHO supplementation.	N/A	Only under certain conditions, BCAA supplementation can also improve physical performance, although the majority of studies have found no effect of BCAA on performance when supplied together with CHO.

Key: d: day; LOE: level of evidence; AA: amino acid; BCAA: branched chain amino acids; CHO: carbohydrates; PRO: protein; N/A: not applicable; g: grams; MJ: mega joules; min: minutes; h: hours; d: day; ConA: concanavalinA; LPS: lipopolysaccharide; IL-1 & 2: interleukin-1 & 2; IFN- γ: interferon; TNF-α: tumor necrosis factor-α.

Table 2.4 (continued): Summary of studies that assessed the ergogenic effects of amino acids.

Author	Year	Level of evidence	Participants	Ergogenic aid under investigation	Recommended dosage and timing	Conclusion
Blomstrand et al [189]	2001	Randomised controlled trial. LOE 2	7 healthy males, all recreational cyclists, none of them being involved in regular exercise training.	BCAA.	15 min before exercise, immediately before exercise, at 15, 30, 45, & 60 min of exercise, & at 15, 30, 60, & 90 min of recovery. Subjects ingested 150 ml of a solution containing a mixture of BCAAs (45% leucine, 30% valine, & 25% isoleucine) or flavoured water.	Results suggest that BCAA has a protein-sparing effect during recovery after exercise, either that protein synthesis has been stimulated &/or protein degradation has decreased.
Hoffman et al [198]	2010	Case-control Study. LOE 3	10 active males.	L-alanyl-L-glutamine (AG; Sustamine™).	0.2 $g.kg^{-1}$or 0.05 $g.kg^{-1}$ p/litre was taken prior to exercise.	Supplementation provided a significant ergogenic benefit by increasing time to exhaustion during a mild hydration stress. This was likely mediated by an enhanced fluid & electrolyte uptake.
Negro et al [199]	2008	Systematic review. LOE 1	N/A	BCAA.	N/A	Decreases DOMS & promotes MPS. Recovers peripheral blood mononuclear cell proliferation in response to mitogens as well as plasma glutamine concentration after long distance intense exercise. BCAA also modifies the pattern of exercise related cytokine production leading to a diversion of the lymphyocyte immune response towards a Th1 type. These findings suggest BCAA as a supplement for muscle recovery & immune regulation for sports events.
Burke et al [186]	2009	Systematic review. LOE 1	N/A	BCAA.	0.03 to 0.05 $g.kg^{-1}.h^{-1}$ or 2 to 4 $g .h^{-1}$. Ingested repeatedly during exercise & recovery, preferably taken as a drink.	There appears to be some evidence of potential benefits of consuming BCAA. Majority of studies found no effect on performance but potentially delays mental fatigue via central fatigue theory.
Coombes et al [194]	2000	Experimental design. LOE 3	16 male students participating in regular physical activity.	BCAA.	For 2 weeks, 6 g twice per day of 33.3 % leucine, 33.3 % isoleucine, 33.3% valine & an additional 20 g before & after exercise.	BCAA supplementation may reduce the muscle damage associated with endurance exercise.

Key: d: day; AA: amino acid; BCAA: branched chain amino acids; CHO: carbohydrates; PRO: protein; N/A: not applicable; g: grams; MJ: mega joules; min: minutes; h: hours; ConA: concanavalinA; LPS: lipopolysaccharide; IL-1 & 2: interleukin-1 & 2; IFN- γ: interferon; TNF-α: tumor necrosis factor-α; p/h: per hour; MPS: muscle-protein synthesis.

Table 2.4 (continued): Summary of studies that assessed the ergogenic effects of amino acids.

Author	Year	Level of evidence	Participants	Ergogenic aid under investigation	Recommended dosage and timing	Conclusion
Bassit et al [200]	2002	Randomised controlled trial. LOE 2	24 marathon runners & 12 male elite triathletes.	BCAA.	Twice a day, after each training session. OR A single dose (6 g of 60 % L-leucine, 20 % L-valine, & 20 % L-isoleucine). A single dose of 3 g 30 min before the triathlon or race; & a single daily dose (3 g), in the morning, in the first week after.	BCAA supplementation recovers the ability of peripheral blood mononuclear cells proliferate in response to mitogens after a long distance intense exercise, as well as plasma glutamine concentration. The amino acids also modify the pattern of cytokine production leading to a diversion of the immune response toward a Th1 type of immune response.
Newsholme & Blomstrand [191]	2006	Systematic review. LOE 2	N/A	BCAA.	N/A	No effect on physical performance has been shown. Oral intake of BCAAs may reduce the uptake of tryptophan & also brain 5-hydroxytryptamine synthesis & release, thereby delaying central fatigue.
Portier et al [192]	2008	Randomised double-blind controlled trial. LOE 1	12 sailors actively involved in endurance training, 10 h a week for at least 10 years.	Protein diets, rich in BCAA.	The BCAA group consumed a standard package diet providing 11.2 MJ day^{-1} (58 % CHO - 423 g, 30 % fat - 87.3 g, 12 % PRO - 57.4 g) with 2 dietary supplements of 1.7MJ day^{-1} each: the first was a mixture available in powder form containing 50 % valine, 35 % leucine, & 15 % isoleucine (72.5 g PRO). This mixture was dissolved in water, & was ingested every 6 h during the sailing period. The second supplement consisted of 35 % PRO - 25.3 g (in the form of ham & chicken), 40 % CHO - 41 g & 25 % fat - 11.2 g in the form of a powder, ingested every 6 h.	These data indicate that although there was no effect on physical performance, fatigue, & decreases short-term memory are reduced by a high-protein diet with BCAA.

Key: d: day; AA: amino acid; BCAA: branched chain amino acids; CHO: carbohydrates; PRO: protein; N/A: not applicable; g: grams; MJ: mega joules; min: minutes; h: hours; ConA: concanavalinA; LPS: lipopolysaccharide; IL-1 & 2: interleukin-1 & 2; IFN- γ: interferon; TNF-α: tumor necrosis factor-α.

2.5.2.4. Electrolyte and Fluid Intake

Fluids and electrolytes are consumed by athletes before, during, and after exercise [201], predominantly to sustain total body water as dehydration will increase cardiovascular and thermal strain and degrade aerobic performance [201]. Preventing excessive fluid deficits will thus maintain exercise capacity, thermoregulation and reduce subjective perception of effort [202]. The increased sensation of effort when exercising in a dehydrated state is likely to lead to a reduction in performance [203]. Studies have confirmed that performance can be impaired when athletes are dehydrated [204].

Electrolytes such as sodium and potassium are lost along with water in the form of sweat during exercise [201]. If not appropriately replaced, water disturbances and electrolyte imbalances (dehydration and hyponatremia) can develop [114,205]. If the replacement fluid contains sodium, it could help decrease the risk of dehydration or hyponatremia [152]. There has been no evidence to suggest that any electrolyte other than sodium has a significant role in hydration before, during or after exercise [201]. Sodium favours retention of water [204], thus sodium also helps the rehydration process by maintaining plasma osmolality and thereby the desire to drink [152]. Although potassium is important for fluid and electrolyte balance, nerve transmission and active transport mechanisms, during intense exercise, plasma potassium concentrations tend to decline to a lesser degree than sodium. A well balanced diet is usually considered adequate for maintaining normal potassium status among athletes [76,114].

An increase in body core temperature is a common response to exercise [201]. Sweat evaporation provides the primary cooling mechanism for the body, and for this reason runners are encouraged to drink fluids to ensure continued fluid availability for evaporation and circulatory flow to the tissues [206]. Dehydration results in reduced sweating and alters skin blood flow responses, thus increasing core and skin temperature [201]. Increased core and skin temperature will increase skin blood flow requirements to displace blood from the central circulation and therefore reduce cardiac filling, and thus stroke volume and possibly cardiac output [201], resulting in a reduction of maximal aerobic power, thus increasing the relative exercise intensity [207]. Since sodium is the primary cation for the intracellular fluid space, its replacement is critical for re-establishing total body water [208] and consequently thermoregulation, cardiac output and performance.

It is recommended that individuals should monitor body weight changes during training and competition to estimate their sweat lost during a particular exercise task with respect to the weather conditions. This allows customized fluid replacement programs to be developed that prevent excessive dehydration (<2% body weight reductions from baseline body weight) [114]. Approximate sweat rates range from ~0.4 to ~1.8 L/h^{-1} and individual sweat rates will probably have a normal unknown variance [209]. Sweat electrolyte losses need to be replaced to reestablish total body water and this can be accomplished during meals if there is no urgency for recovery [114,202,208,210]. If rapid recovery (<24 hours) is desired or severe dehydration (45% reduction in body mass) is encountered, aggressive drinking of fluids (1.5 liters per kg of body weight lost) and consuming electrolytes should be encouraged to facilitate recovery [201].

There appears to be little physiologic need to replace electrolytes during a single exercise session of moderate duration (e.g. less than three to four hours), particularly if sodium was present in the previous meal [152]. However, including sodium in amounts between 0.5 and 0.7 g·L-1 is recommended during exercise lasting longer than one hour because it may enhance palatability and the drive to drink, therefore increasing the amount of fluid consumed [152], thus preventing dehydration. Therefore it can be concluded that if athletes have eaten properly the night before exercise and if exercise lasts less than three to four hours, electrolyte replacement is not required if an appropriate fluid replacement method is followed. However most ultra-marathon runners are exercising for more than three to four hours during races and electrolyte replacement may be essential in these situations.

Guidelines for fluid replacement have recently caused much debate within the literature. Considerable variability exists between individuals, different physical activities, environmental conditions and other factors (e.g. genetic predisposition, heat acclimatization and training status) influencing a person's sweat rate and sweat electrolyte concentration [114]. Therefore it is difficult to recommend a specific fluid and electrolyte replacement schedules [114]. In a position stand in 2003 specific to fluid replacement in marathon runners, Noakes [206] recommended that a reasonable approach is not to drink as much as possible but to drink *"ad libitum"* (according to thirst) and no more than 400 to 800 ml.h^{-1}. These guidelines were reiterated by Noakes in 2007 when he promotes that fluid consumption "*ad libitum*" reduces the risk of athletes over-drinking and inducing hyponatraemia [211].

2.5.3. PHYSIOLOGICAL AIDS

Physiological aids are aimed to alter the body's composition in such a way as to biologically enhancing the body's performance capabilities.

2.5.3.1. Blood Doping

Red blood cell infusions, commonly known as blood doping, increase the bloods' oxygen-carrying capabilities. This improved oxygen delivery to skeletal muscle could enhance endurance during exercise by prolonging the onset of fatigue [212,213]. In addition, a sufficient rise in total red cell mass significantly improves physiological variables such as maximum oxygen uptake, lactate buffering and thermoregulation. These physiological changes are matched by improvements in endurance performance [213]. It has been hypothesised that blood doping benefits endurance athletes, who depend primarily on the aerobic cycle for energy, compared to sprinters, who depend primarily on the anaerobic cycle for energy [212]. There have been several highly publicised scandals involving blood doping in endurance athletes [212,214]. The concept stemmed from the practice of training at high altitudes, as athletes who train at a high altitude naturally produce more haemoglobin thereby increasing the bloods' oxygen-carrying capabilities. However, training at high altitude is considered a legitimate method of enhancing performance [12].

2.5.4. PHARMACOLOGICAL AIDS

Pharmacological aids entail the consumption of a pharmaceutical drug, consumed for the specific purpose of enhancing athletic ability. These may include the likes of erythropoietin (EPO), growth hormone (GH), anabolic steroids, caffeine and medication such as nonsteroidal anti-inflammatory drugs (NSAIDs), analgesics and cortisone. Whilst it is important to recognise that all of these exist, the literature review below will focus on caffeine and EPO.

2.5.4.1. Caffeine

Caffeine has no nutritive value and is classed as a stimulant [215]. Caffeine is one of the most common supplements used in endurance sports [19]. A review of four leading sports fuel and energy drink manufacturers revealed that more than half of their products contained caffeine [18]. From 1980 to 2003, caffeine was included on the list of substances banned by the IOC with urinary concentrations greater than 12 $mg.l^{-1}$ considered a doping infraction; however, the WADA removed caffeine from the banned substance list in 2004 and placed it on the monitoring list [19]. Caffeine has been shown to reduce the onset of fatigue in sustained workloads, and to improve time trial performance [216–222]. Caffeine exerts positive effects on exercise capacity over a diverse range of protocols including prolonged submaximal exercise (> 90 min), sustained high-intensity work (20 to 60 min) and short duration supra-maximal exercise (1 min to 5 min) [223,224].

The exact mechanism by which caffeine enhances performance is still unknown [18,215]. However, various mechanisms of action have been proposed. These include the mobilisation of fat from adipose tissue and the muscle cell, stimulation of the release and activity of adrenaline, effects on cardiac muscle, direct changes to muscle contractility and alterations to the CNS to decrease the RPE or onset of fatigue [216,223,225–227]. However, recent studies have shown that the effect of caffeine on *"glycogen sparing"* during submaximal exercise is short-lived and inconsistent [228]. Pedersen et al [229], showed that caffeine might be useful for recovery as well as performance.

The benefits of caffeine appear to have protocols of use, with variables including the timing and dosage. The vast majority of the studies that reported ergogenic effects in the range of 3 $mg.kg^{-1}$ to 6 $mg.kg^{-1}$ taken approximately one hour before exercise [19,217]. More recently, studies have reported that much lower doses of caffeine (1 $mg.kg^{-1}$ to 2 $mg.kg^{-1}$), especially when taken later during an endurance exercise task, also enhance performance [217]. Several studies suggest that there is no dose–response relationship between caffeine intake and benefits to endurance exercise, or if it exists, there is a plateau at approximately 3 $mg.kg^{-1}$ [217,219,230]. Consumption of more than 7 $mg.kg^{-1}$ does not have a greater ergogenic advantage over 3 $mg.kg^{-1}$ to 6 $mg.kg^{-1}$, indicating that benefits may level off due to adenosine receptor and hepatic caffeine metabolism saturation [219,221,231]. Caffeine may be consumed pre-event as single or multiple doses spread throughout an exercise bout or just prior to the onset of fatigue [217,230]. The time for peak plasma concentration of caffeine is 15 min to 120 min and it has a half-life of between 2.5 hours to 6 hours [223,232,233]. The effects of caffeine may persist for up to six hours or more after ingestion [234,235].

Therefore, an effective strategy might be to ingest a dose of 3 $mg.kg^{-1}$ one hour before the start of an exercise bout, followed by 1 $mg.kg^{-1}$ every two hours thereafter [19]. There also does not seem to be a consistent difference in the performance effects of caffeine between regular users and non-users of caffeine, or as a result of withdrawal from regular caffeine use [223]. There may be disadvantages to avoiding or withdrawing caffeine prior to a performance trial. Caffeine withdrawal may be associated with side effects such as headaches and fatigue. It can also increase the risk, with subsequent caffeine intake, of the negative effects often seen with large caffeine doses [215]. *Table 2.5* provides a summary of the studies that have assessed the ergogenic effects of caffeine.

Table 2.5: Summary of studies that assessed the ergogenic effects of caffeine.

Author	Year	Level of evidence	Participants	Dosage and timing (under investigation or recommended)	Conclusion
Burke & Spriet [215]	2010	Systematic review. LOE 1	N/A	Traditional supplementation: single intake of ~6 $mg.kg^{-1}$, 1 h pre-exercise. Recent studies show: 1to 3 $mg.kg^{-1}$ or 70 to 200 mg caffeine pre-event or as single or multiple doses spread throughout an exercise bout or just prior to the onset of fatigue. Several studies suggest there is no dose–response relationship between caffeine intake & benefits to endurance exercise or there is a plateau at ~3 mg.kg or ~200 mg.	Caffeine exerts positive effects on exercise capacity over a diverse range of exercise protocols. Further potentially beneficial effects of caffeine include the mobilisation of fat from adipose tissue & the muscle cell, stimulation of the release & activity of adrenaline, effects on cardiac muscle, direct changes to muscle contractility & alterations to the central nervous system to change perceptions of effort or fatigue.
Getzin et al [18]	2011	Systematic review. LOE 1	Review focused on studies with ultra-endurance athletes.	While 3 to 6$mg.kg^{-1}$ may be beneficial, higher doses may be more harmful than helpful. Serum concentration peaks 15 to 120 min after ingestion, with a half-life ranging from 2.5 to 6 h. A recommended dose of 15 to 60 min prior to exercise followed by dosing at regular intervals (perhaps every 2 to 5 h) for longer events.	Reduce onset of fatigue & improve TT performance. However, unaware of studies on caffeine use with exercise lasting longer than 3 h which is well below the ultra-endurance level. Potential benefits include increase in lipolysis & preservation of glycogen; mobilization of intracellular calcium; improves muscle contractility; & may alter the athlete's perception of pain & fatigue.
Jeukendrup [19]	2011	Systematic review. LOE 1	Review focused on endurance sports: Marathon, triathlon, & road cycling.	The vast majority of the studies reported ergogenic effects used doses in the range 3to 6$mg.kg^{-1}$ taken approximately 1 h before exercise. Recent studies report much lower doses (1 to 2 $mg.kg^{-1}$), especially when taken later during endurance exercise. Peak plasma concentration of 30 to 90 min & half-life of about 5 h. An effective strategy might be a dose close to 3$mg.kg^{-1}$ 60 min before the start of exercise followed by 1 $mg.kg^{-1}$ every 2 h thereafter.	A large number of studies have reported improvements in endurance performance.

KEY: PLA: placebo; min: minutes; h: hour; TT: time trial; VO_{2max}: maximum aerobic capacity; CHO: carbohydrate; LOE: level of evidence; g: grams; mg: milligrams; decaf: decaffeinated; ml: millilitres; CNS central nervous system; approx: approximately; vs.: versus.

Table 2.5 (continued): Summary of studies that assessed the ergogenic effects of caffeine.

Author	Year	Level of evidence	Participants	Dosage and timing (under investigation or recommended)	Conclusion
Graham [223]	2001	Systematic review. LOE 1	Review focused on endurance & performance.	The lowest dose used (≈2.1 $mg.kg^{-1}$) was ergogenic, but doses of 3.2 & 4.5 $mg.kg^{-1}$ had a greater effect. It appears that a dose of 3 to 6 $mg.kg^{-1}$ is optimal. Plasma concentrations reach approximate maximum level in 1 h. Caffeine's half-life is 4 to 6 h, & individuals maintain a circulating concentration close to this level for 3 to 4 h.	There is no doubt that caffeine is ergogenic in endurance exercise where fatigue occurs in 30 to 60 min. Found to be ergogenic in most if not all exercise situations. There is no doubt that caffeine would be a useful training aid. Even in terms of true performance, the debate would only be about how great is the effect, rather than whether or not there is one.
Graham [224]	2001	Systematic review. LOE 1	Review focused on the impact on exercise performance & metabolism of caffeine, coffee & ephedrine.	The voids in our understanding of caffeine include the dose (what amount is optimal, what vehicle is used to deliver the drug as well as method, pattern, & mode of administration), the potential side effects (particularly in competitive settings), health implications (insulin resistance & if combined with ephedrine, cardiovascular risks) & mechanisms of action.	It is clear that caffeine, in moderate amounts, can be used orally as an ergogenic aid in aerobic activity lasting for more than 1 min. It increases endurance & speed, but not VO_{2max} & related parameters. It appears unlikely that increased fat oxidation & glycogen sparing is the prime ergogenic mechanism.
Pedersen et al [229]	2008	Two experimental trials in a randomized, double-blind crossover design. LOE 1	Seven volunteers were endurance-trained cyclists/triathletes who were cycling >250 $km.wk^{-1}$ (12 to 15 $h.wk^{-1}$).	The evening before an experiment subjects performed intermittent exhaustive cycling and then consumed a low-CHO meal. The next morning subjects rode until volitional fatigue. On completion of this ride, subjects consumed either CHO (4 $g.kg^{-1}$) or the same amount of CHO + caffeine (8 $mg.kg^{-1}$) during 4h of passive recovery.	In trained subjects, co-ingestion of large amounts of caffeine (8 $mg.kg^{-1}$) with CHO has an additive effect on rates of post-exercise muscle glycogen accumulation compared with consumption of CHO alone.

KEY: PLA: placebo; min: minutes; h: hour; TT: time trial; VO_{2max}: maximum aerobic capacity; CHO: carbohydrate; LOE: level of evidence; g: grams; mg: milligrams; decaf: decaffeinated; ml: millilitres; CNS central nervous system; approx: approximately; vs.: versus.

Table 2.5 (continued): Summary of studies that assessed the ergogenic effects of caffeine.

Author	Year	Level of evidence	Participants	Dosage and timing (under investigation or recommended)	Conclusion
Ivy et al [220]	1979	Randomised, double-blind, cross over design. LOE: 1	Nine (7 males 2 females) trained cyclists.	Ingestion of 250 mg of caffeine, 60 min prior to the ride was followed by ingestion of an additional 250 mg fed at 15 min intervals over the first 90 min of the exercise.	This treatment significantly increased work production by 7% & VO_{2max} by 7% as compared to control while the subjects' perception of exertion remained unchanged. Ingestion of approximately 90 g of glucose polymer during the first 90 min (12.8 g/15 min) of the exercise had no effect on total work production or VO_{2max}. It was, however, effective in reducing the rate of fatigue over the last 30 min of cycling.
Cox et al [217]	2002	Blinded, PLA-controlled, cross over design. LOE:2	12 highly trained male cyclists & triathletes.	Four groups were compared: 1) 6 $mg.kg^{-1}$ caffeine 1 h before (Precaf) 2) 6 x 1 $mg.kg^{-1}$ caffeine every 20 min (Durcaf); 3) 10 $ml.kg^{-1}$ Coca-Cola in last 50 min (~1 to 1.5 mg/kg^{-1} caffeine) 4) PLA capsule Improvements in TT performance compared to PLA were noted regardless of timing of intake: Precaf: 3.4 %; Durcaf: 3.1 % & Coke: 3.1 %.	There is an ergogenic effect of caffeine on TT performance at the end of a 2 h endurance cycle.
Kovacs et al [230]	1998	Randomised double-blind, PLA-controlled, cross over design. LOE: 1	15 trained male cyclists.	CHO-fed during cycling 2.1 $mg.kg^{-1}$, 3.2 $mg.kg^{-1}$, & 4.5 $mg.kg^{-1}$ doses vs. PLA; 75 min pre-exercise & at 20 & 40 min during TT. Compared with PLA & the lowest dose of caffeine (2.1 $mg.kg^{-1}$), doses of 3.2 & 4.5 $mg.kg^{-1}$ increased TT performance & work output.	There is an ergogenic effect of caffeine, in relatively low doses, when added to a CHO–electrolyte drink in a 1 h TT.
Costill [216]	1978	Randomised double-blind, cross over design. LOE: 1	9 competitive cyclists (7 males & 2 females).	decaf coffee vs. 330mg of coffee taken 1 h before exercise showed caffeine improved time to fatigue: 76 ± 5 min during the PLA trial to 90 ± 7 min in the caffeine trial.	There is an ergogenic effect of caffeine on endurance exercise performance.

KEY: PLA: placebo; min: minutes; h: hour; TT: time trial; VO_{2max}: maximum aerobic capacity; CHO: carbohydrate; LOE: level of evidence; g: grams; mg: milligrams; decaf: decaffeinated; ml: millilitres; CNS central nervous system; approx: approximately; vs.: versus.

2.5.4.2. Erythropoietin (EPO)

It is proposed that EPO increases the oxygen carrying capabilities of the blood and consequently delay the onset of fatigue, thus EPO will benefit the endurance athlete [12]. Blood doping was the favoured doping method used to enhance aerobic power [236]. Pharmaceutical preparations that mimic the effect of the body's own production of EPO have been developed, allowing for the convenience of a subcutaneous injection as opposed to the dangerous 'blood doping' [73]. The body naturally produces EPO by the kidneys to regulate red blood cell production by the bone marrow. The rate at which the haematocrit (% of red blood cell count) increases depends on the dose of EPO. Doping with EPO leads to an increase in the red blood cell count and haemoglobin, thereby increasing oxygen uptake [12]. The use of EPO has been banned by WADA since 1990. The prevalence of EPO use has only been described in cyclists. Although the ergogenic effects of EPO might be enticing to marathon runners, there is a lack of evidence regarding the use of EPO in endurance runners. Further research is needed to determine the prevalence of use in marathon and ultra-marathon runners.

2.6. SUMMARY OF THE LITERATURE

Marathon running is a popular sport worldwide, with increased participation internationally and nationally [17–19]. Important factors that influence endurance running performance include training, fatigue and recovery. High volumes of training with insufficient recovery periods may lead to symptoms of fatigue and a predisposition to injury [9,20]. Thus athletes tend to use ergogenic aids to prepare their bodies for the demands of training and competition [22], to delay the effects of fatigue [152], and to accelerate the recovery process [52].

The most frequently used ergogenic aids among endurance athletes include caffeine, antioxidants, EPO, and the dietary practice of carbo-loading [73]. However, there is equivocal evidence for the performance-enhancing effects of many purported ergogenic aids. There is also a lack of evidence regarding the effectiveness of ergogenic aids in endurance running, particularly the marathon and ultra-marathon disciplines. The few running-specific studies that have been conducted vary markedly regarding running distances, fitness levels of participants, and findings of effectiveness of different ergogenic aids [237]. In addition, issues regarding product safety, efficacy, and long-term consequences have not been adequately investigated [238]. However, anecdotal evidence suggests that ergogenic aids are frequently used by recreational and competitive endurance runners.

Further research is needed to determine the prevalence of use of ergogenic aids in marathon and ultra-marathon runners. Therefore, the purpose of this study is to describe the use of ergogenic aids in ultra-endurance runners during training and competition. This study will examine the pattern of use of ergogenic aids, the runners' perception of effect of different ergogenic aids, and factors that may predict the use of ergogenic aids in runners.

CHAPTER 3

ERGOGENIC AIDS USED BY ULTRA-MARATHION RUNNERS

3.1. METHODOLOGY

Ergogenic aids are used in an attempt to improve performance, maximise training adaptations and tend to the negative stresses resulting from high intensity exercise [9,11,239]. The use of sports supplements and ergogenic aids are becoming increasingly popular amongst athletes and are carving their own niche in this popular industry [73].

The consumption of ergogenic aids is reportedly common across a number of different sporting disciplines. In international athletes, the estimated prevalence of use of ergogenic aids is between 46% and 100% [13,240,241]. The type of ergogenic aids used and the pattern of use are largely sport-dependent and these statistics are generalized to all sports rather than being specific to endurance runners. There are few studies reporting the prevalence of use specifically within ultra-marathon running. Thus it is difficult to determine the scale of ergogenic practices. The highest use tends to occur in individual endurance-type sports, such as athletics and cycling [13]. Although Hoberman [242] proposed that doping is less prevalent in marathon runners compared to another endurance sport such as cyclists, anecdotal evidence suggests that ergogenic aids are frequently used by recreational and competitive endurance runners. However, unlike other sports, little is known about the use of ergogenic aids in distance running events. In particular, there is a lack of evidence regarding the prevalence and patterns of use of ergogenic aids among ultra-marathon runners. Therefore, the aim of the present investigation was to examine the use of ergogenic aids in ultra-marathon runners during training and competition.

This survey was performed to assess information regarding the current use (last 12 weeks) of dietary practice, supplementary, pharmacological and physiological ergogenic aids amongst ultra-marathon runners. The aim and specific objectives of this dissertation have been described in *Section 1.2.2* (*page 2*).

3.1.1. STUDY DESIGN AND PARTICIPANTS

This study had a descriptive correlational design. The participants consisted of healthy males and females, frequently participating in ultra-marathons. Participants were recruited through electronic correspondence and advertising. All participants were required to provide informed consent before completing the questionnaire (*APPENDIX I).*

3.1.2. INCLUSION CRITERIA

To qualify for inclusion in the study, participants needed to be frequent ultra-marathon runners. In this study, to be classified as a frequent ultra-marathon runner required participation in at least one ultra-marathon per year, and a minimum of twelve months of endurance running training. Participants were also required to read in English and/or Afrikaans, as the questionnaire was only available in those two official languages.

3.1.3. EXCLUSION CRITERIA

Participants were excluded from the study if they failed to provide informed consent or if their questionnaire was incomplete (less than nine pages of the questionnaire completed). Participants were also excluded from the study they had diabetes mellitus or any other metabolic disorders, as these conditions may have limited or influenced nutritional choices [243].

3.1.4. SAMPLE SIZE CALCULATION

In the absence of more definitive data regarding the use of ergogenic aids in endurance runners, the prevalence of supplement use in athletes was used to calculate the required sample size for this study. An expected frequency of 60% was selected based on previous studies, which reported an incidence of supplement use of between 45% to 85% [244,245].

If the worst expected frequency is 55%, with confidence intervals of 80%, 90% and 95%, the required sample size would have been 140, 211 or 276 participants respectively. However, response rates for questionnaire-based studies are often less than 25 to 55% [246,247]. Therefore, at a response rate of 50%, it was calculated that 500 volunteers would need to be recruited for this study to ensure sufficient statistical power should some volunteers fail to complete the survey.

3.1.5. RECRUITMENT OF PARTICIPANTS

Participants were recruited for this study via different electronic platforms, namely emails, a website advertisement and a website blog. The study advertisement was placed onto the South African Runner's World website (http://www.runnersworld.co.za/events-races/race-news-reports/uct-ultra-marathon-study/)* and a post was placed onto the My Runner's World Blog (http://myrunnersworld.co.za/uct-ultra-marathon-research/). These advertisements contained a link that runners could click to gain direct access the online questionnaire. Contact details for local athletic or running clubs as well as race event organisers were sourced from both the Nedbank Runner's Guide and the South African Runner's World websites. Only the athletic clubs and race event organizers who had registered their contact details that included an email address on either of these websites were added to the study contact list for recruitment. The contacts on our list were then informed of the study via email (*APPENDIX II*) and their assistance with the recruitment procedure was requested. They were requested to forward the study advertisement e-mail (*APPENDIX III*) to all the running members on their mailing lists. The advertisement informed the runners in detail about the study and requested their voluntary participation. The participant recruitment began on the 17/08/2012. Follow-up emails to our contact list were sent out on three separate occasions which served as reminders. These follow-up emails were sent out roughly every two weeks. See *Table 3.1* for the exact dates at which the recruitment reminder emails were sent. The presentation of the email changed with the reminders however the content remained similar (*APPENDIX IV*). This was done to encourage recipients to read the email and avoid the recipients' quick recognition of the emails and deleting them without reading the content. The contact list initially consisted of 1222 email addresses. From the 1222 emails sent out during the first recruitment only 908 were delivered, and the remaining emails were either returned as undelivered or the email address does not exist. These undelivered and non-existing emails were deleted from our contact list.

*It is not possible to access the questionnaire via this link anymore, as the FluidSurveys© account was closed once data collection had been completed.

The final reminders were sent out with seven days remaining before the closing date of the survey. *Table 3.2* provides a breakdown of the number of emails sent to athletic clubs and race organisers in different regions across South Africa.

Table 3.1: Dates of initial and reminder recruitment emails sent to participants.

Purpose of email	Date
Initiation of recruitment process	17/08/2013
Date of first reminder	09/09/2013
Date of second reminder	25/09/2013
Date of third and final reminder	07/10/2013
Survey closing date	15/10/2013

Table 3.2: Number of emails sent to the various regions of South Africa. Data are presented as number (n) and percentage (%).

Club/Race organizers	**Emails sent at initial recruitment**	**Percentage of total emails sent**	**Emails sent at final reminder**	**Percentage of total emails sent**
Boland	64	5%	48	5%
Border	27	2%	20	2%
Central Gauteng	187	15%	134	15%
Central North West	14	1%	13	1%
Eastern Province	63	5%	51	6%
Free State	57	5%	36	4%
North Gauteng	143	12%	107	12%
Griqualand West	19	2%	12	1%
KwaZulu Natal	146	12%	116	13%
Limpopo	85	7%	60	7%
Mpumalanga	75	6%	57	6%
North West Cape	27	2%	20	2%
North North West	46	4%	26	3%
SWD	67	6%	48	5%
Vaal	18	2%	16	2%
Western Cape	184	15%	144	16%
Total	1222	100%	908	100%

3.1.6. MEASUREMENT INSTRUMENTATION

A self-developed questionnaire was used for this study. The questionnaire was designed to gather information on the use of ergogenic aid amongst ultra-marathon runners during training and competition; to determine runners' reasons for using different aids; to assess runners' knowledge of different aids; and to determine the perceived effectiveness of different aids. The questionnaire included commonly used ergogenic aids, as determined by a review of the literature. The ergogenic aids addressed in the questionnaire included were both legal and illegal substances. The questionnaire was divided into three sections, namely: Section A, which included demographic details and a brief medical screening; Section B, which included training and competition history; and Section C, which included detailed questions regarding the use and knowledge of ergogenic aids. Sections A and B were compulsory; however in Section C participants were only required to answer questions regarding self-reported used of ergogenic aids. Please refer to *APPENDIX V* APPENDIX V: Word Version of Questionnairefor the complete questionnaire.

The questionnaire was available in English and Afrikaans so as not to bias any runners whose first language was not English. The questionnaire was translated into Afrikaans by a physiotherapist whose first language was Afrikaans. This was then rechecked back into English by the principle investigator using Google Translate to ensure no loss of content occurred during the translation process.

The questionnaire was posted online through FluidSurveys© (www.fluidsurveys.com). FluidSurveys© is an online questionnaire software programme, enabling users to develop surveys, collect and analyse data. Participants were able to access the questionnaire via a link. FluidSurveys© provided a user friendly interface, allowing participants to navigate through the questionnaire with ease and answer all required sections, whilst automatically skipping irrelevant sections based on their answers to previous questions. Issues relating to participants' privacy, and the confidentiality and anonymity of data will be discussed under ethical considerations (See *Section 3.1.11, page 47*).

3.1.7. VALIDITY OF THE ERGOGENIC AIDS QUESTIONNAIRE

The questionnaire was then critically reviewed by a panel of three experts, with specific interests in endurance running performance. The panel of validators consisted of consisted of an Exercise Science doctoral candidate, a sports physiotherapist, and a sports dietician. Once ethical approval was granted, the panel members were contacted requesting their assistance in validating the questionnaire (*APPENDIX VI*). Upon their agreement to assist with the validation process, the panel members were requested to comment on the relevance and importance of the questions and whether the questions were clear and easy to understand. In addition, the panel members were requested to give input regarding potential questions or sections that had not been included, and that may contribute to addressing the study objectives. The panel members were requested to complete their review of the questionnaire within a four-week period. All three experts returned the questionnaires within this time frame. There was no conflicting feedback from the validation panel. The panel of experts all indicated that the questionnaire was thorough and covered all components of the study objectives. The researcher and supervisors reviewed and consolidated the feedback from the three experts, and compiled an updated version of the questionnaire. The validated questionnaire was then uploaded onto the FluidSurveys© website.

3.1.8. FEASIBILITY OF THE ERGOGENIC AIDS QUESTIONNAIRE

A pilot study was conducted to determine the feasibility of the questionnaire. Six ultra-marathon runners, who fulfilled the inclusion criteria for the study, completed the online survey. They were requested to complete the online questionnaire and to provide feedback regarding the comprehensibility and ease of completion of the questionnaire. All participants in the pilot study completed the survey, and no additional feedback was provided.

This online version of the survey was also sent to the three study supervisors requesting any additional feedback before the study was opened to enrollment. Minor changes in the ordering and layout of questions were made following feedback from supervisors. Data from the feasibility study were not included in data analysis of the main study.

3.1.9. PROCEDURE

Once the questionnaire had been validated and piloted, participants were recruited for this study through different electronic platforms. The online survey was available for a two month period, from 16/08/2013 to 15/10/2013. To facilitate the highest possible response rate, three follow-up reminders were made at approximately two-week intervals. These served to remind the participants of the study and encouraged them to complete the online questionnaire.

Participants accessed the online survey through a link provided in recruitment emails, website advertisement and blog (http://fluidsurveys.com/s/ergogenic_aids_for_ultra-marathon_runners)[†]. The opening page of the survey welcomed and thanked the participants for their interest and participation. The purpose and procedure of the study was explained in detail. Participants were required to give informed consent before accessing the questionnaire. If informed consent was not provided, the survey was terminated. Participants were also required to complete some screening questions to determine the inclusion and exclusion criteria for this study. If the screening questions were not answered correctly, the survey was also terminated. Participants then completed the questionnaire.

On completion of the questionnaire the participants were immediately thanked for their participation in the study. At this point, participants were informed that they could enter a competition to win one of five three-month electronic subscriptions to the South African Runner's World Magazine. This small prize was included as a token of appreciation for participants having completed the survey. If participants wished to enter the competition, they were requested to email their contact details to a separate email address (ergogenicaids.win@gmail.com). Competition emails could not be linked to individual survey responses. A random number generator (http://www.randomizer.org/form.htm) was used to randomly select five prize winners.

FluidSurveys© processed all the responses to the questionnaire. The responses to the questionnaires were then allocated a code and were available for the principle investigator to download the data gathered. Only the investigator and supervisors had access to the data.

[†] The link: http://fluidsurveys.com/s/ergogenic_aids_for_ultra-marathon_runners is no longer active and cannot be accessed, as the FluidSurveys© account was closed once data collection was completed. The email address ergogenicaids.win@gmail.com has also been deactivated and no longer exists.

3.1.10. STATISTICAL ANALYSES

Statistical analyses were performed using Statistica software (StatSoft, Inc. 2004) STATISTICA (Data analysis software system, version 11, www.statsoft.com). Pearson's chi-square measures of association and percentages were used for categorical data, for example; gender, competitiveness, influential factor ranking and the self-reported use of ergogenic aids. Independent t-tests were used for all numerical data. Numerical data presented as the mean and standard deviations (X ± SD) were age, and race and training characteristics. Average weekly mileage, number of training runs per week and the number of recovery days taken after an event, timing of intake, are either presented as the number of responses (n) and percentages (%) or mean and standard deviation (X ± SD).

Forward stepwise analyses in IBM SPSS Statistics (version 21, 2012) were performed to predict the probability of participants using a specific ergogenic aid. The predictor (independent) variables were gender, age, level of competitiveness, training frequency ($d.wk^{-1}$), training distance ($km.wk^{-1}$), number of marathons (n), number of ultra-marathons (n) and ultra-marathon experience (yr).

The predictor variables were coded as seen in *Table 3.3.* Regression analyses were performed on all ergogenic aids except for those aids where the response rate was less than ten participants. All variables were entered simultaneously, CIs were 95% and statistical significance was accepted as $p < 0.05$. All of the forward stepwise regression tables show the odds ratio (Exp(B)), p-values, 95% CIs and the Wald test for each of the predictors. The Wald test is used to test the significance of the variable based on the sample estimate [247].

Table 3.3: Predictor variables coded for forward stepwise regression analyses.

Predictor variable	Coded 0	Coded 1
Descriptive model		
Gender	Male	Female
Age (years)	Junior (< 40 years)	Veteran (≥ 40 years)
Level of competitiveness	Competitive[$]	Recreational
Training history model		
Training frequency ($d.wk^{-1}$)	≤ 3	≥ 4
Training distance ($km.wk^{-1}$)	< 40	≥ 40
Number of marathons (n)	< 10	≥ 10
Number of ultra-marathons (n)	< 5	≥ 5
Ultra-marathon experience (yr)	< 10	≥ 10

[$] Runners were classified as 'competitive' or 'recreational' based on previous ultra-marathon performance. Runners with Comrades marathon (~ 90 km) times of under 7:30 and Two Oceans marathon (56 km) times of under 4:30 were classified as 'competitive'.

3.1.11. ETHICAL CONSIDERATIONS

The study was performed in accordance with the principles of the Declaration of Helsinki (Seoul version, 2008)[2]. The study was granted ethical approval from the Human Research Ethics Committee of the Faculty of Health Sciences, University of Cape Town (HREC REF: 280/2012) (*APPENDIX VII*).

3.1.12. INFORMED CONSENT

An informed consent was required to be filled out online by all participants prior to gaining access to the questionnaire. Prior to requesting informed consent the participants were informed about the purpose and requirements of the study. Participants were also informed about their right to withdraw from the study at any time while completing the questionnaire.

---

[2] The researcher is aware that there is a new version of the Declaration of Helsinki (Fortaleza, Brazil, 2013). However the current research was conducted prior to the release of the 2013 version, and therefore the 2008 version of the Declaration of Helsinki has been cited.

However, due to the nature of the online survey and measures that were put in place to ensure anonymity, participants' responses could not be withdrawn once the questionnaire was submitted. They were also assured that all measures will be taken to ensure confidentiality and privacy of their personal information and that the information will solely be used for the purpose of this study.

3.1.12.1. RISKS TO PARTICIPANTS

There were no risks to any participant, as no physical tests were carried out. No personal identifying information was requested, and questionnaires were coded to ensure confidentiality of responses. To ensure the anonymity of responses, participants' IP addresses were concealed via the FluidSurveys© software design; therefore no responses could be traced back to individual respondents. Due to the sensitive nature of the questionnaire inquiring the use of both legal and illegal ergogenic aids, information obtained from the questionnaires was not provided to any regulatory body, such as the South African Institute for Drug-free Sport (SAIDS) and Athletics South Africa (ASA). This was clearly stated in the participant information sheet on the first page of the online questionnaire.

3.1.12.2. BENEFITS TO PARTICIPANTS

There were no direct benefits to participants. There was also no remuneration for taking part in this study. On completion of the questionnaire the participants were given the choice of entering a competition whereby they could stand a chance to win one of five, three-month electronic subscriptions to the South African Runner's World Magazine, as described in *Section 3.1.9* 3.1.9 *(page 45)*.

3.2. RESULTS

3.2.1. PARTICIPANTS

The online questionnaire was open to participants from 16/08/2013 until 15/10/2013, and 529 respondents accessed the questionnaire. Fifty respondents did not qualify for the study as they failed to meet the study inclusion and exclusion criteria. One hundred and fourteen respondents did not provide informed consent, and were excluded from the study. Three hundred and sixty-five participants entered the study. Participants were required to complete the questionnaire up to and including page nine (of 48 pages) for the responses to be considered complete (that is, sufficient information to address the studies objectives), and for their data to be included for analysis. Ninety-nine participants submitted incomplete responses and were excluded from the study. Therefore, 266 responses were included for analysis. The average length of time taken for the participants to complete the survey was 30 ± 17 minutes. The study sample is summarised in *Figure 3.1.*

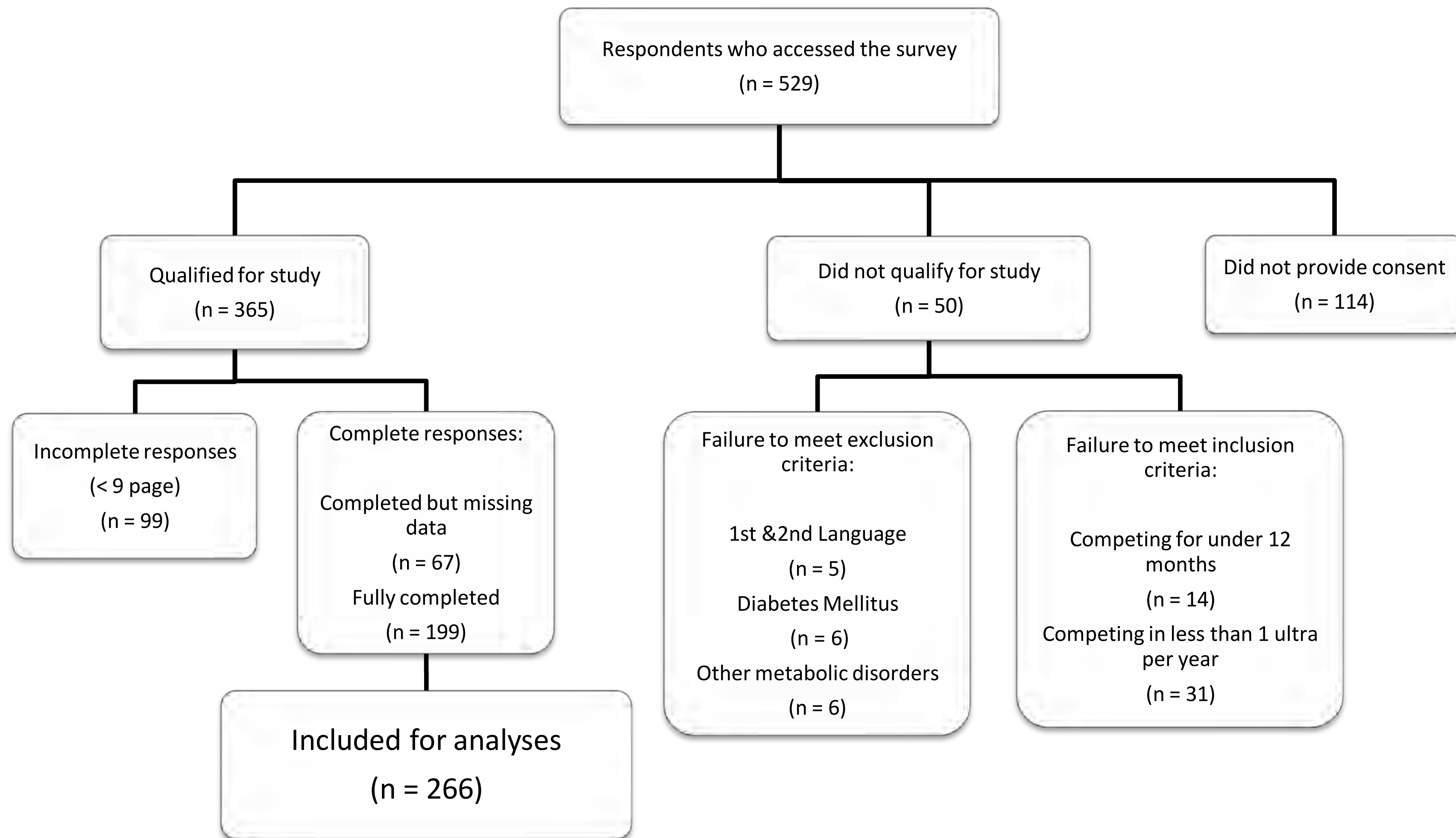


Figure 3.1: Summary of the study sample.

3.2.2. DESCRIPTIVE, TRAINING, AND RACING CHARACTERISTICS

One hundred and seventy-nine participants (67%) were male. The participants were ages ranged from 25 to 65 years (*Table 3.4*). Fifty percent (n = 134) of participants have been running for less than six years and the remaining 50% over a period of six to thirty-six years.

Table 3.4: Descriptive characteristics of the participants ages (n = 266). Data are presented as mean ± standard deviation (SD) and minimum to maximum (min - max).

	Age Mean ± SD (Min - Max)
Male (n = 179)	44 ± 10 (25 – 65 yr)
Female (n = 87)	43 ± 8 (25 – 65 yr)
Total (n = 266)	44 ± 10 (25 – 65 yr)

The training and racing characteristics of participants in this study are shown in *Table 3.5*. Participants had completed a total of 30 ± 29 marathons (range 1 - 100 marathons). The average number of marathons completed per year was 4 ± 2 (range 1 - 12 marathons per year). The mean number of ultra-marathons completed by the participants was 20 ± 22 (range 1 - 100 ultra-marathons). The average number of ultra-marathons completed per year was 3 ± 1 (range 1 - 13 ultra-marathons per year). The number of years that the participants had been competing in ultra-marathons presented with a mean of 10 ± 9 (range 1 - 40 years). See *APPENDIX VIII* for further details on training and race characteristics.

Female participants trained more frequently than male participants ($t = -4.14$; $p < 0.0001$); and male participants had a greater number of rest days per week than female participants ($t = 3.57$; $p < 0.001$). There was no difference in the average training kilometres or weekly training hours run per week between genders. Females began to train sooner after a race than males ($t = 2.69$; $p < 0.01$). Males had competed in more marathons ($t = 3.54$; $p < 0.001$) and ultra-marathons ($t = 3.31$; $p < 0.01$) than females. There was no difference in the number of marathons or ultra-marathons run per year between genders. There was a significant difference between genders in the number of years of ultra-marathon running ($t = 3.66$; $p < 0.001$), with male participants having significantly more experience that female participants.

Table 3.5: Race and training characteristics (n = 266). Data are presented as mean ± standard deviation (SD) and minimum to maximum (min - max).

Race and training characteristics	Total (n = 266)	Gender			
		Males (n = 179)	Females (n = 87)	t-value	p-value
Training frequency ($d.wk^{-1}$)	5 ± 1 (1 - 7)	4.5 ± 1	5.0 ± 1	-4.14	< 0.0001*
Training sessions per day ($n.d^{-1}$)	1 ± 1 (1 - 6)	1 ± 1	1 ± 0.3	0.62	n/s
Average hours training per week (n)	7 ± 3 (1 - 20)	7 ± 3	8 ± 3	-1.73	n/s
Rest days per week ($d.wk^{-1}$)	2 ± 1 (0 - 7)	2.26 ± 1	1.80 ± 1	3.57	< 0.001*
Training distance ($km.wk^{-1}$)	56 ± 20 (10 - 130)	55 ± 22	56 ± 17	-0.41	n/s
Number of rest days post-race before resuming training (d)	4 ± 2 (0 - 14)	4 ± 3	3 ± 2	2.69	< 0.01*
Number of marathons (n)	30 ± 29 (1 - 100)	34 ± 33	21 ± 7	3.54	< 0.001*
Marathons frequency ($d.yr^{-1}$)	4 ± 2 (1 - 12)	4 ± 2	4 ± 2	-0.54	n/s
Number of ultra-marathons (n)	20 ± 22 (1 - 100)	23 ± 25	13 ± 12	3.31	< 0.01*
Ultra-marathons frequency ($n.yr^{-1}$)	3 ± 1 (1 - 13)	2.5 ± 1	2.5 ± 2	-0.56	n/s
Ultra-marathon experience (yr)	10 ± 9 (1 - 40)	11 ± 10	7 ± 5	3.66	< 0.001*

Note: n/s: not significant; d: day; wk: week; yr: year; n: number; km: kilometre.

3.2.3. ERGOGENIC AID USE

Participants in this study used an average of 5 ± 2 (range 1 – 11 aids) ergogenic aids. The most commonly used of the ergogenic aids was sports drinks (n = 213; 80%). None of the participants reported using growth hormone, EPO or blood doping as ergogenic aids. *Table 3.6* shows the reported use of ergogenic aids. Female participants reported a significantly higher use of vitamins compared to male participants (χ^2 = 10.94; $p < 0.001$). The findings for each of the different ergogenic aids will be discussed in more detail under their respective class of ergogenic action (supplementary, dietary, pharmacologic or physiological aids). See *APPENDIX IX* for a further detailed breakdown of the participants' ergogenic aid use.

Table 3.6: Ergogenic aids used by participants (n = 266). Data are presented as number (n) and percentage (%).

Ergogenic aid	Reported use by participants			
	Total (n = 266)	Males (n = 179)	Females (n = 87)	p-value
Dietary practice (Used by 47% of the participants, n =266)				
Carbo-loading	165 (62%)	116 (65%)	49 (56%)	p > 0.1
Protein intake	85 (32%)	57 (32%)	28 (32%)	p > 0.5
Supplementary aids (Used by 45% of the participants, n =266)				
Sports drinks	213 (80%)	144 (80%)	69 (79%)	p > 0.5
Vitamins	181 (68%)	110 (61%)	71 (82%)	p < 0.001*
Gels	163 (61%)	112 (63%)	51 (59%)	p > 0.5
Electrolytes	130 (49%)	83 (46%)	47 (54%)	p > 0.1
Amino acids	19 (7%)	9 (5%)	10 (11%)	p > 0.05
Antioxidants	6 (2%)	3 (2%)	3 (3%)	p > 0.1
Pharmacological aids (Used by 18% of the participants, n =266)				
Medication	104 (39%)	67 (37%)	37 (43%)	p > 0.1
Caffeine	87 (33%)	57 (32%)	30 (34%)	p > 0.5
Growth hormone	0 (0%)	0 (0%)	0 (0%)	-
EPO	0 (0%)	0 (0%)	0 (0%)	-
Physiological aids (Used by 0% of the participants, n =266)				
Blood doping	0 (0%)	0 (0%)	0 (0%)	-

Note: n/s: not significant; -: not attainable due to small sample size.

3.2.4. DIETARY PRACTICE

3.2.4.1. Carbo-loading

One hundred and sixty-five participants reported using carbo-loading as an ergogenic aid. This sample consisted of 116 (70%) males and 49 (30%) females. However, the detailed section of the questionnaire was only completed by 117 (71%) participants. The information that follows therefore refers to data reported by 117 participants.

3.2.4.1.1. Pattern of use

The most common type of carbohydrates used for carbo-loading reported was organic (n = 91; 78%) and refined carbohydrates (n = 41; 35%). The timing at which the practice of carbo-loading commenced prior to a race varied from two days (n = 14; 12%), three days (n = 31; 26%) and seven days (n = 3; 3%) prior to an event. Fourteen participants (12%)reported carbo-loading post events, most of whom reported doing so within 30 minutes of completing the race (n = 8; 7%) or by 2-to-4 hours (n = 5; 4%). There was a greater tendency reported for participants to carbo-load before every race or marathon (n = 56; 48%) than before every training session (n = 1; 1%). See *Table 3.7* below for further details surrounding the pattern of use.

Table 3.7: Pattern of use for carbo-loading (n = 117). Data are presented as number (n) and percentage (%).

Pattern of use	Number of participants (n)
Before every training session	1 (1%)
Before every race or marathon	56 (48%)
Only if the training session is going to be long and hard	27 (23%)
Only if the race is going to be long and hard	69 (59%)
Before and after a race	13 (11%)

In addition, the majority of participants (n = 110; 94%) did not calculate the amount of carbohydrate that they ingested according to their body weight.

3.2.4.1.2. Perceived performance benefit

The majority of the participants (n = 98; 85%) believed that carbo-loading improved their performance whilst three (3%) participants did not and 15 (13%) are unsure. The perceived ergogenic effects of carbo-loading are shown in *Table 3.8*.

Table 3.8: Perceived ergogenic effects of increased carbohydrate intake (n = 117). Data are presented as number (n) and percentage (%).

Reason	Number of participants (n)
Makes me run faster	1 (1%)
Delays fatigue	105 (90%)
Decreases stiffness	7 (6%)
Decreases pain	2 (2%)
Provides an energy boost	44 (38%)
Increases oxygen uptake	8 (7%)
Improves immunity	11 (9%)
Decreases the chance of injury	3 (3%)
Decreases the Severity of Any Injury Sustained	3 (3%)
Increases muscle strength	14 (12%)
Not sure what it does	3 (3%)
Decreases cellular damage	1 (1%)
Improves recovery	22(19%)
Other	5 (4%)

3.2.4.1.3. Factors influencing the use of carbo-loading

Self-experimentation/personal experience, books/magazines and fellow runners were the top three factors that influenced participants' carbo-loading strategies. Please refer to *APPENDIX X* for a detailed table description of all factors influencing participants' use of different ergogenic aids.

3.2.4.1.4. Factors predicting use of carbo-loading

Recreational runners were approximately one third less likely to undertake the dietary practice of carbo-loading than competitive runners (Exp(B) = 0.32; $p < 0.05$). There were no race or training factors that predicted the use of carbo-loading. Please refer to *APPENDIX XI* for a detailed description of all regression analyses.

Table 3.9: Forward stepwise regression analysis of descriptive, race and training factors predicting the use of carbo-loading.

Descriptive factors					
Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	4.67	< 0.001*			11.73
Level of competitiveness	0.32	< 0.05*	0.13	0.80	5.94

3.2.4.2. Protein Intake

Eighty-five participants reported using protein intake as an ergogenic aid. This sample consisted of 57 (67%) males and 28 (33%) females. However, the detailed section of the questionnaire was only completed by 46 (54%) participants. The information that follows therefore refers to data reported by 46 participants.

3.2.4.2.1. Pattern of use

Lean protein (n = 33; 72%) and liquid protein (n = 31; 67%) were the most common methods of using increased protein intake as an ergogenic aid. Seven participants (15%) reported increasing their protein intake three days prior to the event, four participants (9%) two days and one participant (2%) seven days prior to an event. Protein intake was most commonly practiced within 30 minutes of completing the race (n = 18; 39%) followed by two to four hours after the race (n = 14, 30%), then by no specific time frame (n = 8; 17%) and finally by more than six hours after the race (n = 5; 11%). There was a slightly tendency of the participants to increase their protein intake around an event or race compared to during their training schedules (*Table 3.10*).

Table 3.10: Pattern of use for increased protein intake (n = 46). Data are presented as number (n) and percentage (%).

Pattern of use	Number of participants (n)
Before every training run	2 (4%)
Before every race or marathon	9 (20%)
Only if the training run is going to be particularly long or hard	12 (26%)
Only if the race is going to be particularly long or hard	14 (30%)
Only after a race	7 (12%)
Before and after a race	13 (28%)

In addition, the majority of participants (n = 41; 89%) did not calculate the amount of protein that they ingested according to their body weight.

3.2.4.2.2. Perceived performance benefit

The majority of the participants (n = 37; 86%) believed that increased protein intake improved their performance whilst one (2%) participant did not and five (12%) are unsure. Twenty-two (48%) participants believed that increasing their protein intake strategy improved their performance by 'delaying fatigue', 19 (41%) believed that it 'increased their muscle strength' and 18 (39%) believed that it 'improves recovery' (See *Table 3.11* for details).

Table 3.11: Perceived ergogenic effects of increased protein intake (n = 46). Data are presented as number (n) and percentage (%).

Reason	Number of participants (n)
Makes me run faster	2 (4%)
Delays fatigue	22 (48%)
Decreases stiffness	6 (13%)
Decreases pain	3 (7%)
Provides an energy boost	6 (13%)
Improves immunity	8 (17%)
Decreases the chance of injury	8 (17%)
Decreases inflammation prior to it occurring	3 (7%)
Decreases the severity of any injury sustained	9 (20%)
Increases muscle strength	19 (41%)
Increases muscle mass	3 (7%)
Decreases cellular damage	7 (15%)
Improves recovery	18 (39%)
Other	1 (2%)

3.2.4.2.3. Factors influencing the use of increased protein

The most influential factors regarding the intake strategies of increased protein intake was self-experimentation/personal experience, books/magazines and fellow runners. Please refer to *APPENDIX X* for a detailed table description of all factors influencing participants' use of different ergogenic aids.

3.2.4.2.4. Factors predicting use of increased protein intake

Participants who completed more than ten marathons were almost four times more likely to use increased protein as an ergogenic aid than participants who had completed less than ten marathons (Exp(B) = 3.91; $p < 0.05$). Participants who completed more than five ultra-marathons were one tenth less likely to use increased protein as an ergogenic aid than participants who had completed less than five ultra-marathons (Exp(B) = 0.18; $p < 0.01$). Please refer to *APPENDIX XI* for a detailed description of all regression analyses.

Table 3.12: Forward stepwise regression analysis of the descriptive, race and training factors predicting the use of increased protein intake.

Race and training factors					
Steps	Exp(B)	p-value	95% CI Lower	95% CI Upper	Wald
Constant	0.64	> 0.1			2.45
Number of marathons (n)	3.91	< 0.05*	1.38	11.07	6.60
Number of ultra-marathons (n)	0.18	< 0.01*	0.06	0.50	10.68

3.2.5. SUPPLEMENTARY AIDS

3.2.5.1. Fluids

Two hundred and thirteen participants reported using sports drinks for ergogenic purposes. This sample consisted of 144 (68%) males and 69 (32%) females. This detailed section of the questionnaire however includes all fluids consumed by participants not only sports drinks and was thus made compulsory. Therefore the information that follows refers to data reported by all 266 participants and their specified fluids of choice.

3.2.5.1.1. Pattern of use

Water was the most popular choice of fluid during training (n = 203; 76%), followed by sports drinks (n = 22; 8%) and soft drinks (n = 10; 4%). During races however the figures were slightly different. Although water (n = 130; 49%) was still the most common fluid of choice, soft drinks (n = 66; 24%) and sports drinks (n = 48; 18%) were of a more widespread use. The consumption of alcohol increased significantly ($t = -3.38$; $p < 0.001$) as a preferred fluid of choice from during at after a race. The differences between preferred fluid consumption during training, one hour before a race, during races and after races are shown in *Table 3.13*. The intake strategies of the participants varied greatly, with the most common strategy being drinking to thirst (n = 108; 41%), followed by drinking at specific distances (n = 66; 25%), drinking at specific time intervals (n = 44; 17%), and drinking as much as tolerable (n = 19; 7%).

Table 3.13: Preferred fluid of choice during training, during and after races (n = 266). Data are presented as number (n) and percentage (%).

Preferred choice of fluid	During training	One hour before a race	During races	After races
Water	203 (76%)	98 (37%)	130 (49%)	50 (19%)
Sports drinks	22 (8%)	48 (18%)	48 (18%)	51 (19%)
Soft drinks	10 (4%)	1 (0%)	66 (25%)	34 (13%)
Alcohol	0 (0%)	0 (0%)	0 (0%)	11 (4%)
Other	31 (12%)	120 (45%)	22 (8%)	120 (45%)

3.2.5.1.2. Perceived ergogenic effects

Although 194 (79%) of participants believed that fluid intake improved their performance, 29 (12%) did not believe fluid intake improved their performance and 23 (9%) were unsure. The most common reason given for why participants who did not believe or were unsure if fluids improved their performance continue to use the fluids of their choice was for hydration purposes (n = 37; 71%). The majority of the participants listed two perceived ergogenic effects of fluid intake (n = 76; 29%); and one participant listed 14 different perceived ergogenic effects of fluid intake. The most common perceived ergogenic effect of fluid intake was 'delays fatigue' (n = 182; 68%), followed by 'provides an energy boost' (n = 138; 50%) (See *Table 3.14* for details).

Table 3.14: Perceived ergogenic effects of fluid intake (n = 266). Data are presented as number (n) and percentage (%).

Reason	Number of participants (n)
Makes me run faster	9 (3%)
Delays fatigue	182 (68%)
Decreases stiffness	32 (12%)
Decreases pain	11 (4%)
Provides an energy boost	138 (52%)
Increases oxygen uptake	20 (8%)
Improves immunity	26 (10%)
Decreases the chance of injury	19 (7%)
Decreases inflammation prior to it occurring	10 (4%)
Increases muscle strength	20 (8%)
Not sure what it does	16 (6%)
Decreases cellular damage	17 (6%)
Improves recovery	111 (42%)
Hydration/Prevents dehydration	16 (6%)
Prevents cramping	4 (2%)
Prevents overheating	5 (2%)
Influences blood sugar levels	4 (2%)
Other	12 (5%)

3.2.5.1.3. Factors influencing the use of fluids

Self-experimentation/personal experience, fellow runners and books/magazines were the top three factors that influenced participants' fluid intake strategies. Females rated sports associations/athletic clubs and as a significantly more influential factor that determined fluid intake strategies compared to males ($\chi^2 = 9.1$; $p < 0.05$). Please refer to *APPENDIX X* for a detailed table description of all factors influencing participants' use of different ergogenic aids.

3.2.5.1.4. Factors predicting use of sports drinks

Participants who had more than ten years of ultra-marathon running experience were approximately half as likely to consume sports drinks than participants who had less than ten years of ultra-marathon running experience (Exp(B) = 0.53; $p < 0.05$). None of the descriptive factors were predictive for the use of fluids. Please refer to *APPENDIX XI* for a detailed description of all regression analyses.

Table 3.15: Forward stepwise regression analysis of the descriptive, training and racing factors predicting use of the use of sports drinks as ergogenic aids.

Training and race factors					
Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	5.27	< 0.0001*			60.35
Ultra-marathon experience (yr)	0.53	< 0.05*	0.29	0.98	0.31

3.2.5.2. Vitamins

One hundred and eighty-one participants reported using vitamins for ergogenic purposes. This sample consisted of 110 (61%) males and 71 (39%) females. However, the detailed section of the questionnaire was only completed by 108 (76%) participants. The information that follows therefore refers to data reported by 108 participants.

3.2.5.2.1. Pattern of use

The most common choices of vitamins were multi-vitamins (n = 93; 86%), vitamin B12 (n = 53; 49%) and vitamin C (n = 53; 49%). Participants used an average of 2 ± 1 vitamins. One participant reported using seven different vitamin supplements. The majority of vitamins were consumed on a daily basis (n = 74; 69%). Vitamins were also used before every marathon (n = 12; 11%) or only if the marathon was going to be particularly long and hard (n = 12; 11%).

Table 3.16: Pattern of use for the consumption of vitamins (n = 108). Data are presented as number (n) and percentage (%).

Pattern of use	Number of participants (n)
Only if the training run is going to be particularly long or hard	4 (2%)
Before every race or marathon	12 (5%)
Only if the race is going to be particularly long or hard	12 (5%)
Only if not feeling well	3 (1%)
Every day	74 (28%)
1 x per week	5 (2%)
3 x per week	12 (5%)
Only when fatigued/tired	8 (3%)
Before every training run	5 (2%)
Other	5 (2%)

3.2.5.2.2. Perceived ergogenic effects

Although 78 participants (73%) felt that vitamins improved their performance, 11 participants (10%) were not sure and 17 participants (16%) felt vitamins did not improve their performance. The most common perceived ergogenic effect was 'improves immunity' (n = 60; 56%), followed by 'provides an energy boost' (n = 28; 26%), 'improves recovery' (n = 26; 24%), and 'delays fatigue' (n = 24; 22%) (See *Table 3.17* for details).

Table 3.17: Perceived ergogenic effects of vitamins (n = 108). Data are presented as number (n) and percentage (%).

Reason	Number of participants (n)
Delays fatigue	24 (22%)
Decreases stiffness	5 (5%)
Provides an energy boost	28 (26%)
Increases oxygen uptake	11 (10%)
Improves immunity	60 (56%)
Decreases the chance of injury	9 (8%)
Decreases inflammation prior to it occurring	5 (5%)
Decreases the severity of any injury sustained	3 (3%)
Increases muscle strength	5 (5%)
Decreases cellular damage	7 (6%)
Improves recovery	26 (24%)
Other	4 (4%)

3.2.5.2.3. Factors influencing the use of vitamins

The top three most influential factors towards the selection of vitamins as an ergogenic aid was self-experimentation/personal experience, fellow runners and books/magazines. Females rated advertisements as a significantly more influential factor that determined vitamin intake strategies compared to males ($\chi^2 = 10.75$; $p < 0.05$). Please refer to *APPENDIX X* for a detailed table description of all factors influencing participants' use of different ergogenic aids.

3.2.5.2.4. Factors predicting use of vitamin intake

Females were almost three times more likely to use vitamins as an ergogenic aid compared to males (Exp(B) = 2.69; $p < 0.01$). In addition, although not significant, there was a strong tendency for participants who had more than five ultra-marathons to be almost twice as likely to use vitamins as an ergogenic aid than participants who had less than five ultra-marathons (Exp(B) = 1.83; $p = 0.051$). Please refer to *APPENDIX XI* for a detailed description of all regression analyses.

Table 3.18: Forward stepwise regression analysis of the descriptive, race and training factors predicting the use of vitamins.

Descriptive factors					
Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	1.64	< 0.01*			9.94
Gender	2.69	< 0.01*	1.42	5.09	9.21
Race and training factors					
Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	1.33	< 0.50			1.14
Number of ultra-marathons (n)	1.83	> 0.05	1.00	3.36	3.82

3.2.5.3. Gels

One hundred and sixty-three participants reported using gels as an ergogenic aid. This sample consisted of 112 (69%) males and 51 (31%) females. However, the detailed section of the questionnaire was only completed by 118 (72%) participants. The information that follows therefore refers to data reported by 118 participants.

3.2.5.3.1. Pattern of use

The most commonly used brands of gels reported were GU (n = 40; 40%), USN (n = 23; 23%), and Hammer (n = 13; 13%), with the remaining brands making up less than 7% each of the total balance. None of the participants indicated using gels before every training run and 22 (19%) participants indicated that they would consume gels before every marathon or race. *Table 3.20* below portrays that there is a tendency to use gels when races (n = 85; 71%) or training runs (n = 35; 29%) were going to be particularly long and hard (See *Table 3.19* for details).

Table 3.19: Pattern of use for the consumption of gels (n = 118). Data are presented as number (n) and percentage (%).

Pattern of use	Number of participants (n)
Before every training run	0 (0%)
Only if the training run is going to be particularly long or hard	35 (29%)
Before every race or marathon	22 (19%)
Only if the race is going to be particularly long or hard	85 (71%)
During a race	13 (11%)
Only if not feeling well	1 (1%)
Only when fatigued/tired	9 (8%)
Only if 21 km or longer	1 (1%)
Only if 42 km or longer	1 (1%)
Only when I can afford them	1 (1%)

Table 3.20 below shows a detailed comparison of race versus training consumption of gels. Only one participant (0.4%) indicated that they would never consume gels for running a 42.2 km marathon while 62 participants (23%) stated that they would never consume gels for training runs.

Table 3.20: Consumption strategies of gels during races and training runs (n = 118). Data are presented as number (n) and percentage (%).

Consumption strategies	42.2 km Marathon (n)	Training runs (n)
Never	1 (0.4%)	62 (23%)
Once before	0 (0%)	5 (2%)
Once during	9 (3%)	18 (7%)
2 X during	24 (9%)	9 (3%)
3 X during	36 (14%)	2 (1%)
More than 3 x during	21 (8%)	1 (0.4%)
At specific times or specific distances	27 (10%)	5 (2%)

3.2.5.3.2. Perceived performance benefit

The majority of the participants (n = 109; 92%) felt that the gels they are using improves their performance, two (2%) did not think gels improved their performance and seven (6%) participants indicated that they were unsure. The reasons provided by the participants as to how gels improved their performance are listed in the *Table 3.21* below.

Table 3.21: Perceived ergogenic effects of gels (n = 118). Data are presented as number (n) and percentage (%).

Reason	Number of participants (n)
Makes me run faster	8 (7%)
Delays fatigue	80 (68%)
Decreases stiffness	1 (1%)
Provides an energy boost	85 (72%)
Increases oxygen uptake	3 (3%)
Improves immunity	1 (1%)
Decreases the chance of injury	2 (2%)
Decreases inflammation prior to it occurring	2 (2%)
Increases muscle strength	9 (8%)
Not sure what it does	1 (1%)
Decreases cellular damage	1 (1%)
Improves recovery	12 (10%)
Other	4 (3%)

3.2.5.3.3. Factors influencing the use of gels

The top three most influential factors towards the selection of gels as an ergogenic aid was self-experimentation/personal experience, fellow runners and books/magazines. Please refer to *APPENDIX X* for a detailed table description of all factors influencing participants' use of different ergogenic aids.

3.2.5.3.4. Factors predicting use of gel consumption

There were no descriptive or race and training factors that had any effect on the use of gels as an ergogenic aid. Please refer to *APPENDIX XI* for a detailed description of all regression analyses.

3.2.5.4. Electrolytes

One hundred and thirty participants reported using electrolytes as an ergogenic aid. This sample consisted of 83 (64%) males and 47 (36%) females. However, the detailed section of the questionnaire was only completed by 89 (68%) participants. The information that follows therefore refers to data reported by 89 participants.

3.2.5.4.1. Pattern of use

As many as 12 different brands of electrolytes were mentioned by the participants, Rehydrate (n = 54; 63%) and Slowmag (n = 15; 17%) were the most popular brands used. *Table 3.22* below shows the pattern of the electrolyte consumption. It portrays that 69 (78%) of participants would only consume electrolytes if races or training was perceived to be particularly long or hard. Only 13 (15%) of the participants consumed electrolytes before every race or training run.

Table 3.22: Pattern of use for the consumption of electrolytes (n = 89). Data are presented as number (n) and percentage (%).

Pattern of use	Number of participants (n)
Before every training run	2 (2%)
Only if the training run is going to be particularly long or hard	22 (25%)
Before every race or marathon	11 (12%)
Only if the race is going to be particularly long or hard	47 (53%)
Only if not feeling well	2 (2%)
Everyday	3 (3%)
1 X per week	1 (1%)
3 X per week	3 (3%)
Only when fatigued/tired	8 (9%)
During races or training	6 (7%)
After races and training	5 (6%)
4 - 5 Days prior to a race	1 (1%)
Weather dependant on race days	1 (1%)
At predetermined distances	2 (2%)

Eight participants (9%) indicated that they would never consume electrolytes for a 42.2 km marathon while 42 participants (54%) stated that they would never consume electrolytes for training runs (See *Table 3.23* for details).

Table 3.23: Consumption strategies for electrolytes during races and training runs (n = 85). Data are presented as number (n) and percentage (%).

Pattern of use	42.2 km Marathon (n = 85)	Training runs (n = 78)
Never	8 (9%)	42 (54%)
Once before	11 (13%)	8 (10%)
Once during	18 (21%)	16 (21%)
2 X during	22 (26%)	3 (4%)
3 X during	6 (7%)	2 (3%)
More than 3 x during	5 (6%)	1 (1%)
At specific times or specific distances	15 (18%)	6 (8%)

In addition, 57 (65%) participants reported that environmental conditions influenced their use of electrolytes, with increased electrolyte consumption in hot conditions.

3.2.5.4.2. Perceived performance benefit

A high number of participants (n = 74; 84%) believed that electrolytes improved their performance, whilst 8 (9%) did not and 6 (7%) are unsure if they did or did not. The perceived ergogenic effects of electrolytes are shown in *Table 3.24*.

Table 3.24: Perceived ergogenic effects of electrolytes (n = 89). Data are presented as number (n) and percentage (%).

Reason	Number of participants (n)
Makes me run faster	2 (2%)
Delays fatigue	45 (51%)
Decreases stiffness	9 (10%)
Decreases pain	3 (3%)
Provides an energy boost	16 (18%)
Increases oxygen uptake	3 (3%)
Improves immunity	6 (7%)
Decreases the chance of injury	1 (1%)
Decreases inflammation prior to it occurring	3 (3%)
Increases muscle strength	3 (3%)
Decreases cellular damage	4 (4%)
Improves recovery	27 (30%)
Prevents dehydration	2 (2%)
Prevents cramping	9 (10%)
Replaces salts/electrolytes/anything lost	1 (1%)

3.2.5.4.3. Factors influencing the use of electrolytes

The top three most influential factors towards the selection of electrolytes as an ergogenic aid was self-experimentation/personal experience, fellow runners and books/magazines. Please refer to *APPENDIX X* APPENDIX X: Detailed Comparison of the Influential Factors Affecting Ergogenic Aid Intake Strategies.for a detailed table description of all factors influencing participants' use of different ergogenic aids.

3.2.5.4.4. Factors predicting use of electrolyte consumption

There were no descriptive or race and training factors that had any effect on the use of electrolytes as an ergogenic aid. Please refer to *APPENDIX XI* for a detailed description of all regression analyses.

3.2.5.5. Amino Acids

Nineteen participants reported using amino acids as an ergogenic aid. This sample consisted of nine (47%) males and 10 (53%) females. However, the detailed section of the questionnaire was only completed by 13 (68%) participants. The information that follows therefore refers to data reported by 13 participants.

3.2.5.5.1. Pattern of use

The most popular amino acid used by ultra-marathon runners was Glutamine/L-glutamine (n = 6; 46%) followed by the USN brand name (n = 2; 15%). The timing of amino acid consumption varies with five participants (39%) consuming amino acids on a daily basis and the remaining participants consuming amino acids before (n = 2; 15%), during (n = 1; 8%) or after training and races (n = 3; 23%). There was no difference in the timing of the consumption of amino acids during training runs or races.

Table 3.25: Pattern of use for the consumption of amino acids (n = 13). Data are presented as number (n) and percentage (%).

Pattern of use	Number of participants (n)
Before every training session	1 (8%)
Only if the training session is going to be long and hard	1 (8%)
Before every race or marathon	1 (8%)
Only if the race is going to be long and hard	2 (15%)
Only when stiff or sore	1 (8%)
Everyday	5 (39%)
After training and races	3 (23%)

3.2.5.5.2. Perceived performance benefit

Whilst eight participants (67%) felt that the amino acids they were consuming improved their performance, two (17%) of the participants were unsure and two (17%) participants did not believe that the amino acids improved their performance. There were many reasons presented as to how the participants felt that amino acids improved their performance.

The most common amongst these was that amino acids was to 'improves recovery' (n = 5; 38%) and 'decreases the severity of any injury sustained' (n = 4; 31%) (See *Table 3.26* for details).

Table 3.26: Perceived ergogenic effects of amino acids (n = 13). Data are presented as number (n) and percentage (%).

Reason	Number of participants (n)
Delays fatigue	3 (23%)
Decreases pain	1 (8%)
Increases oxygen uptake	1 (8%)
Improves immunity	1 (8%)
Decreases the chance of injury	3 (23%)
Decreases inflammation prior to it occurring	1 (8%)
Decreases the severity of any injury sustained	4 (31%)
Increases muscle strength	3 (23%)
Decreases cellular damage	1 (8%)
Improves recovery	5 (38%)
Other	1 (8%)

3.2.5.5.3. Factors influencing the use of amino acids

The top three most influential factors towards the selection of vitamins as an ergogenic aid was self-experimentation/personal experience, fellow runners and websites. Please refer to *APPENDIX X* for a detailed table description of all factors influencing participants' use of different ergogenic aids.

3.2.5.6. Antioxidants

Six participants reported using antioxidants for ergogenic purposes. Of the six participants there were three (50%) males, three (50%) females, one junior (17%) and five (83%) veteran runners. The detailed section of the questionnaire was only completed by five (83%) participants. The information that follows therefore refers to data reported by five participants.

3.2.5.6.1. Pattern of use

There was no preferred brand or type of antioxidant consumed by the participants, as all five participants who indicated that they were using antioxidants for ergogenic purposes listed different brands. These included: Carotenoids and vitamins, Coenzyme Q10 (Idebenone), Vital, Fit Health and Immunochoice. Daily (n = 2; 40%), five times per week (n = 1; 20%), three times per week (n = 1; 20%), once per week (n = 1; 20%) were when the participants reported to be taking their antioxidants. There were no reports of specifically consuming these surrounding training or race periods.

Table 3.27: Pattern of use for the consumption of antioxidants (n = 5). Data are presented as number (n) and percentage (%).

Pattern of use	Number of participants (n)
Everyday	2 (40%)
Once per week	1 (20%)
3 X per week	1 (20%)
5 X per week	1 (20%)

3.2.5.6.2. Perceived performance benefit

All five participants (100%) that were consuming antioxidants for ergogenic purposes believed that they improved their performance. 'Improves immunity' (n = 4; 80%) followed by 'decreases cellular damage' (n = 2; 40%) and 'increases muscle mass' (n = 2; 40%) were the most common reasons given as to how these participants perceived the antioxidants improved their performance (See *Table 3.28* for details).

Table 3.28: Perceived ergogenic effects of antioxidants (n = 5). Data are presented as number (n) and percentage (%).

Reason	Number of participants (n)
Decreases stiffness	1 (20%)
Improves immunity	4 (80%)
Decreases the chance of injury	1 (20%)
Accelerates healing process	1 (20%)
Decreases cellular damage	2 (40%)
Improves recovery	2 (40%)

3.2.5.6.3. Factors influencing the use of antioxidants

The top three most influential factors towards the selection of antioxidant as an ergogenic aid was self-experimentation/personal experience, fellow runners and books/magazines. Please refer to *APPENDIX X* for a detailed table description of all factors influencing participants' use of different ergogenic aids.

3.2.6. PHARMACOLOGICAL AIDS

3.2.6.1. Medication

One hundred and four participants reported using medication as an ergogenic aid. This sample consisted of 67 (64%) males and 37 (36%) females. However, the detailed section of the questionnaire was only completed by 40 (38%) participants. The information that follows therefore refers to data reported by 40 participants. Accurate interpretation of the reported medications consumed was made difficult as participants would place the medication within the incorrect class (e.g. a participant may have indicated that they consume analgesic medications but when later asked the brand name the participant would list it as an NSAID). The data presented below are based on the classes in which the participant's grouped the medications consumed and not on the correct pharmacological grouping.

3.2.6.1.1. Pattern of use

The most common types of medication reported by the participants were anti-inflammatory medication (n = 27; 68%), followed by analgesics (n = 16; 40%), muscle relaxants (n = 2; 5%) and finally combination medication (n = 1; 3%). Medication was reported to be utilized most when, 'only if the race was going to be particularly long and hard' (n = 16; 40%), 'only when injured' (n = 14; 35%) or 'only when stiff and sore' (n = 14; 35%) (See *Table 3.29* for details).

Table 3.29: Pattern of use for the consumption of medication. Data are presented as number (n) and percentage (%).

Pattern of use	Analgesics (n = 16)	NSAIDS (n = 27)	Muscle relaxants (n = 2)	Combination medications (n = 1)
Before every training session	0 (0%)	1 (4%)	0 (0%)	0 (0%)
Only if the training session is going to be long and hard	1 (6%)	1 (4%)	1 (50%)	0 (0%)
Before every race or marathon	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Only if the race is going to be long and hard	6 (38%)	8 (30%)	2 (100%)	0 (0%)
Only if not feeling well	4 (25%)	3 (11%)	0 (0%)	0 (0%)
Only when injured	4 (25%)	10 (37%)	0 (0%)	0 (0%)
Only when stiff or sore	5 (31%)	8 (30%)	0 (0%)	1 (100%)
3 X per week	0 (0%)	1 (4%)	0 (0%)	0 (0%)
Only when tired or fatigued	2 (13%)	0 (0%)	0 (0%)	0 (0%)
Other	0 (0%)	3 (11%)	0 (0%)	0 (0%)

Table 3.30 demonstrates the strong tendency for participants to use medication during races, in comparison to training.

Table 3.30: Consumption strategies during training and marathons. Data are presented as number (n) and percentage (%).

Consumption strategy	Analgesics (n = 16)		NSAIDS (n = 27)		Muscle relaxants (n = 2)		Combination medications (n = 1)	
	During a 42.2 km marathon	During training	During a 42.2 km marathon	During training	During a 42.2 km marathon	During training	During a 42.2 km marathon	During training
Never	2 (13%)	15 (94%)	7 (26%)	19 (70%)	0 (0%)	1 (50%)	1 (100%)	1 (100%)
Once before	1 (6%)	1 (6%)	8 (30%)	4 (15%)	0 (0%)	1 (50%)	0 (0%)	0 (0%)
Once during	9 (56%)	0 (0%)	6 (22%)	0 (0%)	1 (50%)	0 (0%)	0 (0%)	0 (0%)
Twice during	3 (19%)	0 (0%)	2 (7%)	0 (0%)	1 (50%)	0 (0%)	0 (0%)	0 (0%)
Three times during	1 (6%)	0 (0%)	1 (4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
At specific distances	0 (0%)	0 (0%)	1 (4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

#Key: km: kilometres.

Details of the dosage patterns of medication are represented in *APPENDIX XI*.

3.2.6.1.2. Perceived performance benefit

The majority of runners (n = 36; 80%) believed that their medication of choice improved their performance, while others were unsure (n = 4; 9%) or did not believe (n = 5; 11%) that medication improved their performance. *Table 3.31* shows the different perceived performance benefits through which the participants believed medication improved performance.

Table 3.31: Perceived ergogenic effects of medication. Data are presented as number (n) and percentage (%).

Reason	Analgesics (n = 16)	NSAIDS (n = 27)	Muscle relaxants (n = 2)	Combination medications (n = 1)	Total count (n =40)
Makes me run faster	2 (13%)	1 (4%)	2 (100%)	0 (0%)	5 (13%)
Delays fatigue	6 (38%)	3 (11%)	0 (0%)	1 (100%)	10 (25%)
Decreases stiffness	3 (19%)	10 (37%)	2 (100%)	0 (0%)	15 (38%)
Decreases pain	9 (56%)	9 (33%)	0 (0%)	1 (100%)	19 (48%)
Provides an energy boost	0 (0%)	1 (4%)	0 (0%)	0 (0%)	1 (3%)
Improves immunity	0 (0%)	0 (0%)	1 (50%)	0 (0%)	1 (3%)
Decreases the chance of injury	0 (0%)	2 (7%)	0 (0%)	0 (0%)	2 (5%)
Decreases inflammation prior to it occurring	3 (19%)	10 (37%)	0 (0%)	0 (0%)	13 (33%)
Decreases the severity of any injury sustained	1 (6%)	6 (22%)	1 (50%)	0 (0%)	8 (20%)
Increases muscle strength	0 (0%)	1 (4%)	1 (50%)	0 (0%)	2 (5%)
Decreases cellular damage	0 (0%)	2 (7%)	0 (0%)	0 (0%)	2 (5%)
Improves recovery	0 (0%)	4 (15%)	0 (0%)	0 (0%)	4 (10%)
Other	1 (6%)	1 (4%)	2 (100%)	0 (0%)	4 (10%)

3.2.6.1.3. Factors influencing the use of medication

The top three most influential factors towards the selection of medication as an ergogenic aid was self-experimentation/personal experience, fellow runners and books/magazines. Please refer to *APPENDIX X* for a detailed table description of all factors influencing participants' use of different ergogenic aids.

3.2.6.1.4. Factors predicting use of medication intake

There were no descriptive or race and training factors that were predictive of the use of medication as an ergogenic aid. Please refer to *APPENDIX XI* for a detailed description of all regression analyses.

3.2.6.2. Caffeine

Eighty-seven participants reported using caffeine as an ergogenic aid. This sample consisted of 57 (66%) males and 37 (43%) females. However, the detailed section of the questionnaire was only completed by 37 (43%) participants. The information that follows therefore refers to data reported by 37 participants.

3.2.6.2.1. Pattern of use

Coffee (n = 29; 78%) was the most frequently utilized means of attaining caffeine for ergogenic aid purposes. The second most frequently used factor of caffeine was caffeinated gels (n = 4; 11%) and caffeinated energy drinks such as Red Bull (n = 4; 11%). Caffeine was reportedly used on an everyday basis by 17 (46%) of the participants, whilst 19 (51%) of the participants specifically used caffeine before every race and only 7 (19%) consumed caffeine before every training run (See *Table 3.32* for details).

Table 3.32: Pattern of use for the consumption of caffeine (n = 37). Data are presented as number (n) and percentage (%).

Pattern of use	Number of participants (n)
Before every training session	7 (19%)
Only if the training session is going to be long and hard	8 (22%)
Before every race or marathon	19 (51%)
Only if the race is going to be long and hard	9 (24%)
Only if not feeling well	1 (3%)
Everyday	17 (46%)
Only when tired or fatigued	5 (14%)
Other	4 (11%)

In addition, the majority of participants (n = 26, 90%) were unsure about the amount of caffeine that was needed to achieve an ergogenic effect, with many participants (n = 19, 66%) suggesting that one cup of coffee contained sufficient caffeine to achieve an ergogenic effect.

3.2.6.2.2. Perceived performance benefit

Twenty-six (70%) participants using caffeine as an ergogenic aid believed that caffeine enhanced their performance, 8 (22%) did not and 3 (8%) were unsure. The most common perceived ergogenic effects of caffeine included 'gives me an energy boost' (n = 19; 51%), 'delays fatigue' (n = 8; 22%) and 'makes me run faster' (n = 5; 14%).

Table 3.33: Perceived ergogenic effects of caffeine (n = 37). Data are presented as number (n) and percentage (%).

Reason	Number of participants (n)
Makes me run faster	5 (14%)
Delays fatigue	8 (22%)
Decrease stiffness	1 (3%)
Decreases pain	2 (5%)
Gives me an energy boost	19 (51%)
Increase oxygen uptake	2 (5%)
Increase muscle strength	1 (3%)
Not sure what it does	2 (5%)
Improves recovery	3 (8%)
Other	3 (8%)

3.2.6.2.3. Factors influencing the use of caffeine

The top three most influential factors towards the selection of caffeine as an ergogenic aid was self-experimentation/personal experience, fellow runners and books/magazines. Females rated sports associations/athletic clubs and as a significantly more influential factor that determined caffeine intake strategies compared to males (χ^2 = 8.74; $p < 0.05$). However, males rated self-experimentation/personal experience as a significantly more influential factor that determined caffeine use compared to females (χ^2 = 8.21; $p < 0.05$). Please refer to *APPENDIX X* for a detailed table description of all factors influencing participants' use of different ergogenic aids.

3.2.6.2.4. Factors predicting use of caffeine intake

There were no descriptive or race and training factors that were predictive of the use of caffeine as an ergogenic aid. Please refer to *APPENDIX XI* for a detailed description of all regression analyses.

3.2.7. SUMMARY OF ERGOGENIC AID USE

Participants in this study used an average of 5 ± 2 ergogenic aids. The most commonly used class of ergogenic aids was dietary practice (47%), followed by supplementary aids (45%) and then pharmacological aids (18%). The most commonly used ergogenic aid was sports drinks (n = 213; 80%) followed by vitamins (n = 181; 68%) and then carbo-loading (n = 165; 62%). None of the participants reported using growth hormone, EPO or blood doping as ergogenic aids. *Figure 3.2* illustrates the number of males and females using each of the respective ergogenic aids with the exception of growth hormone, blood doping and EPO for which neither gender indicated the use thereof. There was only a significant difference between genders in the use of vitamins, with a higher reported use in female participants ($\chi^2 = 10.94$; $p < 0.001$).

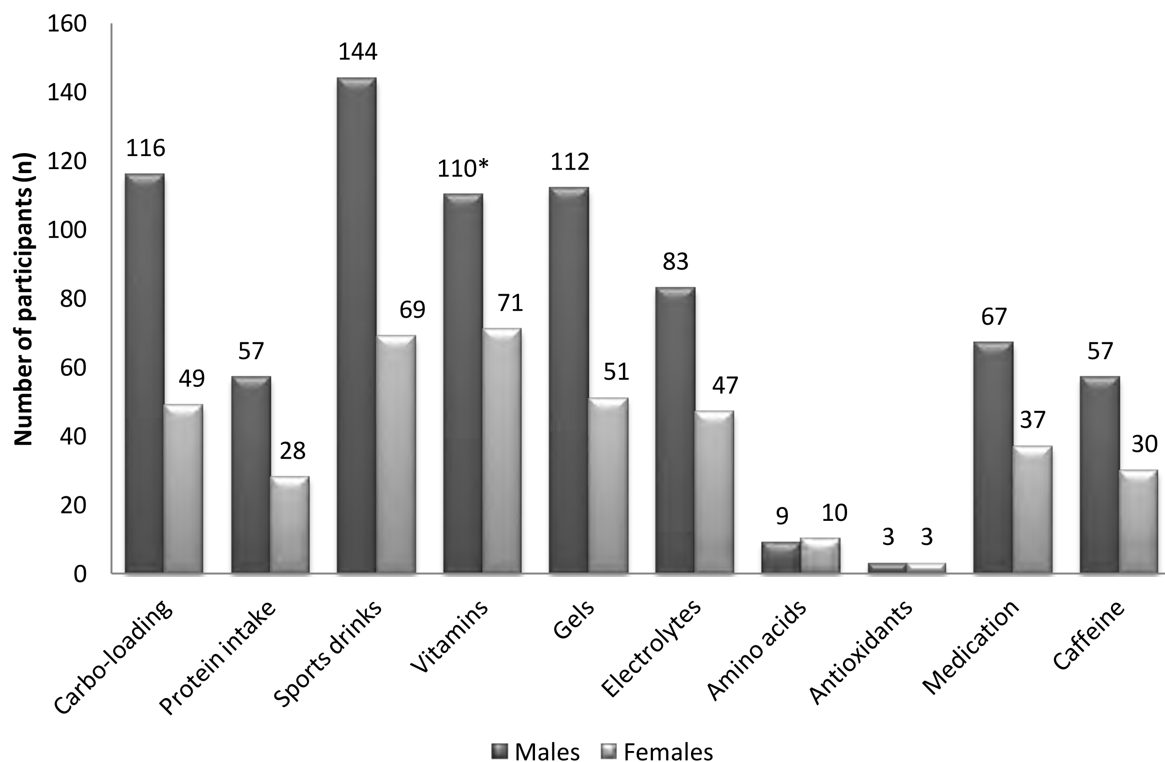


Figure 3.2: The use of different ergogenic aids by male and female participants. Data are expressed as numbers (n).

#Note: EPO, growth hormone, and blood doping are not presented in this figure as no participants reported using either of these ergogenic aids. Significant differences: * p < 0.01

The pattern of use of different ergogenic aids varied greatly, and has been summarised in *Table 3.34*. There was a very strong tendency of the participants to believe that the ergogenic aids that they were using improved their performance, as demonstrated in *Table 3.35* below. The perceived ergogenic effects of different aids have been presented in *Table 3.36.*

Table 3.34: Pattern of use for the consumption of the different ergogenic aids. Data are presented as number (n) and percentage (%).

Pattern of use	Carbo-loading (n = 117)	Protein (n = 46)	Vitamins (n = 108)	Gels (n = 118)	Electrolytes (n = 89)	Amino Acids (n = 13)	Antioxidants (n = 5)	Medication (n = 46)	Caffeine (n = 37)
Before every training session	1 (1%)	2 (4%)	5 (5%)	0 (0%)	2 (2%)	1 (8%)	0 (0%)	1 (2%)	7 (19%)
Only if the training session is going to be long & hard	27 (23%)	12 (26%)	4 (4%)	35 (29%)	22 (25%)	1 (8%)	0 (0%)	3 (7%)	8 (22%)
Before every race or marathon	56 (48%)	9 (20%)	12 (11%)	22 (19%)	11 (12%)	1 (8%)	0 (0%)	0 (0%)	19 (51%)
Only if the race is going to be long and hard	69 (59%)	14 (30%)	12 (11%)	85 (71%)	47 (53%)	2 (15%)	0 (0%)	16 (35%)	9 (24%)
Only if not feeling well	0 (0%)	0 (0%)	3 (3%)	1 (1%)	2 (2%)	0 (0%)	0 (0%)	7 (15%)	1 (3%)
Only when injured	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	14 (30%)	0 (0%)
Only when stiff or sore	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (8%)	0 (0%)	14 (30%)	0 (0%)
Everyday	1 (1%)	6 (13%)	74 (69%)	0 (0%)	3 (3%)	5 (39%)	2 (40%)	0 (0%)	17 (46%)
Once per week	3 (3%)	1 (2%)	5 (5%)	0 (0%)	1 (1%)	0 (0%)	1 (20%)	0 (0%)	0 (0%)
3 X per week	5 (4%)	5 (11%)	12 (11%)	0 (0%)	3 (3%)	0 (0%)	1 (20%)	0 (0%)	0 (0%)
Only when tired or fatigued	1 (1%)	0 (0%)	8 (7%)	9 (8%)	8 (9%)	0 (0%)	0 (0%)	2 (4%)	5 (14%)
Other	17 (15%)	23 (50%)	5 (5%)	16 (14%)	15 (17%)	3 (23%)	1 (20%)	3 (7%)	4 (11%)

#Note: Growth hormone, EPO, and blood doping have not been included in the above table as no participants reported the use thereof. Fluids have also not been included in the table above as a more detailed section was required for their pattern of use. Further details of pattern of use of fluids can be seen in *Table 3.13*.

#Note: Shaded areas present the top two patterns of use within that ergogenic aid's column whereby the darker shaded block is the most common and the lighter shaded block is the second most commonly practiced pattern of use.

Table 3.35: Beliefs of ergogenic aid effectiveness. Data are presented as percentage (%).

Beliefs of ergogenic aid effectiveness to improve performance	Ergogenic aid										
	Carbo-loading (n = 117)	Protein (n = 46)	Fluid of choice (n = 266)	Vitamins (n = 108)	Gels (n = 118)	Electrolytes (n = 89)	Amino Acids (n = 13)	Antioxidants (n = 5)	Medication (n = 40)	Caffeine (n = 37)	Total (n = 839)
Believe	98 (85%)	37 (86%)	194 (79%)	78 (73%)	109 (92%)	74 (84%)	8 (67%)	5 (100%)	36 (80%)	26 (70%)	665 (79%)
Does not believe	3 (3%)	1 (2%)	29 (12%)	17 (16%)	2 (2%)	8 (9%)	2 (17%)	0 (0%)	5 (11%)	8 (22%)	75 (9%)
Unsure	15 (13%)	5 (12%)	23 (9%)	11 (10%)	7 (6%)	6 (7%)	2 (17%)	0 (0%)	4 (9%)	3 (8%)	76 (9%)

Table 3.36: Summary of the perceived ergogenic effects of different aids. Data are presented as number (n) and percentage (%).

Reason	Carbo-loading (n = 117)	Protein (n = 46)	Fluid of choice (n = 266)	Vitamins (n = 108)	Gels (n = 118)	Electrolytes (n = 89)	Amino Acids (n = 13)	Antioxidants (n = 5)	Medication (n = 40)	Caffeine (n = 37)
Makes me run faster	1 (1%)	2 (4%)	9 (3%)	0 (0%)	8 (7%)	2 (2%)	0 (0%)	0 (0%)	5 (13%)	5 (14%)
Delays fatigue	105 (90%)	22 (48%)	182 (68%)	24 (22%)	80 (68%)	45 (51%)	3 (23%)	0 (0%)	10 (25%)	8 (22%)
Decreases stiffness	7 (6%)	6 (13%)	32 (12%)	5 (5%)	1 (1%)	9 (10%)	0 (0%)	1 (20%)	15 (38%)	1 (3%)
Decreases pain	2 (2%)	3 (7%)	11 (4%)	0 (0%)	0 (0%)	3 (3%)	1 (8%)	0 (0%)	19 (48%)	2 (5%)
Gives me an energy boost	44 (38%)	6 (13%)	138 (52%)	28 (26%)	85 (72%)	16 (18%)	0 (0%)	0 (0%)	1 (3%)	19 (51%)
Increases oxygen uptake	8 (7%)	0 (0%)	20 (8%)	11 (10%)	3 (3%)	3 (3%)	1 (8%)	0 (0%)	0 (0%)	2 (5%)
Improves immunity	11 (9%)	8 (17%)	26 (10%)	60 (56%)	1 (1%)	6 (7%)	1 (8%)	4 (80%)	1 (3%)	0 (0%)
Decreases the chance of injury	3 (3%)	8 (17%)	19 (7%)	9 (8%)	2 (2%)	1 (1%)	3 (23%)	1 (20%)	2 (5%)	0 (0%)
Decreases inflammation before it happens	0 (0%)	3 (7%)	10 (4%)	5 (5%)	2 (2%)	3 (3%)	1 (8%)	0 (0%)	13 (33%)	0 (0%)
Decreases the severity of any injury sustained	3 (3%)	9 (20%)	3 (1%)	3 (3%)	0 (0%)	0 (0%)	4 (32%)	1 (20%)	8 (20%)	0 (0%)
Increases muscle strength	14 (12%)	19 (41%)	20 (8%)	5 (5%)	9 (8%)	3 (3%)	3 (23%)	0 (0%)	2 (5%)	1 (3%)
Not sure what it does	3 (3%)	0 (0%)	16 (6%)	0 (0%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (5%)
Increases muscle mass	0 (0%)	3 (7%)	3 (1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Decreases cellular damage	1 (1%)	7 (15%)	17 (6%)	7 (6%)	1 (1%)	4 (5%)	1 (8%)	2 (40%)	2 (5%)	0 (0%)
Improves recovery	22 (19%)	18 (39%)	111 (42%)	26 (24%)	12 (10%)	27 (30%)	5 (39%)	2 (40%)	4 (10%)	3 (8%)
Other	5 (4%)	1 (2%)	35 (16%)	4 (4%)	4 (3%)	12 (13%)	1 (8%)	0 (0%)	4 (10%)	3 (8%)

#Note: Shaded areas present the top two perceived effects within that ergogenic aid's column whereby the darker shaded block is the most common and the lighter shaded block is the second most commonly perceived ergogenic effect.

The top three most influential factors towards the selection of amino acids was self-experimentation/personal experience, fellow runners and websites. The top three most influential factors towards the selection of all the other ergogenic aids was self-experimentation/personal experience, fellow runners and books/magazines.

Recreational runners were approximately one third less likely to undertake the dietary practice of carbo-loading than competitive runners (Exp(B) = 0.32; $p < 0.05$). Participants who had more than ten years of ultra-marathon running experience were approximately half as likely to consume sports drinks than participants who had less than ten years of ultra-marathon running experience (Exp(B) = 0.53; $p < 0.05$). Females were almost three times more likely to use vitamins as an ergogenic aid compared to males (Exp(B) = 2.69; $p < 0.01$). In addition, although not significant, there was a strong tendency for participants who had more than five ultra-marathons to be almost twice as likely to use vitamins as an ergogenic aid than participants who had less than five ultra-marathons (Exp(B) = 1.83; $p = 0.051$). Participants who completed more than ten marathons were four times more likely to use increased protein as an ergogenic aid than participants who had completed less than ten marathons (Exp(B) = 3.91; $p < 0.05$). Participants who completed more than five ultra-marathons were one tenth less likely to use increased protein as an ergogenic aid than participants who had completed less than five ultra-marathons (Exp(B) = 0.18; $p < 0.01$). There were no descriptive or race and training factors that had any effect on the use of gels, electrolytes, medication or caffeine as an ergogenic aids. Statistical tests were not able to be run for amino acids, antioxidants, EPO, growth hormone or blood doping as these sample sizes were too small.

3.3. DISCUSSION

Ergogenic aids have become frequently utilized by athletes to improve their performance in competition [12]. The results of this study reiterate that the use of ergogenic aids is common amongst ultra-marathon runners. This discussion will focus on the main findings of this study, specifically in relation to the study aim and objectives described in *Section 1.2 (page 2).*

3.3.1. PARTICIPANTS AND STUDY DESIGN

3.3.1.1. Recruitment Strategy

Emails were the most effective method of recruitment over websites and online forums. Fluctuations at concentrated time frames of roughly 48 hour periods were noted when participants accessed the survey. These fluctuations started directly after each of the reminder emails were sent out. Periods between the reminder emails saw very few participants accessing the survey. These patterns show that reminder emails served to be a necessary recruitment strategy for this study design. This has also been described by other studies exploring best methods of electronic response rates [248–250]. It is in the author's opinion that the method of recruitment through social media, such as Facebook or Twitter, should not be ignored and may become the preferred choice of recruitment in future studies.

3.3.1.2. Sample Size

Studies investigating supplement use in athletes commonly report low response rates and have shown that athletes are reluctant to discuss their use of performance enhancing products. For example, Petroczi and Naughton [251] distributed 2995 surveys on nutritional supplement use in athletes to sports councils and 874 responses were received. Of these, only 17% of those responses met their criteria for further analysis [251]. In this study, it is not possible to calculate a response rate based on the method of distribution of the questionnaire. A total of 529 participants responded, of which 365 participants qualified for the study following a protocol of inclusion and exclusion criteria. Ninety nine participants did not complete the survey, thus leaving a total sample size of 266 participants. Therefore there was an attrition rate of 27%. According to Miller and Wright [252] the concern of attrition is that *"attrition results in a potential threat of bias if those who drop out have unique characteristics such that remaining sample ceases to be representative of the original sample"* (p. 921) [252]. Although the possible effects of attrition bias cannot be ignored, this study reflected a similar sample representation to other studies within the field.

The gender representation in this study had a greater number of males (67%) than females (33%). Ninety one percent of female participants had been running for less than 15 years and none had reported partaking in marathons for more than 25 years. This is consistent with the history of gender in marathon running, indicative of the growth of female participation over the past two decades. The sample characteristics in this study show that they are representative of the running populations both locally in South Africa and internationally. It has been reported that gender has an important impact on doping decisions [253], and therefore the specific gender differences within the ergogenic aids will be discussed in more detail below.

3.3.1.3. Type of Ergogenic Aids Used

In a descriptive study across multiple sports, 3 887 doping control forms were analysed. There were 6 523 (1.7 per athlete) nutritional supplements (amino acids, vitamins, minerals, creatine, caffeine, herbal supplements, and others) and 3 237 (0.8 per athlete) pharmacological aids (medications) reported [254]. In this study, 1232 ergogenic aids (4.6 per runner), of which 104 (0.4 per runner) pharmacological aids (medications) were reported. In comparing the two studies, this study investigated a greater variety of ergogenic aids and included fluids and dietary practice. A lack of standardised classifications of ergogenic aids within in the literature has made comparisons of findings between studies challenging. A standardised classification of ergogenic aids will enable researchers to compare findings between studies [241] more accurately.

Maughan et al [15] reports of an unpublished survey conducted by the medical and anti-doping commission of the IAAF at international championships from 2005 to 2007, which assessed reasons for and prevalence of supplement use. The questionnaire asked about sports participation, supplements used, reasons for their use, perceived effects, and areas of interest about supplements. Maughan et al [15] reports that during this study a total of 310 questionnaires were collected and analysed (157 males, 153 females) which partly consisted of elite athletes (54% full-time athletes and the remainder students or workers). It found that the supplements most commonly used by track and field athletes were vitamins and antioxidants (84%), minerals (73%), protein and creatine (53%), whilst the ergogenic aids most commonly used were co- enzyme Q10, caffeine, ginseng, and ephedrine (52%).The ergogenic aids commonly used in this study were very different. The ergogenic aids most used in this study were sports drinks (80%), vitamins (68%), and then carbo-loading (62%) with caffeine (33%) ranking seventh and antioxidants (2%) only coming in at twelfth on the list of most commonly used ergogenic aids (*Table 3.6*, *page 53*). Maughan [15] reported that the prevalence of dietary supplement (vitamins, minerals, protein, creatine, and various ‘ergogenic’ compounds) used among elite long distance athletes (3000 m to marathon) was as high as 88%. According to this

study, 45% of the ergogenic aids used were made up from dietary practice, 47% from supplementary aids and 18% pharmacological aids.

3.3.1.4. Pattern of Use of Ergogenic Aids

3.3.1.4.1. Dietary practice (carbohydrates and protein)

Carbo-loading and increased protein intake

Carbo-loading has been common practice for many years, and is said to be the predominant macronutrient athletes choose for fuel during ultra-endurance races, making up as much as 90% of total caloric intake [18]. Carbo-loading was practiced by 62% of participants in this study. The results of the study confirmed that most participants choose to train on their normal diets but choose to carbo-load around races. However it is recommended that individual experimentation during training is done to determine GIT tolerance and effectiveness of ergogenic aids [18].

Regardless of the availability of sound scientific literature, the majority of participants in this study reported they do not calculate their carbohydrate and protein intake per kilogram of body mass. The participants timing of carbo-loading intake is similar to that advised by literature; however the timing at which the participants consume their protein intake is not. They consume protein before and/or after exercise bouts. The literature is clear in that ingestion of additional protein during endurance exercise does not improve performance, reduce proxy markers of muscle damage or hasten the recovery of muscle function [143]. It has been recommended that 'the sooner athletes consume protein after exercise the better' and that relatively frequent protein ingestion (i.e. every 3 to 4 hours) over the 24 hours post exercise is also advised to sustain the elevation in muscle protein synthesis [138].

3.3.1.4.2. Supplementary aids (fluids, vitamins, amino acids, antioxidants, gels and electrolytes)

Fluids, electrolytes and gels

A significant finding of this study revealed an increase in alcohol intake reported as the preferred fluid of choice after an ultra-marathon. This finding was also reported in a study done on rats which concluded the presence of a behavioural interaction where running increases ethanol consumption [255]. However, post exercise rehydration is essential for recovery and alcohol consumption is thus not recommended as it can increase urine output and delay full rehydration [256].

Carbohydrate sports drinks, gels and electrolytes are utilized by runners during races, while water is preferred when training. Although this study did not investigate reasons for runners' choosing different aids during training and racing, it is possible that this might be due both to the affordability of water and availability of carbohydrate drinks on race days.

Due to the widely accepted fact that the ingestion of carbohydrates during exercise can increase performance when the exercise duration is longer than 45 min [257], it is understandable why runners would want to consume carbohydrates before races. However, not doing so during training contradicts what many experienced ultra-endurance runners would advise, namely *"training the GIT"* under simulated ultra-marathon conditions during training. This would encourage runners to consume the same fluids during training as competition to prevent any unpredictable GI disturbances from occurring during competition, and to avoid other more serious problems such as exercise-associated hyponatraemia (EAH), which can have fatal consequences [258–260].

The literature shows that EAH occurs in runners who replace more fluid than necessary [26], many of whom reported following the advice of drinking *"as much as possible"* during exercise [261]. At the International EAH Consensus Development Conferences in 2005 and 2007 it was advised against drinking excessive amounts of fluid [260,262]. Two ways to reduce the risk were agreed upon: 1) drink only according to thirst (i.e. *ad libitum*) and 2) monitor body weight so as to avoid weight gain during exercise [260]. Although 42% of the participants from this study reported drinking to thirst, 7% of runners are still consuming as much fluid as tolerable. This can be interpreted as 58% of participants being at risk of potentially attaining EAH. The educational tactics being utilized need to be revised to empower runners with the necessary knowledge to practice safe fluid replacement strategies.

Vitamin, antioxidants and amino acids

Literature reports vitamin B12, vitamin C and vitamin D as the most popular vitamins used by endurance athletes. Our results showed otherwise as described in *Section 3.2.5.2.1 (page 63)*. Literature suggests antioxidants such as vitamin C (ascorbic acid), vitamin E (α-tocopherol), coenzyme Q10, beta carotene (precursor to vitamin A) and selenium as the popular anti-oxidants being used [151]. Only carotenoids and co-enzyme Q10 were reported as being used by the participants of this study. The most commonly reported amino acids used by endurance athletes in the literature are BCAA's and glutamine. Although no participants in our study reported the use of BCAA's, 46% reported using glutamine. The majority of the participants all consumed these ergogenic aids on a daily basis as opposed to during training or racing.

3.3.1.4.3. Pharmacological aids

Only medication and caffeine will be discussed in the sections that follow, as both EPO and GH were not indicated to have been utilized by any of the participants.

Medication

In this study, accurate interpretation of the medication being utilized was complicated by the fact that many participants incorrectly classified the medication they were consuming. This is concerning as it indicates that these participants are consuming the incorrect medication for the purpose which the participant's intended using them for. It is not uncommon for individuals to self-medicate for acute musculoskeletal injuries [263]. Tscholl [254] reported 23% of participants used NSAID's, 18% used respiratory medication and 11% used analgesic medications. In this study, there was a slightly lower reported rate of use of medication among participants which is encouraging, as literature does not support the use of prophylactic NSAID's prior to sporting events [263].

Although many participants indicated the use of medication during training (See

Table 3.29: Pattern of use for the consumption of medication. Data are presented as number (n) and percentage (%).Table 3.29 for details), this study demonstrated the strong tendency for participants to use medication during races, in comparison to training (*Table 3.30*). It is very concerning that so many runners are consuming medications on a regular basis during training and races as Satterthwaite et al [264] found subjects who are taking medication to be of high risk for injuries and other health problems sustained in a marathon.

Medications are often sought after in order to permit an athlete to compete at his normal level of performance despite injuries or pain. However, the masking of pain may exacerbate the injury [263]. One can expect that strenuous training or an unaccustomed activity may result in muscle soreness but significant pain is the body's response that rest should occur to allow for healing [265]. Too often, athletes do not take the time off from training or competition to allow for adequate healing [266].

Whilst the use of analgesics and NSAIDs, pain may subside but further damage can result from continued exercise [263]. Several authors have found no beneficial results when NSAIDs were administered before and after bouts of lower extremity eccentric exercise [267–269]. In addition, NSAIDs may impede the healing process and muscle regeneration after an acute injury [270]. It is well documented that if NSAIDs are used too early following injury (within the first 24 to 48 h), they will reduce the inflammatory response and may delay acute healing, slow muscle regeneration and compromise long-term healing [271–275].

There is growing support for using paracetamol, as first-line treatment for musculoskeletal sprains and strains, because paracetamol may be just as effective an analgesic as NSAIDs, yet will not increase bleeding into the injury site or potentially impair healing [276,277]. Oral analgesics are important in the treatment of pain, but caution should be used because they can mask symptoms that may suggest more severe damage [278]. However although it is suggested that analgesics should be used instead of NSAIDs, the results from this study show that NSAID use is still greater than analgesic. Analgesics and NSAIDs can effectively relieve pain associated with acute or chronic musculoskeletal injury the data does not adequately support the use of prophylactic NSAIDs prior to sporting events, and should be avoided [263]. The risks for side effects should be considered and compared with the benefits of the medication prior to the consumption thereof.

Caffeine

The literature reports that caffeine is one of the most common supplements used in endurance sports [19]. Yet the results of this study only reported caffeine to be used by 33% of the participants.

This surprising considering the overwhelming evidence that caffeine is safe and has ergogenic effects on endurance sports. The primary source of caffeine was coffee while none of the participants indicated the use of caffeinated capsules. Sources of caffeine such as coffee, tea and soft drinks are not optimally effective [137], as these are weaker than concentrated caffeine in the capsule form [223].

Caffeine was reportedly used on a daily basis by 46% of the participants. However, abstaining from caffeine at least seven days prior to competition will give the greatest chance of optimizing the ergogenic effect [279]. It is well documented that caffeine ingestion can be an effective ergogenic aid for endurance athletes in moderate quantities (3 to 6 mg.kg body mass) [279]. As many as 90% of the participants were 'Not sure' as to how many milligrams (mg) of caffeine they required to reach the desired level to improve their performance. Two thirds of the participants suggested that one cup of coffee was sufficient to attain an ergogenic effect. One cup of instant coffee contains 60 mg of caffeine [215] and it is therefore highly improbable that these athletes are reaching an ergogenic level. Considering that caffeine has been used to aid sports performance for more than a century and has been widely studied by exercise scientists for the past 40 years this knowledge is easily accessible to the public yet their knowledge of best practice for the use of caffeine as an ergogenic aid is limited.

3.3.1.5. Perceived Effect of Ergogenic Aids.

All the ergogenic aids within this study showed similar results whereby the participants reasoning for their use did not correlate with the actual effects of the products being consumed. In summary, these findings emphasise the high number of misconceptions regarding the effects of ergogenic aids. This suggests that runners are generally unaware or uninformed of the mechanism of action of different ergogenic aids, as well as the effects of different aids. It may be that the participants are subjected to incorrect or irresponsible marketing strategies however it is still the responsibility of the individual to adequately research any substance prior to its consumption. Medical personal should also display ethical responsibility towards educating athletes whom they witness consuming products of any nature. This highlights the need for education of runners to facilitate the safe and effective use of ergogenic aids during endurance running training and competition. It may be proposed that regulatory bodies such as WADA or SAIDS should play a more significant role in the education of runners regarding the use of legal ergogenic aids.

3.3.1.5.1. Dietary practice

Participants reported a number of accurate perceived effects of carbo-loading on performance, although some incorrect responses were recorded. In contrast, the majority of the reasons provided for increased protein intake were incorrect, and only 39% of participants identified that protein assists with recovery (*Table 3.11*, *page 18)*. Despite the immense popularity of protein supplementation there is little evidence to support additional consumption of protein as an ergogenic aid [140]. However, increased dietary intake of protein may enhance the post-exercise recovery process [141,142] [136]. Protein ingestion may assist in maintaining muscle structural integrity and power-generating capacity, rather than influencing muscle aerobic capacity [138].

The above mentioned data could be interpreted as 61% of the participants have incorrect perceptions as to the effects of an increase of protein on their bodies. Despite this most of the participants using dietary practice as an ergogenic aid believed that their chosen aid was effective in improving their performance (*Table 3.35*, *page 84*). Similarly Kruseman et al [77] stated that as much as 90% of ultra-marathon runners feel that nutrition has an influence on overall performance.

3.3.1.5.2. Supplementary aids

It has been well documented in the literature that electrolytes assist performance by maintaining hydration [201] and have a potential to assist with exercise associated cramping [280] and recovery [201]. In this study, only 2% of the participants indicated that they believed electrolytes improved performance by assisting with hydration, while 10% and 30% of participants believed electrolytes prevented cramping and improved recovery respectively (*Table 3.36*, *page 85*).

Misconceptions of the ergogenic benefits were not exclusive to electrolytes, all the supplementary aids showed many perceived benefits which are unsupported by the literature. This suggests that participants were aware of the possible ergogenic effects of supplementary aids. Despite being unaware of the specific reasons behind consuming a particular ergogenic aid the majority of the participants using supplementary aids believed that their chosen aid was effective in improving their performance (*Table 3.35*, *page 84*).

3.3.1.5.3. Pharmacological aids

The participants beliefs as to how medication improved performance varied between the classes of the medication consumed (*Table 3.31*, *page 78*). This is to be expected and whilst the majority of the participants were correct in their perceived effects of the medications they consumed the concern was the incorrect classifications of the medications being used. Thus whilst the participant might have the correct reason for consuming medication along with the correct belief of how the medication would act on their bodies, they would be consuming the incorrect medications in order to achieve these.

Despite the current literature is unclear regarding the underlying mechanisms through which caffeine intake is associated with delayed onset of fatigue [215,223]. It is well accepted that caffeine has shown to reduce the onset of fatigue in sustained workloads, and to improve time trial performance [216–222]. However, in this study, only 22% of the participants thought that caffeine improved performance by allowing them to run for longer periods. Many of the reasons that participants gave regarding the perception of effect of caffeine were incorrect (*Table 3.33*, *page 81*). Once again the participants have incorrect perceptions as to the effects of their chosen ergogenic aids have on their bodies, and again almost all of the participants using pharmacological aids as believed that their chosen aid was effective in improving their performance (*Table 3.35*, *page 84*).

3.3.1.6. Source of Information Influencing Use of Different Ergogenic Aids

The top three influential factors for all the ergogenic aids were personal experience, fellow runners and books/magazines with slight variations in the ranking of these factors which have been highlighted in the various sections below. In summary, these findings highlight that runners are more frequently exposed to different sources of anecdotal evidence compared to sources of scientific evidence [12]. This may contribute to the inappropriate use of different ergogenic aids and may also place runners at an increased risk of health-related side-effects [15]. This emphasises the need for greater dissemination of scientific evidence. In addition, popular magazines and websites should incorporate research findings to improve the quality of information that is reaching runners.

In addition, these findings also indicate that sports associations/athletic clubs are potentially under-utilized resources for runners. These associations and clubs might provide a forum for education of runners regarding the effective and safe use of different ergogenic aids.

3.3.1.6.1. Dietary practice

The top three influential factors for dietary practice were similar, with both carbo-loading and increased protein use ranking personal experience as the most influential factor. Participants using carbo-loading ranked fellow runners as the second most influential factor affecting their intake strategy and books/magazines as the third. The opposite was recorded by participants using protein.

3.3.1.6.2. Supplementary aids

Although Willmore et al [281], concluded that the perceived taste of a beverage is important for fluid replacement during exercise, this study ranked taste ninth on the list of factors influencing the participants choice of fluid intake. This shows that taste was not fundamental in the selection of a preferred fluid. The top three influential factors for the use of all supplementary aids included personal experience, followed by fellow runners and then books/magazines.

3.3.1.1. Pharmacological aids

The top three influential factors for the use of medication were personal experience, followed by fellow runners and then books/magazines. In the case of caffeine they were personal experience, followed by books/magazines and then fellow runners.

3.3.1.7. Factors Predicting the Use of Ergogenic Aids

3.3.1.7.1. Dietary practice

The only factor affecting the use of carbo-loading as an ergogenic aid was the level of competitiveness. Competitive runners were approximately one third more likely to undertake the dietary practice of carbo-loading than recreational runners.

The factors affecting increased protein intake were slightly contradictory as participants who completed more than ten marathons were four times more likely to use increased protein as an ergogenic aid than participants who had completed less than ten marathons. Whilst participants who completed more than five ultra-marathons were one tenth less likely to use increased protein as an ergogenic aid than participants who had completed less than five ultra-marathons (*APPENDIX XI*).

3.3.1.7.2. Supplementary aids

The only factor affecting the use of sports drinks as an ergogenic aid was the level of ultra-marathon running experience. Runners who had more than ten years of ultra-marathon running experience were approximately 50% more likely to consume sports drinks than runners with less than ten years of experience.

This study showed that gender had a significant effect on vitamin use. Females were about two and a half times more likely to utilize vitamins as an ergogenic aid than their male counterparts. A reason for this might be that the use of vitamin supplements is more prevalent among females than males within the general population [282,283], and that this may have translated through into the running population and not be specific to ultra-marathon runners. The use of vitamins was also dependant on the number of ultra-marathons performed; participants completing more than five ultra-marathons were almost twice as likely to use vitamins as those completing less than five ultra-marathons.

3.3.1.7.3. Pharmacological aids

There were no descriptive or race and training characteristics that had any effect on the use of either caffeine or medication as an ergogenic aid.

3.3.2. SUMMARY AND RECOMMENDATIONS

The findings of this study highlighted that ergogenic aids, particularly sports drinks, vitamins and carbo-loading, are commonly used by ultra-marathon runners. This study was unable to identify the use of illegal or banned substances. Ergogenic aids were predominantly used to delay the onset of fatigue, to provide an energy boost, and to facilitate recovery. Different patterns of use of ergogenic aids were observed during training and competition, which could possibly result in variability in performance levels and unwanted adverse side effects during competition [18]. In this study, 79% of participants believed that their chosen ergogenic aids improve their performance. This is interesting as many of the participants' patterns of use, dosages or perceptions of effect of different ergogenic aids was incorrect, based on current evidence-based guidelines. In addition, participants relied predominantly on anecdotal sources (personal experience, fellow runners and books/magazines) for information regarding different ergogenic aids.

This study observed different practices regarding the use of ergogenic aids in comparison to previous studies. This highlights the need for further research regarding the use of ergogenic aids in different geographical and cultural contexts. In addition, this study did not examine any local South African ergogenic aids, and context-specific practices may not have been identified in this study. Future studies should identify traditional or local ergogenic aids and examine the use of these aids in endurance runners. Further, this study also demonstrated the concomitant use of many different ergogenic aids. Future studies should recognise that athletes often do not use ergogenic aids in isolation, and should explore the interactions between different ergogenic aids and the effects of these interactions on running performance.

Table 3.37 provides a summary of the incorrect practices associated with use of different ergogenic aids observed in this study; the current evidence-based guidelines for use of different aids; and the practical recommendations arising from this study for the use of different ergogenic aids.

Table 3.37: Summary of the incorrect practices observed in this study, the current evidence-based guidelines for use, and practical recommendations for the use of different ergogenic aids.

<table>
<tr><th colspan="3">Carbo-loading/Gels</th></tr>
<tr><th>Incorrect practices observed in this study</th><th>Evidence-based guidelines for use</th><th>Practical recommendations and advice</th></tr>
<tr>
<td rowspan="3">• Runners seem to be consuming CHO without knowing or understanding the benefits or effects thereof.

• The majority of the participants who CHO-loading reported that they do not calculate their intake according their body mass.

• Runners are not training & competing on the same amounts of CHO &/or are only using CHO during competition.</td>
<td>• CHOs are converted by the body & stored as glycogen. Fatigue is often related to muscle glycogen depletion. CHO-loading is a means of maximizing this limited fuel source.
• CHO dietary regimens are also believed to be involved in enhancing recovery.
• CHO intake during exercise can improve exercise performance & will postpone fatigue by approximately 20% in endurance events lasting more than 90 min.
• High CHO diets have been reported to improve performance by 2 - 3%.
• CHO has been shown to decrease RPE.
• There is strong evidence stating that beginning endurance exercise with a high muscle glycogen concentration & ingesting CHOs during exercise will improve performance.</td>
<td rowspan="3">• CHO increases the glycogen fuel source, delays fatigue, decrease RPE & is believed to be involved in enhancing recovery.

• PRO in conjunction with CHO provides better recovery than CHO or PRO in isolation.

• If using multiple sources of CHO (MTC – gels, bars & fluids) one is less likely to report GIT discomfort.

• To minimize the risks of hypoglycaemia, CHOs can be ingested just prior to exercise (in the last 5 min) or during the warm-up.

• For runners struggling with GIT discomfort during races, it has been recommended that they should consider a CHO mouth rinse while resting the GIT and still attain the CHO benefits.</td>
</tr>
<tr><td>Dosage</td></tr>
<tr><td>• Recommended dosages according to time of exercise:
30 - 75 min = Very small amounts or mouth rinse
1 - 2 h = Up to 30 $g.h^{-1}$ or 0.7 $g.kg^{-1}.h^{-1}$
2 - 3 h = Up to 60 $g.h^{-1}$
> 2.5 h = Up to 90 $g.h^{-1}$ (of which glucose must make up ≤ 60 g)

• MTC (gels, bars & fluids) can increase the CHO oxidation rate from 1 $g.min^{-1}$ to 1.26 $g.min^{-1}$. It is therefore advised for endurance athletes' fuel with a combination of different CHOs to maximise oxidation.
• Based on current evidence there is little evidence to suggest avoiding CHO intake in the hour before exercise as there are no detrimental effects on performance. The ingestion of CHOs during this period may lead to enhanced performance.</td></tr>
</table>

#KEY: g: grams; h: hour; min: minute; CHO: carbohydrate; RPE: rate of perceived exertion; $g.min^{-1}$: grams per minute; $g.h^{-1}$: grams per kilogram of body weight; $g.kg^{-1}.h^{-1}$: grams per kilogram of body weight per hour; MTC: multiple transportable carbohydrates; GIT gastrointestinal tract.

Table 3.37 (continued): Summary of the incorrect practices observed in this study, the current evidence-based guidelines for use, and practical recommendations for the use of different ergogenic aids.

<table>
<tr><th colspan="3">Increased protein intake</th></tr>
<tr><td>Incorrect practices observed in this study</td><td>Evidence-based guidelines for use</td><td>Practical recommendations and advice</td></tr>
<tr><td rowspan="3">• Runners seem to be consuming PRO without knowing or understanding the benefits or effects thereof.
• The majority of the participants who increase their protein intake (93%) reported that they do not calculate their intake according their body mass.
• Runners are not training & competing on the same amounts of PRO &/or are only using PRO during competition.
• The timing of PRO intake is incorrect.</td><td>• The sooner runners consume PRO after exercise the better (within 1 h) & frequent PRO ingestion over the next 24 h (i.e. every 3 - 4 h).
• Ingestion of additional PRO DURING endurance exercise DOES NOT improve performance, reduce proxy markers of muscle damage or hasten the recovery of muscle function.
• POST-exercise PRO ingestion DOES potentiating MPS, maintaining muscle structural integrity & power-generating capacity & aid in recovery process.
• Effective for the maintenance, repair & MPS, thus assists in the recovery processes.
• Consumption of adequate calories, particularly CHOs, to meet those expended & maintain an energy balance, is important to PRO metabolism so that AA are spared for PRO synthesis & not oxidized to assist in meeting energy needs.</td><td rowspan="3">• Effective for the maintenance, repair & MPS, thus assists in the recovery processes.
• PRO in conjunction with CHO provides better recovery than PRO or CHO in isolation.
• Excess PRO is stored as fat & may lead to unwanted weight gain.
• PRO & AA powders are a potential source for illegal substances often not listed on the ingredient label of these products.
• PRO should be consumed within 1 h after exercise & frequent PRO ingestion over the next 24 h (i.e. every 3 - 4 h).</td></tr>
<tr><td>RDA's</td></tr>
<tr><td>• Normal adults RDA is 0.8 - 0.9 $g.kg^{-1}.d^{-1}$
• Endurance runners RDA from 1.2 - 1.4 $g.kg^{-1}.d^{-1}$ for ultra-endurance runners RDA should be at or slightly above this.
• In the case of resistance training, 20 - 25 g of PRO within 1 h after exercise.</td></tr>
</table>

#KEY: PRO: protein; RDA: recommended daily allowance; $g.kg^{-1}.d^{-1}$: grams per kilogram of body weight per day; h: hour; g: gram; MPS: muscle protein synthesis; CHOs: carbohydrates; AA: amino acids; HPT: hypertension; DM: diabetes mellitus.

Table 3.37 (continued): Summary of the incorrect practices observed in this study, the current evidence-based guidelines for use, and practical recommendations for the use of different ergogenic aids.

<table>
<tr><th colspan="3">Fluid & electrolyte replacement</th></tr>
<tr><th>Incorrect practices observed in this study</th><th>Evidence-based guidelines for use</th><th>Practical recommendations and advice</th></tr>
<tr>
<td rowspan="3">• Runners seem to be consuming electrolytes without knowing or understanding the benefits or effects thereof.

• Different fluids are being used during training & competition.

• Electrolytes are only being used during competition & never during training.

• There is a significant increase in alcohol intake post-races.

• Incorrect & dangerous fluid replacement strategies are being used by many runners.

• Weather is not being taken into account when making fuel replacement strategies.</td>
<td>• Fluids & electrolytes sustain total body water, thus indirectly maintain exercise capacity, plasma volume, thermoregulation, delay fatigue, prevent dehydration & hyponatremia, & reduce RPE.
• If not replaced, water disturbances & electrolyte imbalances can develop & adversely impact exercise performance & health.
• Dehydration & hyperthermia can negatively influence physiological responses to exercise & performance.
• No electrolyte other than Na+ has a significant role in hydration & exercise.
• EAMC was hypothesized to result from electrolyte abnormalities, hydration status, metabolic abnormalities, environmental factors & persons who sweat profusely with high Na+ losses. These are not support by the literature.
• Dehydration & electrolyte loss are not the sole causes of EAMC. EAMC may be primarily due to altered neuromuscular control, as a result of the development of muscle fatigue.</td>
<td rowspan="3">• Electrolytes sustain body water, thus maintain exercise capacity, plasma volume, thermoregulation, delay fatigue, prevent dehydration & hyponatremia, & reduce RPE.

• Runners should train & compete with the same fluids. This will help determine the most appropriate fluids & volumes to suit the athlete’s needs & GIT comfort.

• Do not drink as much as tolerable during exercise as this is dangerous & strongly discouraged.

• Alcohol consumption is not recommended post-exercise; it increases urine output, delays rehydration & recovery.

• Runners should measure pre- & post-exercise body weight to determine sweat rates & customize fluid replacement strategies that take weather into account.</td>
</tr>
<tr><td>Dosage</td></tr>
<tr><td>• Suggested fluid replacement strategies vary between drinking to thirst up to 800 ml/h^{-1}.
• If rapid recovery is required (<24 h) or severe dehydration is encountered, aim to drink 1.5 times the amount of sweat lost (1.5 L.kg^{-1} lost).
• Replacement strategy should aim to prevent dehydration >2% body weight.
• Water & electrolytes losses from sweat need to be replaced to re-establish total body water. This can be achieved by normal eating & drinking.
• There is little need to replace electrolytes during an exercise session lasting less than 3 - 4 h, particularly if Na+ was present in the previous meal.</td></tr>
</table>

#KEY: ml/h^{-1}: milliliters per hour; mg: milligrams; g·L^{-1}: grams per liter; h: hour; L: litre; Na+: sodium; K+: potassium; GI: gastrointestinal; EAMC: exercise associated muscle cramps; CHO: carbohydrate; L.kg^{-1}: liters per kilogram of body weight.

Table 3.37 (continued): Summary of the incorrect practices observed in this study, the current evidence-based guidelines for use, and practical recommendations for the use of different ergogenic aids.

<table>
<tr><th colspan="7">Vitamins (Vit) & antioxidants (AOX)</th></tr>
<tr><td>Incorrect practices observed in this study</td><td colspan="5">Evidence-based guidelines for use</td><td>Practical recommendations and advice</td></tr>
<tr><td rowspan="3">• Runners are not aware of the purposes for which the specific vits are to be used & their role towards improving performance.

• Runners are using many different combinations of individual vits as well as multi-vits, despite also possibility having a balanced diet. There is a high risk that these runners are consuming well above the RDA's.</td><td colspan="5">• Vits & AOX do not delay muscular fatigue or improve performance unless an individual's diet is restricted, inadequate or has deficiencies within vit groups.
• Vits & AOX may detoxify free radicals produced by exercise protecting the cell membranes from oxidative damage, thus prevent muscle damage, DOMS & enhance recovery.
• High levels of vits E & C (i.e. 16 times higher than RDA) can blunt the training adaptation to exercise.
• Excessive vit E intake can cause muscle weakness, fatigue, headache & nausea.
• Prophylactic vit E has been associated with a decreased frequency of running-associated GI complaints.
• Vit D plays a role in bone health, development & homeostasis of the nervous system & skeletal muscle.
• Vit B-complex has exercise related functions such as: MPS, tissue repair & maintenance including the CNS, energy & red blood cells production.</td><td rowspan="3">• Vits & AOX may detoxify free radicals produced by exercise, thus prevent muscle damage, DOMS & enhance recovery.

• If maintaining a nutritionally well balanced diet, the athlete may not require AOX's or vit supplements. The only circumstance that may justify vit or AOX supplements is in runners who specifically restrict dietary intake.

• Regular exercise promotes endogenous protection against exercise-induced oxidative damage. Therefore if exercising regularly the data is inadequate to recommend AOX supplements for the specific purpose of preventing exercise-induced oxidative damage.

• Stress fractures, chronic musculoskeletal pain, viral respiratory tract infections & several chronic diseases are associated with vit D deficiency.</td></tr>
<tr><td colspan="5">RDA's</td></tr>
<tr><td><u>*Vit A:*</u>
Females:
700 $\mu g.d^{-1}$
Males:
900 $\mu g.d^{-1}$

UL = 3000 $\mu g.d^{-1}$</td><td><u>*Vit B-complex:*</u>
B12: 2.4 $\mu g.d^{-1}$
B6: 1.3 $mg.d^{-1}$
UL = B12: na
B6: 100 $mg.d^{-1}$

• Exercise may increase the need for B vits as much as twice the RDA.</td><td><u>*Vit C*</u>
Females: 14-18y: 65 $mg.d^{-1}$
18-50y: 75 $mg.d^{-1}$
Males: 14-18y: 75 $mg.d^{-1}$
18-50y: 90 $mg.d^{-1}$
UL = 2000 $mg.d^{-1}$

• Athletes participating in habitual prolonged, strenuous exercise should consume 100 – 1000 $mg.d^{-1}$ of Vit C.</td><td><u>*Vit D:*</u>
2.4 $\mu g.d^{-1}$
UL = na</td><td><u>*Vit E:*</u>
15 $mg.d^{-1}$
UL = 1000 $mg.d^{-1}$</td></tr>
</table>

#Key: UL: upper limit; y: years; RDA: recommended daily allowance; na: not available; GI: gastrointestinal; mg/d^{-1}: milligrams per day; DOMS: delayed onset of muscle soreness; MPS: muscle protein synthesis

Table 3.37 (continued): Summary of the incorrect practices observed in this study, the current evidence-based guidelines for use, and practical recommendations for the use of different ergogenic aids.

Amino Acids (AA)		
Incorrect practices observed in this study	Evidence-based guidelines for use	Practical recommendations and advice
• Not many runners reported using AA however, of those that did none used BCAA. Although BCAA looks to be the most promising AA's for a positive effect on recovery.	• Only under certain conditions can BCAA improve physical performance. • Majority of studies found no effect of BCAA on performance when taken with CHOs. • BCAA has a positive effect on skeletal muscle in the recovery period after endurance exercise. • BCAA decrease CK & LDH values after exercise (CK & LDH values correlate with DOMS). • Taking BCAA's during exercise has exerted positive effects on cognitive performance & RPE. • Both runners with acute or chronic fatigue with infection symptoms show decreases in AA levels, mainly glutamine. Thus supplementation may assist & possibly have a preventative role for runners with these symptoms. **Dosage** • The amount of BCAA recommended is 0.03 - 0.05 $g.kg^{-1}.h^{-1}$ or 2 - 4 $g.h^{-1}$ ingested repeatedly during exercise & recovery, preferably taken as a drink. • Large BCAA doses (30 $g.d^{-1}$) may be detrimental to performance due to increased production of ammonia by the exercising muscle. **RDA's** Protein: Adults: 0.8 - 0.9 $g.kg^{-1}.d^{-1}$ Endurance athletes is 1.2 - 1.4 $g.kg^{-1}.d^{-1}$	• The cost, lack of clear performance benefit & potential risks do not support the routine use of PRO & AA supplementation above 1.4 $g.kg^{-1}.d^{-1}$ for endurance athletes. • Concerns arise over the consumption of single AA, due to the impact of imbalance on other AA's. It is therefore better to opt for an even mix of all or just the essential AA's.

#Key: RDA: recommended daily allowance; $g.kg^{-1}.d^{-1}$: grams per kilogram of body weight per day; $g.h^{-1}$: grams per kilogram of body weight; BCAA: branched chain amino acids; CHO: carbohydrate; PRO: protein; AA: amino acids; RPE: rate of perceived exertion; DOMS: delayed onset of muscle soreness; CK: creatine kinase; LDH: lactate dehydrogenase.

Table 3.37 (continued): Summary of the incorrect practices observed in this study, the current evidence-based guidelines for use, and practical recommendations for the use of different ergogenic aids.

Medication		
Incorrect practices observed in this study	Evidence-based guidelines for use	Practical recommendations and advice
• Many of the brand names listed by the participants were incorrectly categorised, indicating that participants are using the incorrect medications for purposes to which they were intended to be used. • Runners seem to be consuming medication without knowing or understanding the benefits or risks, or effects thereof. • Runners are not training & competing on the same amounts of medication &/or are only using medication during competition.	<u>*NSAIDs*</u> • No benefit of NSAIDs being administered before & after bouts of eccentric exercise. • NSAIDs do not reduce the effects of DOMS after eccentric exercise. • Prophylactic or early post-injury use (24 –48 h) of NSIADs will reduce the inflammatory response & may delay acute healing, slow muscle regeneration, compromise long-term healing, possible long-term effects to the joint & recurrent injury due to premature activity. • There is a potential for increased bleeding & swelling at the site of injury due to NSAIDs decreasing platelet aggregation. • Post injury short term benefits of decreasing the inflammation which may decrease pain & result in earlier return to sporting activity. These short-term benefits in the treatment of acute soft tissue injuries must be weighed against the potential long-term adverse effects on tissue healing, structure, & function. <u>*Analgesics*</u> • Support is growing for using paracetamol, as first-line treatment for musculoskeletal sprains & strains, because it may be as effective as an analgesic yet will not increase bleeding into the injury site or impair healing. Dosage <u>*NSAIDs*</u> • Data do not adequately support the use of prophylactic NSAIDs prior to sporting events & it should be avoided. • If used, length of treatment should be kept as short as possible, 3 - 7 days is recommended.	<u>*NSAIDs*</u> • No benefit of NSAIDs being administered before & after bouts of eccentric exercise. • Adverse GIT effects are common. • Long-term use for symptoms of sport-related injuries should be avoided, due to their side effect s & concern for impeding healing process. • NSAIDs do not take the place of therapeutic modalities & must be considered as an adjunct to rehabilitation. <u>*Analgesics*</u> • Optimal treatment for soft tissue injuries appears to be RICE & paracetamol for pain. • Medication does not improve performance; it is dangerous & irresponsible to consume medication pre/during exercise. • Caution must be taken with analgesics because they can mask symptoms that may suggest more severe damage.

#KEY: NSAIDs: nonsteroidal anti-inflammatory drugs; DOMS: delayed onset of muscle soreness; h: hour; GIT: gastrointestinal tract.

Table 3.37 (continued): Summary of the incorrect practices observed in this study, the current evidence-based guidelines for use, and practical recommendations for the use of different ergogenic aids.

Caffeine (CAF)		
Incorrect practices observed in this study	Evidence-based guidelines for use	Practical recommendations
• Runners seem to be consuming CAF without knowing or understanding the benefits or effects thereof. • Most utilized means of attaining CAF was via coffee (78%), caffeinated gels (11%) & energy drinks (11%). None of the participants indicated using CAF capsules. • 93% of the CAF users are unsure as to how many mg of CAF they required to reach their desired levels to improve their performance, & suggested that 1-2 cups of coffee was sufficient for them to reach ergogenic levels of performance. • Almost none of the participants calculate their intake according their BM. • Runners are not training & competing on the same amounts of CAF &/or are only using CAF during competition.	• A large number of studies report CAF supplementation improves endurance performance. • CAF exerts positive effects on exercise capacity over a diverse range of protocols. Including reducing the onset of fatigue, as well as improve time trial performance. • Exact mechanisms which CAF enhances performance is unknown. Various proposed mechanisms include: mobilisation of fat from adipose tissue & the muscle cell, stimulation of the release & activity of adrenaline, effects on cardiac muscle, direct changes to muscle contractility & alterations to the CNS. • Literature states CAF might also be useful for recovery. • Evidence does not support concerns & state CAF has minor effects on urine losses or the overall hydration. Dosage • Suggested dosage of 3 - 6 mg/kg^{-1}, consumed 15 - 60 min prior to an event as single or multiple doses followed by dosing (1 - 2 $mg.kg^{-1}$) at regular intervals throughout exercise or just prior to the onset of fatigue (perhaps every 2 - 5 h). • Consumption of 97 $mg.kg^{-1}$ does not have a greater ergogenic advantage over 3 - 6 $mg.kg^{-1}$, the benefits level off. • The time for peak plasma concentration of CAF is 15 - 120 min & it has a half-life of between 2.5 - 6 h.	• CAF supplementation improves endurance performance by delaying fatigue &improved time trial performance. • Caffeinated capsules are the best means to attain these levels. • 1 cup of instant coffee contains 60 mg of CAF it is highly improbable that athletes drinking 1 – 2 cups of coffee are attaining sufficient levels of CAF to have ergogenic effects. • CAF users must know their BM & the expected time of exercise in order to correctly calculate the appropriate dosage & correct consumption strategy. • Abstaining from CAF for 7 days prior to competition will optimize the ergogenic effect. However this will increase the risk of side effects.

#KEY: CAF: caffeine; $mg.kg^{-1}$: milligrams per kilogram of body weight; h: hour; min: minute; CNS: central nervous system; mg: milligrams.

CHAPTER 4

SUMMARY AND CONCLUSION

Ergogenic aids are used to decrease the amount of time required to recover from the physiological stresses placed on the body and to improve performance [12]. Athletes tend to use ergogenic aids to prepare their bodies for the demands of training and competition [22], to delay the effects of fatigue [152], and to accelerate the recovery process [52]. There is currently equivocal evidence in the efficacy of various ergogenic aids. There is also a lack of evidence regarding the effectiveness of ergogenic aids in endurance running, particularly the marathon and ultra-marathon disciplines. This is the first study, to this researcher's knowledge, investigating the use of ergogenic aids in ultra-marathon runners before, during and after training and competition.

The aim of this study was to describe the use of ergogenic aids in ultra-marathon runners during training and competition. Based on the evidence provided in this dissertation, the study objectives as described in *Section 1.2.2 (page 2)* may be answered as follows:

(1) To obtain information on ergogenic aid use of ultra-marathon runners, with regard to the type of ergogenic aids used, and the pattern of use during training and competition.

In this study, ultra-marathon runners used an average of 5 ±2 ergogenic aids. Dietary practices were used the most, followed by supplementary aids and then pharmacological ergogenic aids. None of the participants reported the use of illegal or banned substances (EPO, GH or blood doping). Differences were reported in the types of ergogenic aids used in this study compared to other studies in the literature. Demographics and cultural differences may possibly have an influence on this. Ergogenic aids were mostly used during competition and less so during training. The variability in the patterns of use within each of the ergogenic aids reflects inadequate understanding of the proposed mechanisms of action, and may also introduce potential for reduced efficacy associated with inappropriate use. With varying combinations of ergogenic aids being used it is important for participants to fully understand the risks of their potential interactions, particularly with pharmaceutical and dietary practice.

(2) To determine the ultra-marathon runner's perceived performance benefits of ergogenic aids.

The participants in this study had misconceptions regarding the effects of the ergogenic aids. Although some of their perceived benefits of the ergogenic aids were correct, most of the participant's perceived benefits did not correlate with current scientific evidence, but rather with anecdotal evidence. This suggests that their knowledge of ergogenic aids is poor, which is concerning considering their wide use. Consequently, these misconceptions might lead to the ineffective and potentially unsafe use of ergogenic aids during training and competition.

(3) To determine the factors influencing the intake strategies of ergogenic aids.

Personal experience/self-experimentation, fellow runners and books/magazines were consistently rated as the top three most influential factors influencing the participant's intake strategies. The lack of influence of both the coaches/trainers and sports associations/clubs is concerning. The variable pattern of use and misconceptions of perceived performance benefits observed in the findings might be as a consequence of the predominantly anecdotal sources of information used by participants. It is potentially unsafe for athletes to use ergogenic aids without a full understanding of the associated benefits and risks of their chosen ergogenic aids [15]. The implementation of educational interventions is required to empower runners to make informed decisions regarding the use of ergogenic aids.

(4) To explore the possible factors that may predict the use of ergogenic aids, such as age, gender, level of competitiveness, training and competition history.

Gender and the number of ultra-marathons performed influenced the use of vitamins, level of competitiveness influenced the dietary practice of carbo-loading, and the number of ultra-marathons completed influenced the utilization of sports drinks. The number of marathons and the number of ultra-marathons completed conversely affected the use of increased protein. There were no descriptive or race and training characteristics that had any effect on the use of caffeine, medication, gels or electrolytes.

In conclusion, this study demonstrated that the prevalence of the use of legal ergogenic aids is high, despite the lack of evidence concerning the efficacy of many of the ergogenic aids in enhancing endurance running performance. Although this study was unable to identify the prevalence of the use of illegal ergogenic aids, false performance beliefs, the inappropriate and potentially unsafe use of many legal ergogenic aids was identified. These poor practices may compromise performance and inherently place endurance runners at risk of serious adverse events during both training and competition. The strong influence of personal experience and misleading information from fellow runners pertaining to the choice of ergogenic aids to use constitutes a major challenge. Runners are accessing information through social networking, interactions and possibly social media, rather than scientific resources. Anecdotal evidence far precedes scientific evidence in relation to the benefits of using most ergogenic aids. Based on the findings of this study, it is evident that the overall use of legal ergogenic aids is high and often concomitant, which may be associated with potential health-related side-effects. Educational initiatives, with a focus on peer-led education, are essential to encourage the safe and effective use of ergogenic aids. Educational initiatives should target both the most commonly used ergogenic aids in this population (sports drinks, vitamins, carbo-loading, gels and electrolytes) and pharmacological aids due the dangers associated with their abuse, misuse and the safety concerns therein. This study further highlights the importance of collective responsibility of the running community, including regulators, administrators, health care professionals, coaching and support staff, and journalists and authors of books and magazines to ensure that runners are informed about the safe and correct use of legal ergogenic aids.

REFERENCES

1. Thein, L. A., Thein, J. M. & Landry, G. L. Ergogenic aids. *Phys. Ther.* **75,** 426–39 (1995).

2. Marathon. (n.d.) Collins English Dictionary – Complete and Unabridged. (1991, 1994, 1998, 2000, 2003). Retrieved December 3 2014 from http://www.thefreedictionary.com/marathon.

3. Ultramarathon. (n.d.) McGraw-Hill Concise Dictionary of Modern Medicine. (2002). Retrieved December 3 2014 from http://medical-dictionary.thefreedictionary.com/Ultra-marathon.

4. Carbo-loading. (n.d.) Random House Kernerman Webster's College Dictionary. (2010). Retrieved December 3 2014 from http://www.thefreedictionary.com/carbo-loading.

5. Abbiss, C. R. & Laursen, P. B. Models to explain fatigue during prolonged endurance cycling. *Sport. Med.* **35,** 865–898 (2005).

6. Noakes, T. D. The central governor model of exercise regulation applied to the marathon. *Sport. Med.* **37,** 374–377 (2007).

7. Mcinerney, P. *et al.* Failure to repeatedly supercompensate muscle glycogen stores in highly trained men. *Med. Sci. Sport. Exerc.* **37,** 404–411 (2005).

8. Middelkoop, M. Van *et al.* Prevalence and incidence of lower extremity injuries in male marathon runners. *Scand. J. Med. Sci. Sports* **18,** 140–4 (2008).

9. Barnett, A. Using recovery modalities between training sessions in elite athletes does it help? *Sport. Med.* **36,** 781–796 (2006).

10. Sellwood, K. L., Brukner, P., Williams, D., Nicol, A. & Hinman, R. Ice-water immersion and delayed-onset muscle soreness: a randomised controlled trial. *Br. J. Sports Med.* **41,** 392–397 (2007).

11. Burke, L. M. Nutritional practices of male and female endurance cyclists. *Sport. Med.* **31,** 521–532 (2001).

12. Silver, M. D. Use of ergogenic aids by athletes. *J. Am. Acad. Orthop. Surg.* **9,** 61–70 (2001).

13. Loraschi, A., Galli, N. & Cosentino, M. Dietary supplement and drug use and doping knowledge and attitudes in Italian young elite cyclists. *Clin. J. Sport Med.* **24,** 238–44 (2014).

14. Lopez, R. M. & Casa, D. J. The influence of nutritional ergogenic aids on exercise heat tolerance and hydration status. *Curr. Sports Med. Rep.* **8,** 192–9 (2009).

15. Maughan, R. J., Depiesse, F. & Geyer, H. The use of dietary supplements by athletes. *J. Sports Sci.* **25 Suppl 1,** S103–13 (2007).

16. Petróczi, A. Attitudes and doping: a structural equation analysis of the relationship between athletes' attitudes, sport orientation and doping behaviour. *Subst. Abuse Treat. Prev. Policy* **2,** 34 (2007).

17. Rapoport, B. I. Metabolic factors limiting performance in marathon runners. *PLoS Comput. Biol.* **6,** 1–13 (2010).

18. Getzin, A. R., Milner, C. & LaFace, K. M. Nutrition update for the ultra-endurance athlete. *Curr. Sports Med. Rep.* **10,** 330–9 (2011).

19. Jeukendrup, A. E. Nutrition for endurance sports: marathon, triathlon, and road cycling. *J. Sports Sci.* **29 Suppl 1,** S91–9 (2011).

20. Cheung, K., Hume, P. & Maxwell, L. Delayed onset muscle soreness: treatment strategies and performance factors. *Sport. Med.* **33,** 145–164 (2003).

21. Saris, W. H. M. *et al.* PASSCLAIM - Physical performance and fitness. *Eur. J. Nutr.* **42,** I50–I95 (2003).

22. Zaryski, C. & Smith, D. J. Training principles and issues for ultra-endurance athletes. *Curr. Sports Med. Rep.* **4,** 165–170 (2005).

23. Hawley, J. A. & Burke, L. M. Carbohydrate availability and training adaptation: effects on cell metabolism. *Exerc. Sport Sci. Rev.* **38,** 152–60 (2010).

24. Kreider, R. B. Physiological considerations of ultra-endurance performance. *Int. J. Sport Nutr.* **1,** 3–27 (1991).

25. Retrieved December 17 2014 from http://www.findmymarathon.com/statistics.php.

26. Roberts, W. O. The 2006 world congress on the science and medicine of the marathon. *Sport. Med.* **37,** 279–280 (2007).

27. Burfoot, A. The history of the marathon. 1976-present. *Sport. Med.* **37,** 284–287 (2007).

28. http://www.sport24.co.za/OtherSport/Athletics/Comrades-New-Guinness-record-20101019.

29. http://www.comrades.com/.

30. http://www.twooceansmarathon.org.za/news/media/2011/release-12-old-mutual-two-oceans-marathon-attracts-biggest-field-ever.

31. Hoffman, M. D., Ong, J. C. & Wang, G. Historical analysis of participation in 161 km ultramarathons in North America. *Int. J. Hist. Sport* **27,** 1877–91 (2010).

32. Torii, M. Communications to the international conference on dehydration, rehydration and exercise in the heat. *J. Sports Sci.* 347–370 (1996).

33. Powers, S. K. & Jackson, M. J. Exercise-induced oxidative stress: cellular mechanisms and impact on muscle force production. *Physiol. Rev.* **88,** 1243–1276 (2008).

34. Stevenson, R. Fueling the ultra-endurance athlete. *Marathon & Beyond* 60–73 (2012).

35. Rodriguez, N., Di Marco, N. & Langley, S. American College of Sports Medicine position stand. Nutrition and athletic performance. *Med. Sci. Sports Exerc.* **41,** 709–731 (2009).

36. Marcora, S. M. & Bosio, A. Effect of exercise-induced muscle damage on endurance running performance in humans. *Scand. J. Med. Sci. Sports* **17,** 662–671. (2007).

37. Kay, D., Marino, E., Cannon, J., St Clair Gibson, A. & Noakes, T. D. Evidence for neuromuscular fatigue during high-intensity cycling in warm, humid conditions. *Eur. J. Appl. Physiol.* **84,** 115–121 (2001).

38. Millet, G. Y., Millet, G. P., Lattier, G., Maffiuletti, N. A. & Candau, R. Alteration of neuromuscular function after a prolonged road cycling race. *Int. J. Sports Med.* **24,** 190–194 (2003).

39. Millet, G. Y. *et al.* Alterations of neuromuscular function after an ultra-marathon. *J. Appl. Physiol.* **92,** 486–92 (2002).

40. St Clair Gibson, A., Lambert, M. I. & Noakes, T. D. Neural control of force output during maximal and submaximal exercise. *Sport. Med.* **31,** 637–650 (2001).

41. Green, H. J. Mechanisms of muscle fatigue in intense exercise. *J. Sports Sci.* **15,** 247–56 (1997).

42. Lambert, E. V, St Clair Gibson, A. & Noakes, T. D. Complex systems model of fatigue: integrative homoeostatic control of peripheral physiological systems during exercise in humans. *Br. J. Sports Med.* **39,** 52–62 (2005).

43. Noakes, T. D. Physiological models to understand exercise fatigue and the adaptations that predict or enhance athletic performance. *Scand. J. Med. Sci. Sport.* **10,** 123–145 (2000).

44. Bonacci, J., Chapman, A., Blanch, P. & Vicenzino, B. Neuromuscular adaptations to training, injury and passive interventions: implications for running economy. *Sports Med.* **39,** 903–21 (2009).

45. Saunders, P. U., Pyne, D. B., Telford, R. D. & Hawley, J. A. Factors affecting running economy in trained distance runners. *Sports Med.* **34,** 465–85 (2004).

46. Taylor, A. W. & Bachman, L. The effects of endurance training on muscle fibre types and enzyme activities. *Can. J. Appl. Physiol.* **24,** 41–53 (1999).

47. Coffey, V. G. & Hawley, J. A. The molecular bases of training adaptation. *Sports Med.* **37,** 737–63 (2007).

48. Hawley, J. A. Adaptations of skeletal muscle to prolonged, intense endurance training. *Clin. Exp. Pharmacol. Physiol.* **29,** 218–222 (2002).

49. Hawley, J. & Stepto, N. Adaptations to training in endurance cyclists: implications for performance. *Sports Med.* **31,** 511–20 (2001).

50. Faria, E. W., Parker, D. L. & Faria, I. E. The science of cycling: physiology and training - part 1. *Sports Med.* **35,** 285–312 (2005).

51. Coyle, E. F. *et al.* Physiological and biomechanical factors associated with elite endurance cycling performance. *Med. Sci. Sports Exerc.* **23,** 93–107 (1991).

52. Cochrane, D. J. Alternating hot and cold water immersion for athlete recovery: a review. *Phys. Ther. Sport* **5,** 26–32 (2004).

53. Reilly, T. & Ekblom, B. The use of recovery methods post-exercise. *J. Sport. Sci.* **23,** 619–627 (2005).

54. Coffey, V., Leveritt, M. & Gill, N. Effect of recovery modality on 4-hour repeated treadmill running performance and changes in physiological variables. *J. Sci. Med. Sport* **7,** 1–10 (2004).

55. Marcora, S. M. & Bosio, A. Effect of exercise-induced muscle damage on endurance running performance in humans. *Scand. J. Med. Sci. Sports* **17,** 662–671 (2007).

56. Clarkson, P. M., Nosaka, K. & Braun, B. Muscle function after exercise-induced muscle damage and rapid adaptation. *Med. Sci. Sports Exerc.* **24,** 512–520 (1992).

57. Cleak, M. J. & Eston, R. G. Delayed onset muscle soreness: mechanisms and management. *J. Sports Sci.* **10,** 325–341 (1992).

58. Ebbeling, C. B. & Clarkson, P. M. Exercise-induced muscle damage and adaptation. *Sport. Med.* **7,** 207–234 (1989).

59. Smith, L. L. Acute inflammation: the underlying mechanism in delayed onset muscle soreness? *Med. Sci. Sports Exerc.* **23,** 542–551 (1991).

60. Armstrong, R. B. Mechanisms of exercise-induced delayed onset muscular soreness: a brief review. *Med. Sci. Sports Exerc.* **16,** 529–538 (1984).

61. Kuipers, H. Exercise-induced muscle damage. *Int. J. Sports Med.* **15,** 132–135 (1994).

62. MacIntyre, D. L., Reid, W. D. & McKenzie, D. C. Delayed muscle soreness. The inflammatory response to muscle injury and its clinical implications. *Sports Med.* **20,** 24–40 (1995).

63. Smith, L. L. *et al.* The impact of a repeated bout of eccentric exercise on muscular strength, muscle soreness and creatine kinase. *Br. J. Sports Med.* **28,** 267–271 (1994).

64. Armstrong, R. B. Initial events in exercise-induced muscular injury. *Med. Sci. Sports Exerc.* **22,** 429–435 (1990).

65. Gulick, D. T. & Kimura, I. F. Delayed onset muscle soreness: what is it and how do we treat it? *J. Sport Rehabil.* **4,** 234 – 243 (1996).

66. Eston, R. G., Finney, S., Baker, S. & Baltzopoulos, V. Muscle tenderness and peak torque changes after downhill running following a prior bout of isokinetic eccentric exercise. *J. Sports Sci.* **14,** 291–299 (1996).

67. Miles, M. P. & Clarkson, P. M. Exercise-induced muscle pain, soreness, and cramps. *J. Sports Med. Phys. Fitness* **34,** 203–216 (1994).

68. Nosaka, K. & Newton, M. Is recovery from muscle damage retarded by a subsequent bout of eccentric exercise inducing larger decreases in force? *J. Sci. Med. Sport* **5,** 204–218 (2002).

69. Chambers, C., Noakes, T. D., Lambert, E. V. & Lambert, M. I. Time course of recovery of vertical jump height and heart rate versus running speed after a 90-km foot race. *J. Sports Sci.* **16,** 645–651 (1998).

70. Warhol, M. J., Siegel, A. J., Evans, W. J. & Silverman, L. M. Skeletal muscle injury and repair in marathon runners after competition. *Am. J. Pathol.* **118,** 331–339 (1984).

71. Howell, J. N., Chleboun, G. & Conatser, R. Muscle stiffness, strength loss, swelling and soreness following exercise-induced injury in humans. *J. Physiol.* **464,** 183–196 (1993).

72. Connolly, D. A. J., Sayers, S. P. & McHugh, M. P. Treatment and prevention of delayed onset muscle soreness. *J. Strength Cond. Res.* **17,** 197–208 (2003).

73. Juhn, M. S. Ergogenic aids in aerobic activity. *Curr. Sports Med. Rep.* **1,** 233–8 (2002).

74. Burke, L. M., Hawley, J. a, Wong, S. H. S. & Jeukendrup, A. E. Carbohydrates for training and competition. *J. Sports Sci.* **29 Suppl 1,** S17–27 (2011).

75. Nybo, L. *et al.* Impact of carbohydrate supplementation during endurance training on glycogen storage and performance. *Acta Physiol.* **197,** 117–27 (2009).

76. Rodriguez, N. R., Vislocky, L. M. & Gaine, P. C. Dietary protein, endurance exercise, and human skeletal-muscle protein turnover. *Curr. Opin. Clin. Nutr. Metab. Care* **10,** 40–5 (2007).

77. Kruseman, M., Bucher, S., Bovard, M., Kayser, B. & Bovier, P. A. Nutrient intake and performance during a mountain marathon: an observational study. *Eur. J. Appl. Physiol.* **94,** 151–7 (2005).

78. Romijn, J. A. *et al.* Regulation of endogenous fat and carbohydrate metabolism in relation to exercise intensity and duration. *Am. J. Physiol.* **265,** E380–E391 (1993).

79. Jeukendrup, A. E. Carbohydrate intake during exercise and performance. *Nutrition* **20,** 669–77 (2004).

80. Coggan, A. R. & Coyle, E. F. Reversal of fatigue during prolonged exercise by carbohydrate infusion or ingestion. *J. Appl. Physiol.* **63,** 2388–2395 (1987).

81. Coyle, E. F., Coggan, A. R., Hemmert, M. K. & Ivy, J. L. Muscle glycogen utilization during prolonged strenuous exercise when fed carbohydrate. *J. Appl. Physiol.* **61,** 165–72 (1986).

82. Bergström, J., Hermansen, L., Hultman, E. & Saltin, B. Diet, muscle glycogen and physical performance. *Acta Physiol. Scand.* **71,** 140–150 (1967).

83. Costill, D. L., Bowers, R., Branam, G. & Sparks, K. Muscle glycogen utilization during prolonged exercise on successive days. *J. Appl. Physiol.* **31,** 834–838 (1971).

84. Hargreaves, M., Costill, D. L., Coggan, A., Fink, W. J. & Nishibata, I. Effect of carbohydrate feedings on muscle glycogen utilization and exercise performance. *Med. Sci. Sports Exerc.* **16,** 219–22 (1984).

85. Ivy, J. L., Res, P. T., Sprague, R. C. & Widzer, M. O. Effect of a carbohydrate-protein supplement on endurance performance during exercise of varying intensity. *Int. J. Sport Nutr. Exerc. Metab.* **13,** 382–95 (2003).

86. Coyle, E. F. *et al.* Carbohydrate feeding during prolonged strenuous exercise can delay fatigue. *J. Appl. Physiol.* **55,** 230–5 (1983).

87. Glace, B. W., Murphy, C. a & McHugh, M. P. Food intake and electrolyte status of ultra-marathoners competing in extreme heat. *J. Am. Coll. Nutr.* **21,** 553–9 (2002).

88. Kimber, N. E., Ross, J. J., Mason, S. L. & Speedy, D. B. Energy balance during an ironman triathlon in male and female triathletes. *Int. J. Sport Nutr. Exerc. Metab.* **12,** 47–62 (2002).

89. Ahlborg, B. *et al.* Human muscle glycogen content and capacity for prolonged exercise after different diets. *Forsvarsmedicin* 85–99 (1967).

90. Hultman, E. Studies on muscle metabolism of glycogen and active phosphate in man with special reference to exercise and diet. *Scand. J. Clin. Lab. Invest. Suppl.* **94,** 1–63 (1967).

91. Karlsson, J. & Saltin, B. Diet, muscle glycogen, and endurance performance. *J Appl Physiol* **31,** 203–206 (1971).

92. Bergstrom, J. & Hultman, E. Muscle glycogen synthesis after exercise: an enhancing factor localized to the muscle cells in man. *Nature* **210,** 309–310 (1966).

93. Sherman, W. M., Costill, D. L., Fink, W. J. & Miller, J. M. Effect of exercise-diet manipulation on muscle glycogen and its subsequent utilization during performance. *Int. J. Sports Med.* **2,** 114–8 (1981).

94. Bussau, V. A., Fairchild, T. J., Rao, A., Steele, P. & Fournier, P. A. Carbohydrate loading in human muscle: an improved 1 day protocol. *Eur. J. Appl. Physiol.* **87,** 290–5 (2002).

95. Temesi, J., Johnson, N. A., Raymond, J., Burdon, C. A. & O'Connor, H. T. Carbohydrate ingestion during endurance exercise improves performance in adults. *J. Nutr.* **141,** 890–7 (2011).

96. Hawley, J. A., Palmer, G. S. & Noakes, T. D. Effects of 3 days of carbohydrate supplementation on muscle glycogen content and utilisation during a 1-h cycling performance. *Eur. J. Appl. Physiol. Occup. Physiol.* **75,** 407–12 (1997).

97. Burke, L. M. *et al.* Carbohydrate loading failed to improve 100-km cycling performance in a placebo-controlled trial. *J. Appl. Physiol.* **88,** 1284–90 (2000).

98. Hawley, J. A., Schabort, E. J., Noakes, T. D. & Dennis, S. C. Carbohydrate-loading and exercise performance. An update. *Sport. Med.* **24,** 73–81 (1997).

99. Coyle, E. F., Jeukendrup, A. E., Oseto, M. C., Hodgkinson, B. J. & Zderic, T. W. Low-fat diet alters intramuscular substrates and reduces lipolysis and fat oxidation during exercise. *Am. J. Physiol. Endocrinol. Metab.* **280,** E391–E398 (2001).

100. Hansen, A. K. *et al.* Skeletal muscle adaptation: training twice every second day vs. training once daily. *J. Appl. Physiol.* **98,** 93–9 (2005).

101. Hulston, C. J. *et al.* Training with low muscle glycogen enhances fat metabolism in well-trained cyclists. *Med. Sci. Sports Exerc.* **42,** 2046–55 (2010).

102. Yeo, W. K. *et al.* Skeletal muscle adaptation and performance responses to once a day versus twice every second day endurance training regimens. *J. Appl. Physiol.* **105,** 1462–70 (2008).

103. Akerstrom, T. C. A. *et al.* Glucose ingestion during endurance training does not alter adaptation. *J. Appl. Physiol.* **106,** 1771–9 (2009).

104. De Bock, K. *et al.* Effect of training in the fasted state on metabolic responses during exercise with carbohydrate intake. *J. Appl. Physiol.* **104,** 1045–55 (2008).

105. Van Proeyen, K., Szlufcik, K., Nielens, H., Ramaekers, M. & Hespel, P. Beneficial metabolic adaptations due to endurance exercise training in the fasted state. *J. Appl. Physiol.* **110,** 236–45 (2011).

106. Cox, G. R. *et al.* Daily training with high carbohydrate availability increases exogenous carbohydrate oxidation during endurance cycling. *J. Appl. Physiol.* **109,** 126–34 (2010).

107. Rauch, H. G., Hawley, J. A., Noakes, T. D. & Dennis, S. C. Fuel metabolism during ultra-endurance exercise. *Eur. J. Physiol.* **436,** 211–9 (1998).

108. Jentjens, R. L. P. G., Moseley, L., Waring, R. H., Harding, L. K. & Jeukendrup, A. E. Oxidation of combined ingestion of glucose and fructose during exercise. *J. Appl. Physiol.* **96,** 1277–84 (2004).

109. Currell, K. & Jeukendrup, A. E. Superior endurance performance with ingestion of multiple transportable carbohydrates. *Med. Sci. Sport. Exerc.* **40,** 275–281 (2008).

110. Jentjens, R. L. P. G. & Jeukendrup, A. E. High rates of exogenous carbohydrate oxidation from a mixture of glucose and fructose ingested during prolonged cycling exercise. *Br. J. Nutr.* **93,** 485–492 (2005).

111. Jeukendrup, A. E. Carbohydrate feeding during exercise. *Eur. J. Sport Sci.* **8,** 77–86 (2008).

112. Wallis, G. A., Rowlands, D. S., Shaw, C., Jentjens, R. L. P. G. & Jeukendrup, A. E. Oxidation of combined ingestion of maltodextrins and fructose during exercise. *Med. Sci. Sports Exerc.* **37,** 426–32 (2005).

113. Jeukendrup, A. E. Carbohydrate and exercise performance: the role of multiple transportable carbohydrates. *Curr. Opin. Clin. Nutr. Metab. Care* **13,** 452–7 (2010).

114. Sawka, M. N. *et al.* American College of Sports Medicine position stand. Exercise and fluid replacement. *Med. Sci. Sports Exerc.* **39,** 377–90 (2007).

115. Jeukendrup, A. E. *et al.* Exogenous carbohydrate oxidation during ultra-endurance exercise. *J. Appl. Physiol.* **100,** 1134–41 (2006).

116. Pfeiffer, B., Stellingwerff, T., Zaltas, E. & Jeukendrup, A. E. Oxidation of solid versus liquid CHO sources during exercise. *Med. Sci. Sport. Exerc.* **42,** 2030–2037 (2010).

117. Koivisto, V. A., Karonen, S. L. & Nikkilä, E. A. Carbohydrate ingestion before exercise: comparison of glucose, fructose, and sweet placebo. *J. Appl. Physiol.* **51,** 783–787 (1981).

118. Jeukendrup, A. E. & Killer, S. C. The myths surrounding pre-exercise carbohydrate feeding. *Ann. Nutr. Metab.* **57,** 18–25 (2010).

119. Achten, J. & Jeukendrup, A. E. Effects of pre-exercise ingestion of carbohydrate on glycaemic and insulinaemic responses during subsequent exercise at differing intensities. *Eur. J. Appl. Physiol.* **88,** 466–71 (2003).

120. Jentjens, R. L. P. G. & Jeukendrup, A. E. Prevalence of hypoglycemia following pre-exercise carbohydrate ingestion is not accompanied By higher insulin sensitivity. *Int. J. Sport Nutr. Exerc. Metab.* **12,** 398–413 (2002).

121. Jentjens, R. L. P. G., Cale, C., Gutch, C. & Jeukendrup, A. E. Effects of pre-exercise ingestion of differing amounts of carbohydrate on subsequent metabolism and cycling performance. *Eur. J. Appl. Physiol.* **88,** 444–52 (2003).

122. Jentjens, R. L. P. G. & Jeukendrup, A. E. Effects of pre-exercise ingestion of trehalose, galactose and glucose on subsequent metabolism and cycling performance. *Eur. J. Appl. Physiol.* **88,** 459–65 (2003).

123. Moseley, L., Lancaster, G. I. & Jeukendrup, A. E. Effects of timing of pre-exercise ingestion of carbohydrate on subsequent metabolism and cycling performance. *Eur. J. Appl. Physiol.* **88,** 453–8 (2003).

124. Sherman, W. M., Peden, C. M. & Wright, D. A. Carbohydrate feedings 1 h before improves cycling performance exercise. *Am. J. Clin. Nutr.* **54,** 866–870 (1991).

125. Short, K. R., Sheffield-Moore, M. & Costill, D. L. Glycemic and insulinemic responses to multiple preexercise carbohydrate feedings. *Int. J. Sport Nutr.* **7,** 128–37 (1997).

126. Foster, C., Costill, D. L. & Fink, W. J. Effects of pre-exercise feedings on endurance performance. *Med. Sci. Sports* **11,** 1–5 (1979).

127. Chryssanthopoulos, C., Hennessy, L. C. & Williams, C. The influence of pre-exercise glucose ingestion on endurance running capacity. *Br. J. Sports Med.* **28,** 105–9 (1994).

128. Devlin, J. T., Calles-Escandon, J. & Horton, E. S. Effects of pre-exercise snack feeding on endurance cycle exercise. *J. Appl. Physiol.* **60,** 980–985 (1986).

129. Febbraio, M., Chiu, A., Angus, D., Arkinstall, M. J. & Hawley, J. A. Effects of carbohydrate ingestion before and during exercise on glucose kinetics and performance. *J. Appl. Physiol.* **89,** 2220–2226 (2000).

130. Hargreaves, M., Costill, D. L., Fink, W. J., King, D. S. & Fielding, R. A. Effect of pre-exercise carbohydrate feedings on endurance cycling performance. *Med. Sci. Sports Exerc.* **19,** 33–6 (1987).

131. McMurray, R. G. The effects of fructose and glucose on high intensity endurance performance. *Res. Q. Exerc. Sport* **54,** (1983).

132. Okano, G. *et al.* Effect of pre-exercise fructose ingestion on endurance performance in fed men. *Med. Sci. Sports Exerc.* **20,** 105–9 (1988).

133. Thomas, D. E., Brotherhood, J. R. & Brand, J. C. Carbohydrate feeding before exercise: effect of glycemic index. *Int. J. Sports Med.* **12,** 180–6 (1991).

134. Smith, J. W. *et al.* Fuel selection and cycling endurance performance with ingestion of glucose: evidence for a carbohydrate dose response. *J. Appl. Physiol.* **108,** 1520–9 (2010).

135. Smith, J. W. *et al.* Evidence of a carbohydrate dose and prolonged exercise performance relationship. *Med. Sci. Sport. Exerc.* **42,** 84 (2010).

136. Burd, N. A., Tang, J. E., Moore, D. R. & Phillips, S. M. Exercise training and protein metabolism: influences of contraction, protein intake, and sex-based differences. *J. Appl. Physiol.* **106,** 1692–701 (2009).

137. Maughan, R. J., King, D. S. & Lea, T. Dietary supplements. *J. Sports Sci.* **22,** 95–113 (2004).

138. Phillips, S. M. *et al.* A to Z of nutritional supplements: dietary supplements, sports nutrition foods and ergogenic aids for health and performance - Part 32. *Br. J. Sports Med.* **46,** 454–6 (2012).

139. Burke, L. & Deakin, V. *Clinical Sports Nutrition*. (McGraw-Hill, 2006).

140. Juhn, M. Popular sports supplements and ergogenic aids. *Sport. Med.* **33,** 921–39 (2003).

141. Buckley, J. D. *et al.* Supplementation with a whey protein hydrolysate enhances recovery of muscle force-generating capacity following eccentric exercise. *J. Sci. Med. Sport* **13,** 178–81 (2010).

142. Cooke, M. B., Rybalka, E., Stathis, C. G., Cribb, P. J. & Hayes, A. Whey protein isolate attenuates strength decline after eccentrically-induced muscle damage in healthy individuals. *J. Int. Soc. Sports Nutr.* **7,** 30 (2010).

143. Breen, L., Tipton, K. D. & Jeukendrup, A. E. No effect of carbohydrate-protein on cycling performance and indices of recovery. *Med. Sci. Sports Exerc.* **42,** 1140–8 (2010).

144. Howarth, K. R., Moreau, N. A., Phillips, S. M. & Gibala, M. J. Coingestion of protein with carbohydrate during recovery from endurance exercise stimulates skeletal muscle protein synthesis in humans. *J. Appl. Physiol.* **106,** 1394–402 (2009).

145. Tipton, K. D. *et al.* Stimulation of net muscle protein synthesis by whey protein ingestion before and after exercise. *Am. J. Physiol. Endocrinol. Metab.* **292,** E71–6 (2007).

146. Tipton, K. D. *et al.* Timing of amino acid-carbohydrate ingestion alters anabolic response of muscle to resistance exercise. *Am. J. Physiol. Endocrinol. Metab.* **281,** E197–E206 (2001).

147. Nissen, S. L. & Sharp, R. L. Effect of dietary supplements on lean mass and strength gains with resistance exercise: a meta-analysis. *J. Appl. Physiol.* **94,** 651–9 (2003).

148. Medved, I. *et al.* N-acetylcysteine enhances muscle cysteine and glutathione availability and attenuates fatigue during prolonged exercise in endurance-trained individuals. *J. Appl. Physiol.* **97,** 1477–85 (2004).

149. McKenna, M. J. *et al.* N-acetylcysteine attenuates the decline in muscle Na+, K+-pump activity and delays fatigue during prolonged exercise in humans. *J. Physiol.* **576,** 279–88 (2006).

150. Nieman, D. C., Stear, S. J., Castell, L. M. & Burke, L. M. A-Z of nutritional supplements: dietary supplements, sports nutrition foods and ergogenic aids for health and performance - Part 15. *Br. J. Sports Med.* **44,** 1202–1205 (2010).

151. Clarkson, P. M. & Thompson, H. S. Antioxidants: what role do they play in physical activity and health? *Am. J. Cinical Nutr.* **72,** 637S–46S (2000).

152. Manore, M., Barr, S. I. & Butterfield, G. E. American College of Sports Medicine, American Dietetic Association, and Dietitians of Canada Joint Position Statement. Nutrition and athletic performance. *Med. Sci. Sport. Exerc.* **32,** 2130–2145 (2000).

153. Stear, S. J., Burke, L. M. & Castell, L. M. A-Z of nutritional supplements: dietary supplements, sports nutrition foods and ergogenic aids for health and performance - Part 3. *Br. J. Sports Med.* **43,** 890–892 (2009).

154. Dekkers, J. C., van Doornen, L. J. & Kemper, H. C. The role of antioxidant vitamins and enzymes in the prevention of exercise-induced muscle damage. *Sport. Med.* **21,** 213–38 (1996).

155. Thompson, D. *et al.* Muscle soreness and damage parameters after prolonged intermittent shuttle-running following acute vitamin C supplementation. *Int. J. Sports Med.* **22,** 68–75 (2001).

156. Nielsen, A. N. *et al.* No effect of antioxidant supplementation in triathletes on maximal oxygen uptake, 31P-NMRS detected muscle energy metabolism and muscle fatigue. *Int. J. Sports Med.* **20,** 154–8 (1999).

157. Weston, S. B., Zhou, S., Weatherby, R. P. & Robson, S. J. Does exogenous coenzyme Q10 affect aerobic capacity in endurance athletes? *Int. J. Sport Nutr.* **7,** 197–206 (1997).

158. Buchman, A. L. *et al.* Short-term vitamin E supplementation before marathon running: a placebo-controlled trial. *Nutrition* **15,** 278–283 (1999).

159. Matuszczak, Y. *et al.* Effects of N-acetylcysteine on glutathione oxidation and fatigue during handgrip exercise. *Muscle Nerve* **32,** 633–8 (2005).

160. Medved, I., Brown, M. J., Bjorksten, A. R. & Mckenna, M. J. Effects of intravenous N-acetylcysteine infusion on time to fatigue and potassium regulation during prolonged cycling exercise. *J. Appl. Physiol.* **96,** 211–217 (2004).

161. Powers, S. K., DeRuisseau, K. C., Quindry, J. & Hamilton, K. L. Dietary antioxidants and exercise. *J. Sports Sci.* **22,** 81–94 (2004).

162. Driskell, J. in *Sport. Nutr. Vitam. Trace Elem.* (Driskell, J. & Wolinsky, I.) 323–331 (CRC Press, 2006).

163. Lukaski, H. C. Vitamin and mineral status: effects on physical performance. *Nutrition* **20,** 632–44 (2004).

164. Woolf, K. & Manore, M. M. B-vitamins and exercise: does exercise alter requirements? *Int. J. Sport Nutr. Exerc. Metab.* **16,** 453–84 (2006).

165. Williams, M. H. Ergogenic and ergolytic substances. *Med. Sci. Sport. Exerc.* **24,** S344–S348 (1992).

166. Johnson, W. A. & Landry, G. L. Nutritional supplements: fact vs. fiction. *Adolesc. Med.* **9,** 501–13 (1998).

167. Institute of Medicine. *Dietary reference intakes for thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, pantothenic acid, biotin, and choline*. (National Academies Press, 2000).

168. American Dietetic Association. Position of the American Dietetic Association and Dieticians of Canada: vegetarian diets. *J. Am. Diet. Assoc.* **103,** 748–65 (2003).

169. Institute of Medicine. *Dietary reference intakes for calcium, phosphorus, magnesium, vitamin D, and fluoride.* (National Academies Press, 1997).

170. Tang, B. M. P., Eslick, G. D., Nowson, C., Smith, C. & Bensoussan, A. Use of calcium or calcium in combination with vitamin D supplementation to prevent fractures and bone loss in people aged 50 years and older: a meta-analysis. *Lancet* 657–666 (2007).

171. Holick, M. F. Vitamin D deficiency. *N. Engl. J. Med.* 266–281 (2007).

172. Nakagawa, K. Effect of vitamin D on the nervous system and the skeletal muscle. *Clin. Calcium* **16,** 1182–1187 (2006).

173. Cannell, J. J. & Hollis, B. W. Use of vitamin D in clinical practice. *Altern. Med. Rev.* **13,** 6–20 (2008).

174. Willis, K. S., Peterson, N. J. & Larson-meyer, D. E. Should we be concerned about the vitamin D status of athletes? *Int. J. Sport Nutr. Exerc. Metab.* **18,** 204–224 (2008).

175. Burke, L. M. *et al.* A-Z of nutritional supplements: dietary supplements, sports nutrition foods and ergogenic aids for health and performance - Part 7. *Br. J. Sports Med.* **44,** 389–391 (2010).

176. Maïmoun, L. *et al.* The intensity level of physical exercise and the bone metabolism response. *Int. J. Sports Med.* **27,** 105–11 (2006).

177. Whiting, S. J. & Barabash, W. A. Dietary reference intakes for the micronutrients: considerations for physical activity. *Appl. Physiol. Nutr. Metab.* **31,** 80–5 (2006).

178. Meier, C., Woitge, H. W., Witte, K., Lemmer, B. & Seibel, M. J. Supplementation with oral vitamin D3 and calcium during winter prevents seasonal bone loss: a randomized controlled open-label prospective trial. *J. Bone Miner. Res.* **19,** 1221–30 (2004).

179. Bischoff-ferrari, H. A. *et al.* Higher 25-hydroxyvitamin D concentrations are associated with better lower-extremity function in both active and inactive persons aged > or =60 y. *Am. J. Clin. Nutr.* **80,** 752–758 (2004).

180. Heaney, R. P., Barger-lux, M. J., Davies, K. M., Chen, T. C. & Holick, M. F. Human serum 25-hydroxycholecalciferol response to extended oral dosing with cholecalciferol. *Am. J. Clin. Nutr.* **77,** 204–10 (2003).

181. Vieth, R., Chan, P. R. & Macfarlane, G. D. Efficacy and safety of vitamin D3 intake exceeding the lowest observed adverse effect level. *Am. J. Clin. Nutr.* 288–294 (2001).

182. Vieth, R. *et al.* The urgent need to recommend an intake of vitamin D that is effective. *Am. J. Clin. Nutr.* 649–650 (2007).

183. Cannell, J. J., Hollis, B. W., Sorenson, M. B., Taft, T. N. & Anderson, J. J. B. Athletic performance and vitamin D. *Med. Sci. Sports Exerc.* **41,** 1102–10 (2009).

184. Institute of Medicine. *Dietary reference intakes for vitamin C, vitamin E, selenium, and carotenoids.* (National Academies Press, 2000).

185. Bryant, R. J. Effects of vitamin E and C supplementation either alone or in combination on exercise-induced lipid peroxidation in trained cyclists. *J. Strength Cond. Res.* **17,** (2003).

186. Burke, L. M. *et al.* A-Z of nutritional supplements: dietary supplements, sports nutrition foods and ergogenic aids for health and performance - Part 4. *Br. J. Sports Med.* **43,** 1088–1090 (2009).

187. Lemon, P. in *Exerc. Sport. Sci.* (Garrett, W. E. & Kirkendall, D. T.) 19–27 (Lippencott Williams & Wilkins, 2000).

188. Paul, G. L., Gautsch, T. A. & Layman, D. K. in *Nurtition Exerc. Sport* (Wolinsky, I.) 125–158 (Boca Raton: CRC Press, 1998).

189. Blomstrand, E. V. A. & Saltin, B. BCAA intake affects protein metabolism in muscle after but not during exercise in humans. *Am. J. Physiol. Endocrinol. Metab.* E365–374 (2001).

190. Castell, L. M., Poortmans, J. R. & Newsholme, E. A. Does glutamine have a role in reducing infections in athletes? *Eur. J. Appl. Physiol. Occup. Physiol.* **73,** 488–490 (1996).

191. Newsholme, E. A. & Blomstrand, E. Branched-chain amino acids and central fatigue. *J. Nutr.* **136,** 274–276 S. (2006).

192. Portier, H. *et al.* Effects of branched-chain amino acids supplementation on physiological and psychological performance during an offshore sailing race. *Eur. J. Appl. Physiol.* **104,** 787–94 (2008).

193. Meeusen, R., Watson, P., Hasegawa, H., Roelands, B. & Piacentini, M. F. Central fatigue: the serotonin hypothesis and beyond. *Sport. Med.* **36,** 881–909 (2006).

194. Coombes, J. S. & McNaughton, L. R. Effects of branched-chain amino acid supplementation on serum creatine kinase and lactate dehydrogenase after prolonged exercise. *J. Sports Med. Phys. Fitness* **40,** 240–246 (2000).

195. Kingsbury, K. J., Kay, L. & Hjelm, M. Contrasting plasma free amino acid patterns in elite athletes: association with fatigue and infection. *Br. J. Sports Med.* 25–33 (1998).

196. Bassit, R. A., Sawada, L. A., Bacurau, R. F. P., Navarro, F. & Costa Rosa, L. F. B. P. The effect of BCAA supplementation upon the immune response of triathletes. *Med. Sci. Sport. Exerc.* **32,** 1214–1219 (2000).

197. Marwood, S. & Bowtell, J. No effect of glutamine supplementation and hyperoxia on oxidative metabolism and performance during high-intensity exercise. *J. Sports Sci.* **26,** 1081–90 (2008).

198. Hoffman, J. R. *et al.* Examination of the efficacy of acute L-alanyl-L-glutamine ingestion during hydration stress in endurance exercise. *J. Int. Soc. Sports Nutr.* **7,** 8 (2010).

199. Negro, M., Giardina, S., Marzani, B. & Marzatico, F. Branched-chain amino acid supplementation does not enhance athletic performance but affects muscle recovery and the immune system. *J. Sports Med. Phys. Fitness* **48,** 347–351 (2008).

200. Bassit, R. A. *et al.* Branched-chain amino acid supplementation and the immune response of long-distance athletes. *Nutrition* **18,** 376–379 (2002).

201. Shirreffs, S. M. & Sawka, M. N. Fluid and electrolyte needs for training, competition, and recovery. *J. Sports Sci.* **29 Suppl 1,** S39–46 (2011).

202. Maughan, R. J. & Shirreffs, S. M. Nutrition for sports performance: issues and opportunities. *Proc. Nutr. Soc.* **71,** 112–9 (2012).

203. Cheuvront, S. N., Kenefick, R. W., Montain, S. J. & Sawka, M. N. Mechanisms of aerobic performance impairment with heat stress and dehydration. *J. Appl. Physiol.* **109,** 1989–95 (2010).

204. Von Duvillard, S. P., Braun, W. A., Markofski, M., Beneke, R. & Leithäuser, R. Fluids and hydration in prolonged endurance performance. *Nutrition* **20,** 651–6 (2004).

205. Casa, D. J., Clarkson, P. M. & Roberts, W. O. American College of Sports Medicine roundtable on hydration and physical activity: consensus statements. *Curr. Sports Med. Rep.* **4,** 115–27 (2005).

206. Noakes, T. D. Fluid replacement during marathon running. *Clin. J. Sport Med.* **13,** 309–318 (2003).

207. Cheuvront, S. N., Carter, R., Castellani, J. W. & Sawka, M. N. Hypohydration impairs endurance exercise performance in temperate but not cold air. *J. Appl. Physiol.* **99,** 1972–6 (2005).

208. Nose, H., Mack, G. W., Shi, X. R. & Nadel, E. R. Involvement of sodium retention hormones during rehydration in humans. *J Appl Physiol* **65,** 332–336 (1988).

209. Montain, S. J., Cheuvront, S. N. & Sawka, M. N. Exercise associated hyponatraemia: quantitative analysis to understand the aetiology. *Br. J. Sports Med.* **40,** 98–105; discussion 98–105 (2006).

210. Shirreffs, S. M. & Maughan, R. J. Volume repletion after exercise-induced volume depletion in humans: replacement of water and sodium losses. *Am J Physiol Ren. Physiol* **274,** F868–875 (1998).

211. Noakes, T. D. Drinking guidelines for exercise: what evidence is there that athletes should drink "as much as tolerable", "to replace the weight lost during exercise" or "ad libitum"? *J. Sports Sci.* **25,** 781–96 (2007).

212. Brien, A. J. & Simon, T. L. The effects of red blood cell infusion on 10-km race time. *J. Am. Med. Assoc.* **257,** 2761–5 (1987).

213. Jones, M. & Tunstall Pedoe, D. S. Blood doping-a literature review. *Br. J. Sports Med.* **23,** 84–8 (1989).

214. Klein, H. G. Blood transfusion and athletics. Games people play. *N. Engl. J. Med.* **312,** 854–6 (1985).

215. Stear, S. J., Castell, L. M., Burke, L. M. & Spriet, L. L. A-Z of nutritional supplements: dietary supplements, sports nutrition foods and ergogenic aids for health and performance - Part 6. *Br. J. Sports Med.* **44,** 297–8 (2010).

216. Costill, D. L., Dalsky, G. P. & Fink, W. J. Effects of caffeine ingestion on metabolism and exercise performance. *Med. Sci. Sports* **10,** 155–8 (1978).

217. Cox, G. R. *et al.* Effect of different protocols of caffeine intake on metabolism and endurance performance. *J. Appl. Physiol.* **93,** 990–9 (2002).

218. Graham, T. E. & Spriet, L. L. Performance and metabolic responses to a high caffeine dose during prolonged exercise. *J. Appl. Physiol.* **71,** 2292–8 (1991).

219. Graham, T. E. & Spriet, L. L. Metabolic, catecholamine, and exercise performance responses to various doses of caffeine. *J. Appl. Physiol.* **78,** 867–74 (1995).

220. Ivy, J. L., Costill, D. L., Fink, W. J. & Lower, R. W. Influence of caffeine and carbohydrate feedings on endurance performance. *Med. Sci. Sports* **11,** 6–11 (1979).

221. Pasman, W. J., van Baak, M. A., Jeukendrup, A. E. & de Haan, A. The effect of different dosages of caffeine on endurance performance time. *Int. J. Sports Med.* **16,** 225–30 (1995).

222. Yeo, S. E., Jentjens, R. L. P. G., Wallis, G. A. & Jeukendrup, A. E. Caffeine increases exogenous carbohydrate oxidation during exercise. *J. Appl. Physiol.* **99,** 844–50 (2005).

223. Graham, T. E. Caffeine and exercise: metabolism, endurance and performance. *Sport. Med.* **31,** 785–807 (2001).

224. Graham, T. E. Caffeine, coffee and ephedrine: impact on exercise performance and metabolism. *Can. J. Appl. Physiol.* **26,** S103–19 (2001).

225. Davis, J. M. *et al.* Central nervous system effects of caffeine and adenosine on fatigue. *Am. J. Physiol. Regul. Integr. Comp. Physiol.* **284,** R399–404 (2003).

226. Fredholm, B. B. On the mechanism of action of theophylline and caffeine. *Acta Med. Scand.* **217,** 149–53 (1985).

227. Laurent, D. *et al.* Effects of caffeine on muscle glycogen utilization and the neuroendocrine axis during exercise. *J. Clin. Endocrinol. Metab.* **85,** 2170–5 (2000).

228. Chesley, A., Howlett, R., Heigenhauser, G. J., Hultman, E. & Spriet, L. L. Regulation of muscle glycogenolytic flux during intense aerobic exercise after caffeine ingestion. *Am. J. Physiol.* **275,** R596–R603 (1998).

229. Pedersen, D. J. *et al.* High rates of muscle glycogen resynthesis after exhaustive exercise when carbohydrate is coingested with caffeine. *J. Appl. Physiol.* **105,** 7–13 (2008).

230. Kovacs, E., Stegen, J. & Brouns, F. Effect of caffeinated drinks on substrate metabolism, caffeine excretion, and performance. *J. Appl. Physiol.* **82,** 709–715 (1998).

231. Eichner, E. R. Sports medicine pearls and pitfalls: java jolt. *Curr. Sports Med. Rep.* **8,** 42–3 (2009).

232. Arnaud, M. J. The pharmacology of caffeine. *Prog. Drug Res.* **31,** 273–313 (1987).

233. Goral, M. Evaluation of Acth, steroids, barbiturates, benzodiazpines, beta-blockers, caffeine, cannabis and cocaine dopings in Sportsmen. *Res. J. Biol. Sci.* **3,** 830–836 (2008).

234. Rigato, I., Blarasin, L. & Kette, F. Severe hypokalemia in 2 young bicycle riders due to massive caffeine intake. *Clin. J. Sport Med.* **20,** 128–30 (2010).

235. Keisler, B. D. & Armsey, T. D. Caffeine as an ergogenic aid. *Curr. Sports Med. Rep.* **5,** 215–9 (2006).

236. Celsing, F., Svedenhag, J., Pihlstedt, P. & Ekblom, B. Effects of anaemia and stepwise-induced polycythaemia on maximal aerobic power in individuals with high and low haemoglobin concentrations. *Acta Physiol. Scand.* **129,** 47–54 (1987).

237. Schubert, M. & Astorino, T. A systematic review of the efficacy of ergogenic aids for improving running performance. *J. Strength Cond. Res.* **27,** 1699 – 1707 (2013).

238. Bernstein, A., Safirstein, J. & Rosen, J. E. Athletic ergogenic aids. *Bull. Hosp. Jt. Dis.* **61,** 164–171 (2003).

239. Pritchett, K., Bishop, P., Pritchett, R., Green, M. & Katica, C. Acute effects of chocolate milk and a commercial recovery beverage on postexercise recovery indices and endurance cycling performance. *Appl. Physiol. Nutr. Metab.* **34,** 1017–22 (2009).

240. Huang, S.-H. S., Johnson, K. & Pipe, A. L. The use of dietary supplements and medications by Canadian athletes at the Atlanta and Sydney Olympic Games. *Clin. J. Sport Med.* **16,** 27–33 (2006).

241. McDowall, J. A. Supplement use by young athletes. *J. Sports Sci. Med.* **6,** 337–42 (2007).

242. Hoberman, J. History and prevalence of doping in the marathon. *Sports Med.* **37,** 386–8 (2007).

243. Ivy, J. L. J. *et al.* Early postexercise muscle glycogen recovery is enhanced with a carbohydrate-protein supplement. *J. Appl. Physiol.* **93,** 1337–44 (2002).

244. Ronsen, O., Sundgot-Borgen, J. & Maehlum, S. Supplement use and nutritional habits in Norwegian elite athletes. *Scand. J. Med. Sci. Sports* **9,** 28–35 (1999).

245. Sobal, J. & Marquart, L. F. Vitamin/mineral supplement use among athletes: a review of the literature. *Int. J. Sport Nutr.* **4,** 320–334 (1994).

246. Cook, C., Heath, F. & Thompson, R. L. A meta-analysis of response rates in web- or internet-based surveys. *Educ. Psychol. Meas.* **60,** 821–836 (2000).

247. Baruch, Y. Response rate in academic studies - A comparative analysis. *Hum. Relations* **52,** 421–438 (1999).

248. Kaplowitz, M. D., Hadlock, T. D. & Levine, R. A comparison of web and mail survey response rates. *Public Opin. Q.* **68,** 94–101 (2004).

249. Asch, D. A., Jedrziewski, M. K. & Christakis, N. A. Response rates to mail surveys published in medical journals. *J. Clin. Epidemiol.* **50,** 1129–1136 (1997).

250. Sheehan, K. B. E-mail survey response rates: a review. *J. Comput. Commun.* **6,** (2006).

251. Petroczi, A. & Naughton, D. P. The age-gender-status profile of high performing athletes in the UK taking nutritional supplements: lessons for the future. *J. Int. Soc. Sports Nutr.* **5,** 2 (2008).

252. Miller, R. B. & Wright, D. W. Detecting and correcting attrition bias in longitudinal family research. *J. Marriage Fam.* **57,** 921–929 (1995).

253. Pitsch, W. & Emrich, E. The frequency of doping in elite sport: results of a replication study. *Int. Rev. Sociol. Sport* **47,** 559–580 (2011).

254. Tscholl, P., Alonso, J. M., Dollé, G., Junge, A. & Dvorak, J. The use of drugs and nutritional supplements in top-level track and field athletes. *Am. J. Sports Med.* **38,** 133–40 (2010).

255. Werme, M., Lindholm, S., Thorén, P., Franck, J. & Brené, S. Running increases ethanol preference. *Behav. Brain Res.* **133,** 301–8 (2002).

256. Shirreffs, S. M., Taylor, A. J., Leiper, J. B. & Maughan, R. J. Post-exercise rehydration in man: effects of volume consumed and drink sodium content. *Med. Sci. Sports Exerc.* **28,** 1260–71 (1996).

257. Jeukendrup, A. E., Brouns, F., Wagenmakers, A. J. & Saris, W. H. Carbohydrate-electrolyte feedings improve 1 h time trial cycling performance. *Int. J. Sports Med.* **18,** 125–9 (1997).

258. Ayus, J. C., Varon, J. & Arieff, A. I. Hyponatremia, cerebral edema, and noncardiogenic pulmonary edema in marathon runners. *Ann. Intern. Med.* **132,** 711–4 (2000).

259. Siegel, A. J. *et al.* Hyponatremia in marathon runners due to inappropriate arginine vasopressin secretion. *Am. J. Med.* **120,** 461.e11–7 (2007).

260. Hew-butler, T. *et al.* Statement of the second international exercise-associated hyponatremia consensus development conference , New Zealand , 2007. *Clin. J. Sport Med.* **18,** 111–121 (2008).

261. Davis, D. P. *et al.* Exercise-associated hyponatremia in marathon runners: a two-year experience. *J. Emerg. Med.* **21,** 47–57 (2001).

262. Hew-Butler, T. *et al.* Consensus statement of the 1st international exercise-associated hyponatremia consensus development conference, Cape Town, South Africa, 2005. *Clin. J. Sport Med.* **15,** 208–213 (2005).

263. Feucht, C. L. & Patel, D. R. Analgesics and anti-inflammatory medications in sports: use and abuse. *Pediatr. Clin. North Am.* **57,** 751–74 (2010).

264. Satterthwaite, P., Norton, R., Larmer, P. & Robinson, E. Risk factors for injuries and other health problems sustained in a marathon. 22–26 (1999).

265. Smith, B. J. & Collina, S. J. Pain medications in the locker room: to dispense or not. *Curr. Sports Med. Rep.* **6,** 366–370 (2007).

266. Alaranta, A., Alaranta, H. & Helenius, I. Use of prescription drugs in athletes. *Sport. Med.* **38,** 449–463 (2008).

267. Donnelly, A. E., Maughan, R. J. & Whiting, P. H. Effects of ibuprofen on exercise-induced muscle soreness and indices of muscle damage. *Br. J. Sports Med.* **24,** 191–5 (1990).

268. Donnelly, A. E. & Maughan, R. J. Effects of a non-steroidal anti-inflammaroty drug on delayed onset muscle soreness and incidies of damage. *Br. J. Sports Med.* **22,** 35–38 (1988).

269. Kuipers, H., Keizer, H. A., Verstappen, F. T. & Costill, D. L. Influence of a prostaglandin-inhibiting drug on muscle soreness after eccentric work. *Int. J. Sports Med.* **6,** 336–339 (1985).

270. Gulick, D. T., Kimura, I. F., Sitler, M., Paolone, a & Kelly, J. D. Various treatment techniques on signs and symptoms of delayed onset muscle soreness. *J. Athl. Train.* **31,** 145–152 (1996).

271. Almekinders, L. C. Anti-inflammatory treatment of muscular injuries in sport. An update of recent studies. *Sport. Med.* **28,** 383–388 (1999).

272. Hertel, J. The role of nonsteroidal anti-inflammatory drugs in the treatment of acute soft tissue injuries. *J. Athl. Train.* **32,** 350–8 (1997).

273. Stovitz, S. D. & Johnson, R. J. NSAIDs and musculoskeletal treatment: what is the clinical evidence? *Physician Sport. Med.* **31,** 35 (2002).

274. Reynolds, F. *et al.* Non-steroidal anti-inflammatory drugs fail to enhance healing of acute hamstring injuries treated with physiotherapy. *South African Med. J.* **85,** 517–522 (1995).

275. Beiner, J. M., Jokl, P., Cholewicki, J. & Panjabi, M. M. The effect of anabolic steroids and corticosteroids on healing of muscle contusion injury. *Am. J. Sports Med.* **27,** 2–9 (1999).

276. Paoloni, J. J. A. & Orchard, J. J. W. The use of therapeutic medications for soft-tissue injuries in sports medicine. *Med. J. Aust.* **183,** 384–388 (2005).

277. Rahusen, F. T. G., Weinhold, P. S. & Almekinders, L. C. Nonsteroidal anti-inflammatory drugs and acetaminophen in the treatment of an acute muscle injury. *Am. J. Sports Med.* **32,** 1856–1859 (2004).

278. Braund, R. Should NSAIDs be routinely used in the treatment of sprains and strains? *Pharm. J.* **276,** 655–656 (2006).

279. Ganio, M. S., Klau, J. F., Casa, D. J., Armstrong, L. E. & Maresh, C. M. Effect of caffeine on sport-specific endurance performance: a systematic review. *J. Strength Cond. Res.* **23,** 315–24 (2009).

280. Jung, A. P., Bishop, P. A., Al-Nawwas, A. & Dale, R. B. Influence of hydration and electrolyte supplementation on incidence and time to onset of exercise-associated muscle cramps. *J. Athl. Train.* **40,** 71–75 (2005).

281. Wilmore, J. H., Morton, A. R., Gilbey, H. J. & Wood, R. J. Role of taste preference on fluid intake during and after 90 min of running at 60% of VO2max in the heat. *Med. Sci. Sports Exerc.* **30,** 587–595 (1998).

282. Lyle, B. J. *et al.* Supplement users differ from nonusers in demographic, lifestyle, dietary and health characteristics. *J. Nutr.* 2355–2362 (1998).

283. Stewart, M. L., McDonald, J. T., Levy, A. S., Schucker, R. E. & Henderson, D. P. Vitamin/mineral supplement use: a telephone survey of adults in the United States. *J. Am. Diet. Assoc.* **85,** 1585–90 (1985).

284. Phillips, S., Moore, D. & Tang, J. E. A critical examination of dietary protein requirements, benefits, and excesses in athletes. *Int. J. Sport Nutr. Exerc. Metab.* S58–S76 (2007).

285. Tipton, K. D. & Witard, O. C. Protein requirements and recommendations for athletes: relevance of ivory tower arguments for practical recommendations. *Clin. Sports Med.* **26,** 17–36 (2007).

APPENDIX I: Questionnaire Background and Informed Consent

School of Health and Rehabilitation Sciences

Faculty of Health Sciences

Division of Physiotherapy

F45 Old Main Building, Groote Schuur Hospital,

Observatory 7925

Welcome and THANK YOU for taking the time to fill in our questionnaire!

This questionnaire will greatly add to the body of knowledge and literature surrounding the use of ergogenic aids by ultra-marathon runners.

This study is investigating the use of ergogenic aids by ultra-marathon runners.

The aim of this study is to describe the use of ergogenic aids in recreational and competitive ultra-marathon runners.

Specific objectives of this study:

1) To determine which ergogenic aids are being used by ultra-marathon runners before and after training as well as between successive training sessions.
2) To determine which ergogenic aids are being used by ultra-marathon runners before, during and after races.
3) To investigate the ultra-marathon runners' knowledge in the use of ergogenic aids.

CLOSING DATE FOR QUESTIONNAIRE SUBMISSION: 30 September 2013

INSTRUCTIONS

The questionnaire will take approximately 15 to 30 minutes to complete. Please follow the instructions and complete only the sections which are relevant to you.

Each questionnaire will be coded to ensure that your confidentiality and anonymity is assured. We understand the need for extreme sensitivity as some of the questions below are based on banned substances. We take confidentiality and anonymity very seriously and therefore no personal information asked will be able to be traced back to you. The information collected will only be used for research purposes and the information gained will only be accessible and seen by the primary researcher. Information obtained from the questionnaires will not be provided to any regulatory body, such as South African Institute for Drug free Sport (SAIDS), Athletics South Africa (ASA) or World Anti-Doping Agency (WADA).

All information is strictly confidential.

Please answer all the questions in sections A and B as these are compulsory sections, whilst section C only the relevant sections will need to be filled in.

Section A: Personal and Medical Information

Section B: Training and Race History (Past 12 weeks)

Section C: Ergogenic Aids

In order to qualify for participation you are required to be competing regularly (one ultra-marathon or more per year) in ultra-marathons >50 km's and you need have been competing for more than 12 months.

If you have questions regarding the survey please feel free to contact the following people:

Michael Gwilliams (Principle Investigator) : gwilliams.michael@gmail.com

Dr Theresa Burgess (Study supervisor) : theresa.burgess@uct.ac.za

Prof Andrew Bosch (Co-supervisor) : andrew.bosch@uct.ac.za

Prof Mike Lambert (Co-supervisor) : mike.lambert@uct.ac.za

Any questions or concerns regarding your rights as research participants please contact:

Human Research Ethics Committee (HREC Ref: 280/2012)...marc.blockman@uct.ac.za

Participation in this study is voluntary.

You have the right to withdraw from this study at any time without reason or prejudice.

You will be required to indicate informed consent by ticking the appropriate box.

Please note that by accepting the option to participate in the study you are providing your informed consent. This will then lead you to the questionnaire.

Would you like to participate in this study?

- ○ **Yes**
- ○ **No**

APPENDIX II: Email to Running Clubs and Race Organisers

Department of Health and Rehabilitation Sciences

Faculty of Health Sciences

Division of Physiotherapy

F45 Old Main Building, Groote Schuur Hospital, Observatory 7925

Tel: +27 (0) 21 406 6401 Fax: +27 (0) 21 406 6323

To whom it may concern,

I am a physiotherapist currently studying my Masters of Philosophy in Sports Physiotherapy at the University of Cape Town. As part of my Masters I am required to conduct a research study.

I have selected to do my research in the field of marathon running and I am appealing to you for your assistance. I am investigating the use of ergogenic aids (performance enhancers – such as carbo-loading, energy drinks, caffeine etc.) used by ultra-marathon runners. The study will help us to identify which ergogenic aids are being used by ultra-marathon runners and why they choose to use these particular aids. It will also assess the general knowledge of ergogenic aids amongst ultra-marathon runners. There is currently a lack of evidence in this field. The aim of this study is to therefore clarify the unknown and highlight the needs or changes required in the education and safe use of ergogenic aids.

This study has been given ethical approval by the Human Research Ethics Committee, Faculty of Health Sciences, University of Cape Town (HREC REF 2012/280).

We will be conducting an online survey and need to distribute the questionnaire among the ultra-marathon running community. We require a large number of participants for the study to have scientific value. It would therefore be greatly appreciated if you could assist me in achieving this number by forwarding the attached recruitment advert to all the ultra-marathon runners on your email list. This advert will inform them of the study and will request their voluntary participation.

Participation in the study will be anonymous and all information will be kept strictly confidential. There will be no personal identifiers on the questionnaire. All participants will remain anonymous in any ensuing publication. Any information gained from this questionnaire will be used for the purposes of this study alone, and will not be forwarded to South African Institute for Drug free Sport (SAIDS), Athletics South Africa (ASA) or World Anti-Doping Agency (WADA).

There are no risks with taking part in the study, as no physical tests are being performed. Should the participants choose they will stand a chance to win 1 of 5 digital subscriptions to the Runner's World magazine. There will be no remuneration for taking part in the study.

This study is being supervised by Dr Theresa Burgess, Associate Professor Andrew Bosch and Professor Mike Lambert.

Thanking you in advance for your support in assisting with research in the field of ultra-marathon running. Please do not hesitate to contact me or the study supervisors should you have any queries.

Kind regards,

Michael Gwilliams

Tel number: 018 771 3628

E-mail: gwilliams.michael@gmail.com

Study supervisor:

Dr Theresa Burgess — Tel number: 021 406 6171

E-mail: theresa.burgess@uct.ac.za

Study co-supervisors:

Associate Professor Andrew Bosch — Tel number: 021 650 4578

E-mail: andrew.bosch@uct.ac.za

Professor Mike Lambert — Tel number: 021 650 4558

E-mail: mike.lambert@uct.ac.za

APPENDIX III: Email Advertisement

Department of Health and Rehabilitation Sciences

Faculty of Health Sciences

Division of Physiotherapy

F45 Old Main Building, Groote Schuur Hospital, Observatory 7925

Tel: +27 (0) 21 406 6401 Fax: +27 (0) 21 406 6323

Ultra-Marathon Runners

We would like to invite you to take part in a research study investigating the use of ergogenic aids by ultra-marathon runners

Study outline

The University of Cape Town, investigating the use of ergogenic aids (performance enhancers) by ultra-marathon runners. The study aims to describe the use of ergogenic aids in recreational and competitive ultra-marathon runners.

The study requires you to complete an anonymous questionnaire, which will take approximately 15 to 30 minutes of your time. Information gathered will remain completely confidential and no information gathered will be submitted to any sporting regulatory board.

The questionnaire can be accessed by clicking on the following link:

http://fluidsurveys.com/s/ergogenic_aids_for_ultra-marathon_runners/

or by entering the following into your Google search bar

http://fluidsurveys.com/s/ergogenic_aids_for_ultra-marathon_runners/

If you are interested in participating, we require that you

- Run at least one ultra-marathon (>50 km) per year
- Have been running ultra-marathons for 12 months or more

Benefits of participating in the study include

- You will stand a chance of winning 1 of 5 digital subscriptions to the Runner's World Magazine (T's & C's apply).

CLOSING DATE FOR QUESTIONNAIRE SUBMISSION: 30 September 2013

If you have any queries regarding the study please do not hesitate to contact:

Michael Gwilliams

Cell: 083 565 0685

Email: gwilliams.michael@gmail.com

APPENDIX IV: Examples of Reminder Emails

To all concerned

This email is a reminder for ALL ultra-marathon runners to please take the time (15-20min) to fill in an online questionnaire about ergogenic aids (performance enhancers) used by ultra-marathon runners. The study is being conducted by the University of Cape Town and needs your help to achieve the numbers required to make a difference.

COMPLETE the survey and submit your details to STAND A CHANCE TO WIN 1 0F 5 DIGITAL RUNNERS WORLD SUBSCRIPTIONS!!!!!

Please assist us by FORWARDING this email with the attached advert to all your club members and running colleagues. The greater the number of participants, the greater and more accurate the knowledge will be.

If you have already completed the survey, we thank you very much for your assistance.

If you started but have not completed the survey, we strongly advise you to please complete the survey as WE CAN ONLY USE COMPLETED surveys for statistical reasons. So please persist and complete the survey.

See the attachment for more details about the survey, or click the link below to gain direct access to the survey.

http://fluidsurveys.com/s/ergogenic_aids_for_ultra-marathon_runners/

Please do not hesitate to contact us should you have any queries.

Kind regards

Michael Gwilliams

gwilliams.michael@gmail.com

083 565 0685

To all running clubs/race organisers/and fellow runners

PLEASE forward this email to all your running club members and everyone on your running email lists, colleagues and friends.

Only 6 days left! Closing date is the

15 October 2013.

It is your last chance to help us figure out how we can help to improve running performance. Fill in our online survey and provide us with the information as to what you are currently using to improve your performance. We are trying to gather as much of this information as possible to see what is being used and how it is being implemented as well as your understanding thereof. We hope to analyse this information and then advise accordingly on our findings.

Stand a chance to WIN 1 of 5 Runners World digital subscriptions. (Simply by completing the survey)

Click on the link below to access the survey directly:

http://fluidsurveys.com/s/ergogenic_aids_for_ultra-marathon_runners/

Open the attachments to see more details about the study.

We appreciate you assisting us with this ground breaking research.

Please do not hesitate to call me should you have any queries.

Kind regards and happy trails

Michael Gwilliams

gwilliams.michael@gmail.com

083 565 0685

APPENDIX V: Word Version of Questionnaire

Inclusion criteria and medical screening questions

Do you compete in one or more ultra-marathon per year?

- ○ Yes
- ○ No

Have you been competing in ultra-marathon running for more than one year?

- ○ Yes
- ○ No

Do you suffer from Diabetes?

- ○ Yes
- ○ No

Do you suffer from any other metabolic condition?

- ○ Yes
- ○ No

SECTION A

Personal Information

Personal Details

Gender

Age

Home Language (1st)	Second Language (2nd)
English	English
Afrikaans	Afrikaans
Zulu	Zulu
Xhosa	Xhosa
Tswana	Tswana
Pedi	Pedi
Venda	Venda
Sotho	Sotho
German	German
Other	Other

SECTION B

Training and Race History

Please answer the following questions as applicable to the **past 12 weeks**

Training History (Past 12 weeks)

How many days do you train per week?

On your training days, how many times do you train per day?

What is the average number of hours spent training per week?

How many rest days do you have per week?

How many km's on average do you run in training per week?

At what intensity do you train? (Past 12 weeks)

(How hard would you rate your training)

1 = very light training

2 = easy training

3 = moderate training

4 = high intensity training

5 = very high intensity training

Day-to-day	1	2	3	4	5
Week before a race	1	2	3	4	5
Week after a race	1	2	3	4	5

On average, how many days after a race would you begin training again?

Race History

How many marathons have you completed?

On average, how many marathons do you complete in one year?

How many ultra-marathons have you completed?

On average, how many ultra-marathons do you complete in one year?

How many years have you been running ultra-marathons?

What is your best time and in what year was it for the following events?

	Time	Year
Comrades Marathon		
Loskop Ultra-marathon		
Two Oceans Ultra-marathon		
Other		

If you answered 'Other' to the above question, please specify which race and the year in which you achieved this below:

How many km on average do you run the week before an ultra-marathon?

SECTION C

Ergogenic Aids

Ergogenic aids are any products or means of increasing or improving performance and recovery in sport. Athletes frequently use a variety of products to help improve their performance.

Examples may include: caffeine, carbo-loading, specific drinks (Energade, PVM, Powerade, USN, Coca-Cola, etc.), vitamin supplementation (injections or tablets), nutritional supplementation (whey protein), blood doping, growth hormone, creatine, steroids, corticosteroids, gu's and gels.

We would like to determine what products ultra-marathon runners are ingesting or using; when they are doing so and how they believe it works for them. The study is purely for research purposes and statistics. We would like to re-iterate that information obtained from the questionnaires is strictly confidential and will not be provided to any regulatory body, such as South African Institute for Drug free Sport (SAIDS), Athletics South Africa (ASA) or World Anti-Doping Agency (WADA).

Which ergogenic aid do you use?

(Please only select the options that are **applicable to you**. This will ensure that you are not asked irrelevant questions)

- ○ Sports Drinks...............................(Energade, Powerade, etc.)
- ○ Vitamin Supplementation............(Multivitamins, Vit B12, etc.)
- ○ Caffeine......................................(Coffee, caffeine capsules, Energy drinks like Red Bull, etc.)
- ○ Carbo-loading.............................(Eating high carbohydrate foods e.g. Pasta, etc.)
- ○ Increased Protein Intake.............(Eating high protein foods e.g. fish, eggs, etc.)
- ○ Nutritional Supplementation.......(e.g. Protein shakes, Creatine, USN, etc.)
- ○ Gels/GU's
- ○ Blood Doping.............................(Blood transfusions - replacing your blood)
- ○ Growth Hormone.......................(Pills or injections that stimulate growth, cell reproduction and regeneration)
- ○ Amino Acids..............................(e.g. BCAA, Tryptophan, Glutamine, Aspartates, etc.)
- ○ Antioxidants..............................(e.g. Carotenoids, Flavonoids, Selenium, Glutathione, Coenzyme Q10, etc.)
- ○ Erythropoietin (EPO)
- ○ Anti-inflammatories...................(e.g. Cataflam, Ibuprofen, Brufen, Celebrex, Neurofenetc.)
- ○ Pain Killers/Analgesics.............(e.g. Paracetamol, Betapyn, Tramadol, etc.)
- ○ Electrolytes................................(e.g. Rehydrate, Slow-mag, etc.)
- ○ Other, Please specify:
- ○ I do not use any ergogenic aids

Section C

Sub-section 1

FLUID INTAKE

How would you best describe your fluid intake during a race?

- ○ When I'm thirsty
- ○ At specific distances
- ○ At specific time intervals
- ○ Drink as much as tolerable
- ○ Drink according to a pre-determined drinking schedule
- ○ Drink to prevent weight loss
- ○ Do not drink
- ○ Other: please specify:

What is your preferred choice of fluid…

	Preferred choice	Please specify the brand name
During training	Water	
	Sports Drinks	
	Other, please specify	
1 hour before a race	Water	
	Sports Drinks	
	Other, please specify	
During a race	Water	
	Sports Drinks	
	Other, please specify	
After a race	Water	
	Sports Drinks	
	Other, please specify	

Why do you use the particular fluid/s that you do?

Do you combine fluids during training or races?

e.g. I drink water and sports drinks when running

- Yes
- No

What percentage of your fluid intake will consist of these beverages during a race?

Water	0%	1-20%	21-40%	41-60%	61-80%	81-100%	100%
Sports drinks	0%	1-20%	21-40%	41-60%	61-80%	81-100%	100%
Coke	0%	1-20%	21-40%	41-60%	61-80%	81-100%	100%
Other	0%	1-20%	21-40%	41-60%	61-80%	81-100%	100%

If you selected 'Other' to the previous question. Please specify:

What is your estimated fluid intake (ml) during a race 42.2km marathon?

What is your estimated fluid intake (ml) after a race at...

30 min

6 hours

24 hours

Do you feel that the fluids you are using improve your performance?

- Yes
- No
- Not sure

If no or unsure, why do you consume these fluids?

In your opinion, how do fluids help to improve performance? (You may select more than one option.)

- ○ Make me run faster
- ○ Allows me to run for longer
- ○ Decrease stiffness
- ○ Decrease the amount of pain I might feel
- ○ Gives me an energy boost
- ○ Increase my oxygen uptake
- ○ Keeps me healthy by increasing my immune system
- ○ Decrease the chance of injury
- ○ Decrease inflammation before it happens
- ○ If I get injured they will decrease the severity thereof
- ○ Increase my muscle strength
- ○ Not sure what it does
- ○ Increase my muscle mass
- ○ Decrease cellular damage
- ○ Improves recovery
- ○ Other, Please specify:

Do you think your performance would deteriorate if you did not take the fluids you are using?

- ○ Yes
- ○ No
- ○ Not sure

From the list below, please rank your 'Top 3' sources of information according to their importance to influencing your fluid intake

1 = being the most influential

3 = least influential

	1	2	3
Coach/ Trainer			
Fellow runners			
Books/magazines			
Websites			
Adverts			
Sports Associations			
Self-experimentation / Personal experience			
Other			

If you selected 'Other' to the previous question. Please specify:

SECTION C
Sub-section 2

VITAMINS

Are you using Vitamins as an ergogenic aid?

If select 'Yes' additional important questions regarding your vitamin intake will be shown.
If you select 'No' you will be redirected to the next ergogenic aid you selected.

- ○ Yes
- ○ No

Which vitamin supplements do you use?

(You may select more than one option.)

- Vit B12
- Vit C
- Vit E
- Multi-vitamins
- Other, Please specify:

When do you take these vitamins?

(You may select more than one option.)

- Before every training run
- Only if the training run is going to be particularly long or hard
- Before every race or marathon
- Only if the race is going to be particularly long or hard
- Only if not feeling well
- Only when I'm injured
- Only when I'm stiff and sore
- Everyday
- 1 X per week
- 3 X per week
- Only when I am fatigued/tired
- Other, Please specify:

Do you feel that the vitamins you use improve your performance?

- Yes
- No
- Not sure

If no or unsure, why do you take vitamins?

In your opinion, how do vitamins help to improve performance?

(You may select more than one option.)

- ○ Make me run faster
- ○ Allows me to run for longer
- ○ Decrease stiffness
- ○ Decrease the amount of pain I might feel
- ○ Gives me an energy boost
- ○ Increase my oxygen uptake
- ○ Keeps me healthy by increasing my immune system
- ○ Decrease the chance of injury
- ○ Decrease inflammation before it happens
- ○ If I get injured they will decrease the severity thereof
- ○ Increase my muscle strength
- ○ Not sure what it does
- ○ Increase my muscle mass
- ○ Decrease cellular damage
- ○ Improves recovery
- ○ Other, Please specify:

Do you think your performance would deteriorate if you did not take these vitamins?

- ○ Yes
- ○ No
- ○ Not sure

From the list below, please rank your 'Top 3' sources of information according to their importance to influencing your vitamin intake

1 = being the most influential

3 = least influential

	1	2	3
Coach/ Trainer			
Fellow runners			
Books/magazines			
Websites			
Adverts			
Sports Associations / Clubs			
Self experimentation / Personal experience			
Other			

If you selected 'Other' to the previous question. Please specify:

SECTION C

Sub-section 3

CAFFEINE

Are you using caffeine as an ergogenic aid?

If select 'Yes' additional important questions regarding your caffeine intake will be shown. If you select 'No' you will be redirected to the next ergogenic aid you selected.

- o Yes
- o No

Through which source do you attain your caffeine for ergogenic purposes?

(You may select more than one option.)

- ○ Coffee
- ○ Energy drinks e.g. Red Bull.
- ○ Capsules (e.g. Regmakers/Alert)
- ○ Other

Coffee

How many mg of caffeine are in one cup of instant coffee?

How many cups of coffee would you need to drink to attain a desirable ergogenic aid effect?

What type of coffee do you prefer to use for the purposes of an ergogenic aid?

How many mg of caffeine do you require to attain your ergogenic effect?

Caffeine-containing energy drinks

How many caffeine-containing energy drinks would you need to drink to attain a desirable ergogenic aid effect?

What type of energy drink do you prefer to use for ergogenic purposes? (Brand name)

How many mg of caffeine do you require to attain your ergogenic effect?

Caffeine capsules

How many capsules do you need to take to attain a desirable ergogenic aid effect?

What type of capsules do you prefer to use? (Brand name)

How many mg of caffeine do you require to attain your ergogenic effect?

'Other' sources of caffeine

Through what 'Other' means do you attain the caffeine you need to acquire the ergogenic effect of caffeine?

How many mg of caffeine do you require to attain your ergogenic effect?

When do you take the caffeine?

- Before every training run
- Only if the training runs is going to be particularly long or hard
- Before every race or marathon
- Only if the race is going to be particularly long or hard
- Only if not feeling well
- Only when I'm injured
- Only when I'm stiff and sore
- Everyday
- 1 X per week
- 3 X per week
- Only when I am fatigued/tired
- Other, Please specify:

Do you feel that the caffeine you use improves your performance?

- Yes
- No
- Not sure

If no or unsure, why do you take caffeine?

In your opinion, how does caffeine help to improve performance?

(You may select more than one option.)

- ○ Make me run faster
- ○ Allows me to run for longer
- ○ Decrease stiffness
- ○ Decrease the amount of pain I might feel
- ○ Gives me an energy boost
- ○ Increase my oxygen uptake
- ○ Keeps me healthy by increasing my immune system
- ○ Decrease the chance of injury
- ○ Decrease inflammation before it happens
- ○ If I get injured they will decrease the severity thereof
- ○ Increase my muscle strength
- ○ Not sure what it does
- ○ Increase my muscle mass
- ○ Decrease cellular damage
- ○ Improves recovery
- ○ Other, Please specify:

Do you think your performance would deteriorate if you did not take caffeine?

- ○ Yes
- ○ No
- ○ Not sure

From the list below, please rank your 'Top 3' sources of information according to their importance to influencing your caffeine intake

1 = being the most influential
3 = least influential

	1	2	3
Coach/ Trainer			
Fellow runners			
Books/magazines			
Websites			
Adverts			
Sports Associations			
Self experimentation / Personal experience			
Other			

If you selected 'Other' to the previous question. Please specify:

Section C

Sub-section 4

CARBO-LOADING

Are you using carbo-loading as an ergogenic aid?

If select 'Yes' additional important questions regarding your carbo-loading intake will be shown. If you select 'No' you will be redirected to the next ergogenic aid you selected.

- ○ Yes
- ○ No

Do you try to eat/drink a specific amount of carbohydrates calculated according to your body mass?

- Yes
- No

If yes, how do you calculate this?

When do you carbo-load specifically as an ergogenic aid?

(You may select more than one option.)

- Before every training run
- Only if the training run is going to be particularly long or hard
- Before every race or marathon
- Only after a race
- Before and after a race
- Only if the race is going to be particularly long or hard
- Only if not feeling well
- Only when I'm injured
- Only when I'm stiff and sore
- Everyday
- 1 X per week
- X per week
- Only when I am fatigued/tired
- Other, Please specify:

If before or before and after a race how many days prior to the race would you start to increase your carbohydrates intake?

How soon after completing a race would you increase your carbohydrate intake?

- Within 30 min of completing the race
- 2-4 hours after completing the race
- More than 6 hours after completing the race
- No specific time frame

What form of carbohydrates do you consume when carbo-loading?

(You may select more than one option.)

- Refined (sports drinks, sugars, sweets etc.)
- Organic (whole wheat bread, pastas, etc.)
- Supplementation (formulas or powders)
- Other. Please specify

If you ticked REFINED carbohydrate in the above question, then please indicate which product type you use most. Rate each product on a scale from 1-5 where:

1 = is most frequently used

2 = use a lot

3 = sometime use

4 = hardly use

5 = never use

	1	2	3	4	5
Sports Drinks (Energade, Powerade)					
Soft Drinks (Coke)					
Sweets (Jelly babies)					
Gu/Gels					
Sports Bars (Energy bars)					
Other					

If you selected 'Other' to the previous question. Please specify:

If you ticked ORGANIC carbohydrates in the above question, then please indicate which product type you use most. Rate each product on a scale from 1-5 where:

1 = is most frequently used

2 = use a lot

3 = sometime use

4 = hardly use

5 = never use

	1	2	3	4	5
Bread					
Cereal					
Pasta					
Potato					
Rice					
Fruit					
Other					

If you selected 'Other' to the previous question. Please specify:

How would you best describe your carbo-loading preparation (5 days prior) leading up to a race? (You may select more than one option.)

- ○ Carbo-load the night before the race
- ○ High carbohydrate diet for 3-5 days before a race
- ○ Increase fluid (water) intake for 3-5 days prior to the race
- ○ I don’t change anything
- ○ Other: Please specify:

Do you feel that the carbo-loading improves your performance?

- ○ Yes
- ○ No
- ○ Not sure

If no or unsure, why do you carbo-load?

In your opinion, how does carbo-loading help to improve performance?

(You may select more than one option.)

- ○ Make me run faster
- ○ Allows me to run for longer
- ○ Decrease stiffness
- ○ Decrease the amount of pain I might feel
- ○ Gives me an energy boost
- ○ Increases my oxygen uptake
- ○ Keeps me healthy by increasing my immune system
- ○ Decrease the change of injury
- ○ Decrease inflammation before it happens
- ○ Accelerate the healing of any injury
- ○ Increases my muscle strength
- ○ Not sure what it does
- ○ Increases muscle mass
- ○ Decreases cellular damage
- ○ Improves recovery
- ○ Other, Please specify:

Do you think your performance would deteriorate if you did not carbo-load?

- ○ Yes
- ○ No
- ○ Not Sure

From the list below, please rank your 'Top 3' sources of information according to their importance in influencing your carbo-loading

1 = being the most influential

3 = least influential

	1	2	3
Coach/ Trainer			
Fellow runners			
Books/magazines			
Websites			
Adverts			
Sports Associations			
Self experimentation / Personal experience			
Other			

If you selected 'Other' to the previous question. Please specify:

Section C

Sub-section 5

INCREASED PROTEIN INTAKE

Are you using increased protein intake as an ergogenic aid?

If select 'Yes' additional important questions regarding your increased protein intake will be shown. If you select 'No' you will be redirected to the next ergogenic aid you selected.

- Yes
- No

Do you try to eat/drink a specific amount of protein calculated according to your body mass?

- Yes
- No

If yes, how do you calculate this?

When do you increase your protein intake specifically for ergogenic purposes? (You may select more than one option.)

- Before every training run
- Only if the training run is going to be particularly long or hard
- Before every race or marathon
- Only after a race
- Before and after a race
- Only if the race is going to be particularly long or hard
- Only if not feeling well
- Only when I'm injured
- Only when I'm stiff and sore
- Everyday
- 1 X per week
- X per week
- Only when I am fatigued/tired
- Other, Please specify:

If before or before and after a race how many days prior to the race would you start to increase your protein intake?

How soon after completing a race do you increase your protein intake?

- ○ Within 30 min of completing the race
- ○ 2-4 hours after completing the race
- ○ More than 6 hours after completing the race
- ○ No specific time frame
- ○ N/A

What form of proteins do you consume when specifically increasing your protein intake? (You may select more than one option.)

- ○ Liquid (milk, liquid meal replacement powder)
- ○ Lean protein (chicken, meat, eggs, fish)
- ○ Supplements/capsules (amino acids)
- ○ Other. Please specify

If you ticked LIQUID protein in the above question, then please indicate which product type you use most. Rate each product on a scale from 1-5 where:

1= is most frequently used

2= use a lot

3= sometime use

4= hardly use

5 = never use

	1	2	3	4	5
Milk					
Liquid meal replacement					
Body building protein powder					
Milk powder					
Other					

If you selected 'Other' to the previous question. Please specify:

If you ticked LEAN protein in the above question, then please indicate which product type you use most. Rate each product on a scale from 1-5 where:

1 = is most frequently used

2 = use a lot

3 = sometime use

4 = hardly use

5 = never use

	1	2	3	4	5
Skinless chicken					
Fish					
Eggs					
Lean meat					
Low fat yogurt					
Other					

If you selected 'Other' to the previous question. Please specify:

If you ticked LEAN protein in the above question, then please indicate which product type you use most. Rate each product on a scale from 1-5 where:

1 = is most frequently used

2 = use a lot

3 = sometime use

4 = hardly use

5 = never use

	1	2	3	4	5
Skinless chicken					
Fish					
Eggs					
Lean meat					
Low fat yogurt					
Other					

If you selected 'Other' to the previous question. Please specify:

How would you best describe your increased protein intake (5 days before) that led to a race? (You may select more than one option.)

- ○ High protein diet the night before the race
- ○ High protein diet for 3-5 days before a race
- ○ Increase fluid (water) intake for 3-5 days prior to the race
- ○ I don't change anything
- ○ Other: Please specify:

Do you feel that the increased protein intake improves your performance?

- ○ Yes
- ○ No
- ○ Not sure

If no or unsure, why do you increase your protein intake?

In your opinion, how does increasing your protein intake help to improve performance? (You may select more than one option.)

- ○ Make me run faster
- ○ Allows me to run for longer
- ○ Decrease stiffness
- ○ Decrease the amount of pain I might feel
- ○ Gives me an energy boost
- ○ Increases my oxygen uptake
- ○ Keeps me healthy by increasing my immune system
- ○ Decrease the change of injury
- ○ Decrease inflammation before it happens
- ○ Accelerate the healing of any injury
- ○ Increases my muscle strength
- ○ Not sure what it does
- ○ Increases muscle mass
- ○ Decreases cellular damage
- ○ Improves recovery
- ○ Other, Please specify:

Do you think your performance would deteriorate if you did not increase your protein intake?

- ○ Yes
- ○ No
- ○ Not sure

From the list below, please rank your 'Top 3' sources of information according to their importance in influencing your increased protein intake

1 = being the most influential
3 = least influential

	1	2	3
Coach/ Trainer			
Fellow runners			
Books/magazines			
Websites			
Adverts			
Sports Associations			
Self experimentation / Personal experience			
Other			

If you selected 'Other' to the previous question. Please specify:

Section C

Sub-section 6

NUTRITIONAL SUPPLEMENTS

(e.g. Creatine, USN, Mass builder etc.)

Are you using nutritional supplements as an ergogenic aid?

If select 'Yes' additional important questions regarding your nutritional supplementation will be shown.

If you select 'No' you will be redirected to the next ergogenic aid you selected.

- Yes
- No

What nutritional supplements are you using as an ergogenic aid? (Brand name)

When do you take these nutritional supplements?

(You may select more than one option.)

- ○ Before every training run
- ○ Only if the training run is going to be particularly long or hard
- ○ Before every race or marathon
- ○ Only if the race is going to be particularly long or hard
- ○ Only if not feeling well
- ○ Only when I'm injured
- ○ Only when I'm stiff and sore
- ○ Everyday
- ○ 1 X per week
- ○ X per week
- ○ Only when I am fatigued/tired
- ○ Other, Please specify:

Do you feel that the nutritional supplements you use improve your performance?

- ○ Yes
- ○ No
- ○ Not sure

If no or unsure, why do you take nutritional supplements?

In your opinion, how do these nutritional supplements help to improve performance? (You may select more than one option.)

- ○ Make me run faster
- ○ Allows me to run for longer
- ○ Decrease stiffness
- ○ Decrease the amount of pain I might feel
- ○ Gives me an energy boost
- ○ Increases my oxygen uptake
- ○ Keeps me healthy by increasing my immune system
- ○ Decrease the change of injury
- ○ Decrease inflammation before it happens
- ○ Accelerate the healing of any injury
- ○ Increases my muscle strength
- ○ Not sure what it does
- ○ Increases muscle mass
- ○ Decreases cellular damage
- ○ Improves recovery
- ○ Other, Please specify

Do you think your performance would deteriorate if you did not take these nutritional supplements?

- ○ Yes
- ○ No
- ○ Not Sure

From the list below, please rank your 'Top 3' sources of information according to their importance in influencing your nutritional supplementation

1 = being the most influential
3 = least influential

	1	2	3
Coach/ Trainer			
Fellow runners			
Books/magazines			
Websites			
Adverts			
Sports Associations			
Self experimentation / Personal experience			
Other			

If you selected 'Other' to the previous question. Please specify:

Section C

Sub-section 7

GEL/GU

Are you using Gels/GU's as an ergogenic aid?

If select 'Yes' additional important questions regarding your Gel/GU intake will be shown. If you select 'No' you will be redirected to the next ergogenic aid you selected.

- ○ Yes
- ○ No

Which Gels/GU's do you use? (Brand names)

When do you take these Gels/GU's?

(You may select more than one option.)

- Before every training run
- Only if the training run is going to be particularly long or hard
- Before every race or marathon
- Only if the race is going to be particularly long or hard
- Only if not feeling well
- Only when I'm injured
- Only when I'm stiff and sore
- Everyday
- 1 X per week
- X per week
- Only when I am fatigued/tired
- Other, Please specify:

If you were to use Gels/GU's, how often would you consume during a 42.2 km marathon or training?

42.2 km marathon	Training
Never	Never
Thrice (3 x) during the race	Thrice (3 x) during the race
Once before the race	Once before the race
Once during the race	Once during the race
More than 3 x during the race	More than 3 x during the race
At specific times or specific distances	At specific times or specific distances
Twice (2x) during the race	Twice (2x) during the race

If you selected 'at specific times or distances' to the previous question. Please specify:

Do you feel that the Gels/GU's you use improve your performance?

- ○ Yes
- ○ No
- ○ Not sure

If no or unsure, why do you take these Gels/GU's?

In your opinion, how do Gels/GU's help to improve performance?

(You may select more than one option.)

- ○ Make me run faster
- ○ Allows me to run for longer
- ○ Decrease stiffness
- ○ Decrease the amount of pain I might feel
- ○ Gives me an energy boost
- ○ Increases my oxygen uptake
- ○ Keeps me healthy by increasing my immune system
- ○ Decrease the change of injury
- ○ Decrease inflammation before it happens
- ○ Accelerate the healing of any injury
- ○ Increases my muscle strength
- ○ Not sure what it does
- ○ Increases muscle mass
- ○ Decreases cellular damage
- ○ Improves recovery
- ○ Other, Please specify:

Do you think your performance would deteriorate if you did not take these Gels/GU's?

- ○ Yes
- ○ No
- ○ Not sure

From the list below, please rank your 'Top 3' sources of information according to their importance in influencing your Gels/GU's

1 = being the most influential

3 = least influential

	1	2	3
Coach/ Trainer			
Fellow runners			
Books/magazines			
Websites			
Adverts			
Sports Associations			
Self experimentation / Personal experience			
Other			

If you selected 'Other' to the previous question. Please specify:

Section C

Sub-section 8

BLOOD DOPING

Are you using blood doping as an ergogenic aid?

If select 'Yes' additional important questions regarding your blood doping will be shown. If you select 'No' you will be redirected to the next ergogenic aid you selected.

- ○ Yes
- ○ No

For how many years have you been using blood doping as an ergogenic aid?

- < 1 year
- 1 - 2 years
- -5 years
- 6 - 10 years
- 11 - 15 years
- 15 years +

When do you blood dope?

(You may select more than one option.)

- Before every training run
- Only if the training run is going to be particularly long or hard
- Before every race or marathon
- Only if the race is going to be particularly long or hard
- Only if not feeling well
- Only when I'm injured
- Only when I'm stiff and sore
- Everyday
- 1 X per week
- X per week
- Only when I am fatigued/tired
- Other, Please specify:

Do you require any help attaining or administrating blood doping from any of the following people?

- I do need any help attaining or administrating
- Doctor
- Physiotherapist
- Fitness trainer
- Coach
- Fellow runners
- Other, please specify:

Do you feel that the blood doping improves your performance?

- ○ Yes
- ○ No
- ○ Not sure

If no or unsure, why do you blood dope?

In your opinion, how does blood doping help to improve performance?

(You may select more than one option.)

- ○ Make me run faster
- ○ Allows me to run for longer
- ○ Decrease stiffness
- ○ Decrease the amount of pain I might feel
- ○ Gives me an energy boost
- ○ Increases my oxygen uptake
- ○ Keeps me healthy by increasing my immune system
- ○ Decrease the change of injury
- ○ Decrease inflammation before it happens
- ○ Accelerate the healing of any injury
- ○ Increases my muscle strength
- ○ Not sure what it does
- ○ Increases muscle mass
- ○ Decreases cellular damage
- ○ Improves recovery
- ○ Other, Please specify:

Do you think your performance would deteriorate if you did not blood dope?

- ○ Yes
- ○ No
- ○ Not sure

From the list below, please rank your 'Top 3' sources of information according to their importance in influencing your blood doping strategy

1 = being the most influential

3 = least influential

	1	2	3
Coach/ Trainer			
Fellow runners			
Books/magazines			
Websites			
Adverts			
Sports Associations			
Self experimentation / Personal experience			
Other			

If you selected 'Other' to the previous question. Please specify:

Section C

Sub-section 9

GROWTH HORMONE

Are you using growth hormone as an ergogenic aid?

If select 'Yes' additional important questions regarding your growth hormone use will be shown. If you select 'No' you will be redirected to the next ergogenic aid you selected.

- ○ Yes
- ○ No

Do you use growth hormones for therapeutic purposes or as an ergogenic aid?

- Therapeutic use
- Ergogenic use

If therapeutic, what is the medical condition you are using the growth hormones for?

What growth hormone products do you use? (Brand names)

For how many years have you been using growth hormones as an ergogenic aid?

When do you use your growth hormones?

(You may select more than one option.)

- Before every training run
- Only if the training run is going to be particularly long or hard
- Before every race or marathon
- Only if the race is going to be particularly long or hard
- Only if not feeling well
- Only when I’m injured
- Only when I’m stiff and sore
- Everyday
- 1 X per week
- X per week
- Only when I am fatigued/tired
- Other, Please specify:

How do you administer your growth hormones?

- Orally
- Intravenously (injection)
- Other, Please specify:

Do you require any help attaining or administrating growth hormone from any of the following people?

- ○ I do need any help attaining or administrating
- ○ Doctor
- ○ Physiotherapist
- ○ Fitness trainer
- ○ Coach
- ○ Fellow runners
- ○ Other, please specify:

Do you feel that the growth hormones you use improve your performance?

- ○ Yes
- ○ No
- ○ Not sure

If no or unsure, why do you take growth hormones?

In your opinion, how do the growth hormones help to improve performance?

(You may select more than one option.)

- ○ Make me run faster
- ○ Allows me to run for longer
- ○ Decrease stiffness
- ○ Decrease the amount of pain I might feel
- ○ Gives me an energy boost
- ○ Increases my oxygen uptake
- ○ Keeps me healthy by increasing my immune system
- ○ Decrease the change of injury
- ○ Decrease inflammation before it happens
- ○ Accelerate the healing of any injury
- ○ Increases my muscle strength
- ○ Not sure what it does
- ○ Increases muscle mass
- ○ Decreases cellular damage
- ○ Improves recovery
- ○ Other, Please specify

Do you think your performance would deteriorate if you did not take these growth hormones?

- ○ Yes
- ○ No
- ○ Not sure

From the list below, please rank your 'Top 3' sources of information according to their importance in influencing your growth hormones

1 = being the most influential

3 = least influential

	1	2	3
Coach/ Trainer			
Fellow runners			
Books/magazines			
Websites			
Adverts			
Sports Associations			
Self experimentation / Personal experience			
Other			

If you selected 'Other' to the previous question. Please specify:

Section C

Sub-section 10

AMINO ACIDS

e.g. BCAA

Are you using amino acids as an ergogenic aid?

If select 'Yes' additional important questions regarding your amino acid intake will be shown. If you select 'No' you will be redirected to the next ergogenic aid you selected.

- ○ Yes
- ○ No

Which amino acids do you use? (Brand names)

For how many years have you been using amino acids as an ergogenic aid?

When do you take these amino acids?

(You may select more than one option.)

- Before every training run
- Only if the training run is going to be particularly long or hard
- Before every race or marathon
- Only if the race is going to be particularly long or hard
- Only if not feeling well
- Only when I'm injured
- Only when I'm stiff and sore
- Everyday
- 1 X per week
- X per week
- Only when I am fatigued/tired
- Other, Please specify:

Do you feel that the amino acids you use improve your performance?

- Yes
- No
- Not sure

If no or unsure, why do you take amino acids?

In your opinion, how do amino acids help to improve performance?

(You may select more than one option.)

- ○ Make me run faster
- ○ Allows me to run for longer
- ○ Decrease stiffness
- ○ Decrease the amount of pain I might feel
- ○ Gives me an energy boost
- ○ Increases my oxygen uptake
- ○ Keeps me healthy by increasing my immune system
- ○ Decrease the change of injury
- ○ Decrease inflammation before it happens
- ○ Accelerate the healing of any injury
- ○ Increases my muscle strength
- ○ Not sure what it does
- ○ Increases muscle mass
- ○ Decreases cellular damage
- ○ Improves recovery
- ○ Other, Please specify:

Do you think your performance would deteriorate if you did not take these amino acids?

- ○ Yes
- ○ No
- ○ Not sure

From the list below, please rank your 'Top 3' sources of information according to their importance in influencing your amino acid intake

1 = being the most influential

3 = least influential

	1	2	3
Coach/ Trainer			
Fellow runners			
Books/magazines			
Websites			
Adverts			
Sports Associations			
Self experimentation / Personal experience			
Other			

If you selected 'Other' to the previous question. Please specify:

Section C

Sub-section 11

ANTIOXIDANTS

(e.g. carotenoids, flavonoids, coenzyme Q10, etc.)

Are you using antioxidants as an ergogenic aid?

If select 'Yes' additional important questions regarding your antioxidant intake will be shown. If you select 'No' you will be redirected to the next ergogenic aid you selected.

- ○ Yes
- ○ No

Which antioxidants do you use? (Brand names)

For how many years have you been using antioxidants as an ergogenic aid?

When do you take these antioxidants?

(You may select more than one option.)

- Before every training run
- Only if the training run is going to be particularly long or hard
- Before every race or marathon
- Only if the race is going to be particularly long or hard
- Only if not feeling well
- Only when I'm injured
- Only when I'm stiff and sore
- Everyday
- 1 X per week
- X per week
- Only when I am fatigued/tired
- Other, Please specify:

Do you feel that the antioxidants you use improve your performance?

- Yes
- No
- Not sure

If no or unsure, why do you take antioxidants?

In your opinion, how do amino antioxidants help to improve performance?

(You may select more than one option.)

- ○ Make me run faster
- ○ Allows me to run for longer
- ○ Decrease stiffness
- ○ Decrease the amount of pain I might feel
- ○ Gives me an energy boost
- ○ Increases my oxygen uptake
- ○ Keeps me healthy by increasing my immune system
- ○ Decrease the change of injury
- ○ Decrease inflammation before it happens
- ○ Accelerate the healing of any injury
- ○ Increases my muscle strength
- ○ Not sure what it does
- ○ Increases muscle mass
- ○ Decreases cellular damage
- ○ Improves recovery
- ○ Other, Please specify:

Do you think your performance would deteriorate if you did not take these antioxidants?

- ○ Yes
- ○ No
- ○ Not sure

From the list below, please rank your 'Top 3' sources of information according to their importance in influencing your antioxidant intake

1 = being the most influential
3 = least influential

	1	2	3
Coach/ Trainer			
Fellow runners			
Books/magazines			
Websites			
Adverts			
Sports Associations			
Self experimentation / Personal experience			
Other			

If you selected 'Other' to the previous question. Please specify:

Section C

Sub-section 12

ERYTHROPOIETIN (EPO)

Are you using EPO as an ergogenic aid?

If select 'Yes' additional important questions regarding your EPO use will be shown.
If you select 'No' you will be redirected to the next ergogenic aid you selected.

- Yes
- No

Do you use EPO for therapeutic purposes or as an ergogenic aid?

- ○ Therapeutic use
- ○ Ergogenic use

If therapeutic, what is the medical condition you are using the EPO for?

For how many years have you been using EPO as an ergogenic aid?

Do you require any help attaining or administrating EPO from any of the following people?

- ○ I do need any help attaining or administrating
- ○ Doctor
- ○ Physiotherapist
- ○ Fitness trainer
- ○ Coach
- ○ Fellow runners
- ○ Other, please specify

When do you take EPO?

(You may select more than one option.)

- ○ Before every training run
- ○ Only if the training run is going to be particularly long or hard
- ○ Before every race or marathon
- ○ Only if the race is going to be particularly long or hard
- ○ Only if not feeling well
- ○ Only when I'm injured
- ○ Only when I'm stiff and sore
- ○ Everyday
- ○ 1 X per week
- ○ X per week
- ○ Only when I am fatigued/tired
- ○ Other, Please specify

Do you feel that the EPO improves your performance?

- Yes
- No
- Not sure

If no or unsure, why do you take EPO?

In your opinion, how does EPO help to improve performance?

(You may select more than one option.)

- Make me run faster
- Allows me to run for longer
- Decrease stiffness
- Decrease the amount of pain I might feel
- Gives me an energy boost
- Increases my oxygen uptake
- Keeps me healthy by increasing my immune system
- Decrease the change of injury
- Decrease inflammation before it happens
- Accelerate the healing of any injury
- Increases my muscle strength
- Not sure what it does
- Increases muscle mass
- Decreases cellular damage
- Improves recovery
- Other, Please specify:

Do you think your performance would deteriorate if you did not take EPO?

- ○ Yes
- ○ No
- ○ Not sure

From the list below, please rank your 'Top 3' sources of information according to their importance in influencing your EPO intake

1 = being the most influential

3 = least influential

	1	2	3
Coach/ Trainer			
Fellow runners			
Books/magazines			
Websites			
Adverts			
Sports Associations			
Self experimentation / Personal experience			
Other			

If you selected 'Other' to the previous question. Please specify:

Section C

Sub-section 13

ANTI-INFLAMMATORIES

(e.g. Cataflam, Celebrex, Brufen, etc.)

Are you using anti-inflammatories as an ergogenic aid?

If select 'Yes' additional important questions regarding your anti-inflammatory intake will be shown.
If you select 'No' you will be redirected to the next ergogenic aid you selected.

- Yes
- No

Which anti-inflammatories do you use? (Brand name)

How do you administer these anti-inflammatories?

- ○ Orally
- ○ Intravenously (injection)
- ○ Other, Please specify:

If taken orally, on average, how many anti-inflammatories would you take per dose?

If taken orally, on average, how many doses would you take per day?

If taken orally, on average how many days will you continue to take anti-inflammatories for?

When do you take these anti-inflammatories?

- ○ Before every training run
- ○ Only if the training run is going to be particularly long or hard
- ○ Before every race or marathon
- ○ Only if the race is going to be particularly long or hard
- ○ Only if not feeling well
- ○ Only when I'm injured
- ○ Only when I'm stiff and sore
- ○ Everyday
- ○ 1 X per week
- ○ X per week
- ○ Only when I am fatigued/tired
- ○ Other, Please specify:

Do you feel that the anti-inflammatories you use improve your performance?

- ○ Yes
- ○ No
- ○ Not sure

If no or unsure, why do you take anti-inflammatories?

In your opinion, how do anti-inflammatories help to improve performance?

(You may select more than one option.)

- Make me run faster
- Allows me to run for longer
- Decrease stiffness
- Decrease the amount of pain I might feel
- Gives me an energy boost
- Increases my oxygen uptake
- Keeps me healthy by increasing my immune system
- Decrease the change of injury
- Decrease inflammation before it happens
- Accelerate the healing of any injury
- Increases my muscle strength
- Not sure what it does
- Increases muscle mass
- Decreases cellular damage
- Improves recovery
- Other, Please specify:

Do you think your performance would deteriorate if you did not take these anti-inflammatories?

- Yes
- No
- Not sure

From the list below, please rank your 'Top 3' sources of information according to their importance in influencing your anti-inflammatory intake

1 = being the most influential
3 = least influential

	1	2	3
Coach/ Trainer			
Fellow runners			
Books/magazines			
Websites			
Adverts			
Sports Associations			
Self experimentation / Personal experience			
Other			

If you selected 'Other' to the previous question. Please specify:

Section C

Sub-section 14

PAIN KILLERS

(e.g. Paracetamol, Betapyn, Tramadol, etc.)

If select 'Yes' additional important questions regarding your pain killer intake will be shown. If you select 'No' you will be redirected to the next ergogenic aid you selected.

- Yes
- No

Which pain killers do you use? (Brand name)

How do you administer these pain killers?

- ○ Orally
- ○ Intravenously (injection)
- ○ Other, Please specify:

If taken orally, on average, how many pain killers would you take per dose?

If taken orally, on average, how many doses would you take per day?

If taken orally, on average how many days will you continue to take pain killers for?

When do you take these pain killers?

- ○ Before every training run
- ○ Only if the training run is going to be particularly long or hard
- ○ Before every race or marathon
- ○ Only if the race is going to be particularly long or hard
- ○ Only if not feeling well
- ○ Only when I'm injured
- ○ Only when I'm stiff and sore
- ○ Everyday
- ○ 1 X per week
- ○ X per week
- ○ Only when I am fatigued/tired
- ○ Other, Please specify:

Do you feel that the pain killers you use improve your performance?

- ○ Yes
- ○ No
- ○ Not sure

If no or unsure, why do you take pain killers?

In your opinion, how do pain killers help to improve performance?

(You may select more than one option.)

- ○ Make me run faster
- ○ Allows me to run for longer
- ○ Decrease stiffness
- ○ Decrease the amount of pain I might feel
- ○ Gives me an energy boost
- ○ Increases my oxygen uptake
- ○ Keeps me healthy by increasing my immune system
- ○ Decrease the change of injury
- ○ Decrease inflammation before it happens
- ○ Accelerate the healing of any injury
- ○ Increases my muscle strength
- ○ Not sure what it does
- ○ Increases muscle mass
- ○ Decreases cellular damage
- ○ Improves recovery
- ○ Other, Please specify:

Do you think your performance would deteriorate if you did not take these pain killers?

- ○ Yes
- ○ No
- ○ Not sure

From the list below, please rank your 'Top 3' sources of information according to their importance in influencing your pain killer intake

1 = being the most influential

3 = least influential

	1	2	3
Coach/ Trainer			
Fellow runners			
Books/magazines			
Websites			
Adverts			
Sports Associations			
Self experimentation / Personal experience			
Other			

If you selected 'Other' to the previous question. Please specify:

Section C

Sub-section 15

ELECTROLYTES

(e.g. Rehydrate, Slow-mag)

Are you using electrolytes as an ergogenic aid?

If select 'Yes' additional important questions regarding your electrolyte intake will be shown. If you select 'No' you will be redirected to the next ergogenic aid you selected.

- Yes
- No

Which electrolytes do you use? (Brand name)

How do you consume these electrolytes?

- Pre-mixed drinks
- Capsules/Pills
- Dissolved in water
- Other, Please specify:

If you were to use electrolytes, how often would you consume during a 42.2 km marathon or training?

42.2 km marathon

- Never
- Thrice (3 x) during the race
- Twice (2x) during the race
- Once before the race
- At specific distances or specific times
- Once during the race
- More than 3 x during the race

Training

- Never
- Thrice (3 x) during the race
- Twice (2x) during the race
- Once before the race
- At specific distances or specific times
- Once during the race
- More than 3 x during the race

If you selected 'at specific times or distances' to the previous question. Please specify:

Does the weather or temperature affect your electrolyte consumption?

- Yes
- No

If yes, how does the weather or temperature affect your electrolyte consumption?

When do you take these electrolytes?

- ○ Before every training run
- ○ Only if the training run is going to be particularly long or hard
- ○ Before every race or marathon
- ○ Only if the race is going to be particularly long or hard
- ○ Only if not feeling well
- ○ Only when I'm injured
- ○ Only when I'm stiff and sore
- ○ Everyday
- ○ 1 X per week
- ○ X per week
- ○ Only when I am fatigued/tired
- ○ Other, Please specify:

Do you feel that the electrolytes you use improve your performance?

- ○ Yes
- ○ No
- ○ Not sure

If no or unsure, why do you take electrolytes?

In your opinion, how do electrolytes help to improve performance?

(You may select more than one option.)

- ○ Make me run faster
- ○ Allows me to run for longer
- ○ Decrease stiffness
- ○ Decrease the amount of pain I might feel
- ○ Gives me an energy boost
- ○ Increases my oxygen uptake
- ○ Keeps me healthy by increasing my immune system
- ○ Decrease the change of injury
- ○ Decrease inflammation before it happens
- ○ Accelerate the healing of any injury
- ○ Increases my muscle strength
- ○ Not sure what it does
- ○ Increases muscle mass
- ○ Decreases cellular damage
- ○ Improves recovery
- ○ Other, Please specify:

Do you think your performance would deteriorate if you did not take these electrolytes?

- ○ Yes
- ○ No
- ○ Not sure

From the list below, please rank your 'Top 3' sources of information according to their importance in influencing your electrolyte intake

1 = being the most influential
3 = least influential

	1	2	3
Coach/ Trainer			
Fellow runners			
Books/magazines			
Websites			
Adverts			
Sports Associations			
Self experimentation / Personal experience			
Other			

If you selected 'Other' to the previous question. Please specify:

Section C

Sub-section 16

OTHER ERGOGENIC AIDS NOT LISTED

Are you using other ergogenic aid/s not already mentioned?

If select 'Yes' additional important questions regarding your ergogenic aid use will be shown. If you select 'No' you will be redirected to the next ergogenic aid you selected.

- Yes
- No

How many other ergogenic aids not listed do you use?

What other ergogenic aids do you use? (Brand names)

How do you administer/take these ergogenic aids?

- Orally
- Intravenously
- Other, please specify:

For how many years have you been using these as an ergogenic aid?

When do you take these ergogenic aids?

(You may select more than one option.)

- Before every training run
- Only if the training run is going to be particularly long or hard
- Before every race or marathon
- Only if the race is going to be particularly long or hard
- Only if not feeling well
- Only when I'm injured
- Only when I'm stiff and sore
- Everyday
- 1 X per week
- X per week
- Only when I am fatigued/tired
- Other, Please specify:

Do you feel that these ergogenic aids you use improve your performance?

- Yes
- No
- Not sure

If no or unsure, why do you take these ergogenic aids?

In your opinion, how do these ergogenic aids help to improve performance?

(You may select more than one option.)

- ○ Make me run faster
- ○ Allows me to run for longer
- ○ Decrease stiffness
- ○ Decrease the amount of pain I might feel
- ○ Gives me an energy boost
- ○ Increases my oxygen uptake
- ○ Keeps me healthy by increasing my immune system
- ○ Decrease the change of injury
- ○ Decrease inflammation before it happens
- ○ Accelerate the healing of any injury
- ○ Increases my muscle strength
- ○ Not sure what it does
- ○ Increases muscle mass
- ○ Decreases cellular damage
- ○ Improves recovery
- ○ Other, Please specify:

Do you think your performance would deteriorate if you did not take these ergogenic aids?

- ○ Yes
- ○ No
- ○ Not sure

From the list below, please rank your 'Top 3' sources of information according to their importance in influencing your ergogenic aid use

1 = being the most influential
3 = least influential

	1	2	3
Coach/ Trainer			
Fellow runners			
Books/magazines			
Websites			
Adverts			
Sports Associations			
Self experimentation / Personal experience			
Other			

If you selected 'Other' to the previous question. Please specify:

APPENDIX VI: Emails Contacting Validation Panel

Department of Health and Rehabilitation Sciences

Faculty of Health Sciences

Division of Physiotherapy

F45 Old Main Building, Groote Schuur Hospital, Observatory 7925

Dear *(insert individuals name)*

Request for Assistance: Validation of an Ultra-marathon Running Ergogenic Aids Questionnaire

I am a Masters of Philosophy in Sports Physiotherapy student at the University of Cape Town, and am writing to you to request your assistance with the validation of a questionnaire on ergogenic aids used by ultra-marathon runners. This study has been given ethical approval by the Human Research Ethics Committee, Faculty of Health Sciences, University of Cape Town (HREC REF: 280/2012). This study is being supervised by Dr Theresa Burgess, Associate Professor Andrew Bosch and Professor Mike Lambert.

We have developed an online questionnaire to assess the use and knowledge of ergogenic aids by ultra-marathon runners. To qualify for inclusion in the study the participants must be frequent ultra-marathon runners. For the purpose of this study a frequent ultra-marathon runner has been defined as a runner who is running between 40-60 km/week, participates in at least one ultra-marathon per year and is required to have been competing for no less than 12 months. The runners which will be recruited will be those who completed the 2012 Old Mutual Two Oceans Ultra-Marathon in less than five hours. A further inclusion criterion is that the participants are required to converse and read English and/or Afrikaans, as these will be the two languages in which the questionnaire will be made available.

Participants will be excluded from the study if the questionnaires are incomplete or inappropriately completed, or if the athletes are participating in half marathons (21.1 km) or marathons (42.2 km) only as opposed to ultra-marathons (>50 km). Furthermore exclusion will be based on their failure to provide informed consent, or if the participants have any metabolic disorders such as diabetes mellitus (DM), as these influence and impact perceived performance.

The study will help us to identify which ergogenic aids are being used by ultra-marathon runners and why they choose to use these particular aids. It will also assess the general knowledge of ergogenic aids amongst ultra-marathon runners. There is currently a lack of evidence in this field, and we hope that this study will contribute to this field with the goal of ensuring the safe use of ergogenic aids in endurance running.

As a recognised *(insert individuals specific expertise)* and an expert in the field of *(marathon running &/or ergogenic aids)*, I therefore wish to request your assistance with the validation of the content of the questionnaire. Please could you review the questionnaire to ensure that the questions are clear and easy to understand; that the questions adequately assess the spectrum of available ergogenic aids; and the use and knowledge of ergogenic aids?

As a validator, you will not be considered as a study participant and all information will be treated with utmost confidentiality. The questionnaire is 45 pages, and it should take approximately *(insert time frame)* to review the questionnaire.

I have attached the questionnaire and have allocated a comment page after each section with question numbers to allow for per question comments to be made. Please bear in mind that although the questionnaire may seem rather lengthy, the participants will only complete relevant sections of the questionnaire, based on their use of ergogenic aids.

If possible, please could you return any feedback before 11th February 2013? Your feedback will be greatly appreciated. Please contact me should you have further questions or should you be unable to assist with the validation process.

Thanking you in advance for your support in assisting research in the field of ultra-marathon running. Please do not hesitate to contact me or the study supervisors should you have any queries.

Kind regards,

Michael Gwilliams

Tel number: 018 771 3628

Cell number: 083 565 0685

E-mail: gwilliams.michael@gmail.com

Study supervisor:

Dr Theresa Burgess	Tel number:	021 406 6171
	E-mail:	theresa.burgess@uct.ac.za

Study co-supervisors:

Associate Professor Andrew Bosch	Tel number:	021 650 4578
	E-mail:	andrew.bosch@uct.ac.za
Professor Mike Lambert	Tel number:	021 650 4558
	E-mail:	mike.lambert@uct.ac.za

APPENDIX VII: Letter of Approval for Study

UNIVERSITY OF CAPE TOWN

Faculty of Health Sciences
Faculty of Health Sciences Research Ethics Committee
Room E52-24 Groote Schuur Hospital Old Main Building
Observatory 7925
Telephone [021] 406 6338 • **Facsimile** [021] 406 6411
e-mail: sumayah.ariefdien@uct.ac.za

24 July 2012

HREC REF: 280/2012

Mr M Gwilliams
c/o Dr T Burgess
Health & Rehab Sciences
F-45
OMB

Dear Mr Gwilliams

PROJECT TITLE: THE USE OF ERGOGENIC AIDS BY ULTRA-MARATHON RUNNERS

Thank you for addressing the issues raised by the committee.

It is a pleasure to inform you that the Ethics Committee has **formally approved** the above-mentioned study.

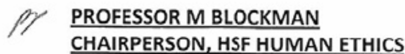
Approval is granted for one year till the 28 July 2013.

Please submit a progress form, using the standardised Annual Report Form (FHS016), if the study continues beyond the approval period. Please submit a Standard Closure form (FHS010)if the study is completed within the approval period.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please quote the REC. REF in all your correspondence.

Yours sincerely



PROFESSOR M BLOCKMAN
CHAIRPERSON, HSF HUMAN ETHICS

Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

sAriefdien

APPENDIX VIII: Training and Race Characteristics

Appendix VIII A: Training and race characteristics according to gender, age and level of competitiveness. Data has been presented as mean and standard deviation (SD).

Characteristics	Gender				Age				Competitiveness			
	Males	Females	t-value	p-value	Junior	Veteran	t-value	p-value	Competitive	Recreational	t-value	p-value
Training frequency ($d.wk^{-1}$)	4.5 ± 1	5.0 ± 1	-4.14469	0.000046**	4.6 ± 1	4.7 ± 1	-0.78804	0.431380	5.0 ± 1	4.6 ± 1	-2.22929	0.026673**
Training session's ($n.d^{-1}$)	1 ± 1	1 ± 0.3	0.62210	0.534416	1 ± 0.7	1 ± 0.6	0.61393	0.539788	1 ± 0.8	1 ± 0.6	-0.22131	0.825033
Ave hours training ($h.wk^{-1}$)	7 ± 3	8 ± 3	-1.73041	0.084726	8 ± 4	7 ± 3	1.67402	0.095310	7 ± 3	7 ± 3	-0.28669	0.774587
Number of rest days ($d.wk^{-1}$)	2.26 ± 1	1.80 ± 1	3.57011	0.000424**	2 ± 1	2 ± 1	0.30619	0.759703	2 ± 1	2 ± 1	1.94000	0.053490
Training distance ($km.wk^{-1}$)	55 ± 22	56 ± 17	-0.41889	0.675639	54 ± 24	56 ± 18	-0.71022	0.478197	60 ± 17	55 ± 21	-1.30736	0.192277
Training commencing post race (d)	4 ± 3	3 ± 2	2.69678	0.007464**	3 ± 2	4 ± 2	-0.59948	0.549381	4 ± 3	4 ± 2	0.14121	0.887820
Number of marathons (n)	34 ± 33	21 ± 7	3.54413	0.000466**	14 ± 11	39 ± 32	-7.33928	<0.00001**	62 ± 38	26 ± 25	-7.36062	<0.00001**
Marathons frequency ($d.yr^{-1}$)	4 ± 2	4 ± 2	-0.54902	0.583456	3 ± 2	4 ± 2	-2.00870	0.045587**	4 ± 1	4 ± 2	0.23109	0.817430
Number of ultra-marathons (n)	23 ± 25	13 ± 12	3.31676	0.001039**	9 ± 8	26 ± 25	-6.43888	<0.00001**	46 ± 34	16 ± 17	-8.02532	<0.00001**
Ultra-marathons frequency ($n.yr^{-1}$)	2.5 ± 1	2.5 ± 2	-0.56721	0.571053	2.3 ± 1	2.5 ± 1	-1.21723	0.224604	2.7 ± 1	2.5 ± 1	-1.26865	0.205731
Ultra-marathon experience (yr)	11 ± 10	7 ± 5	3.66463	0.000299**	4 ± 3	13 ± 9	-9.01791	<0.00001**	19 ±1 2	9 ± 7	-6.79840	<0.00001**

#Note: Statistical significance: *p<0.05 ** p<0.01

Appendix VIII B: Average number of weekly training hours. Data has been presented as number (n) and percentage (%).

Ave hours training per week	Males runners (n = 179)	Females runners (n = 87)	Row total (n = 266)		Junior runners (n = 94)	Veteran runners (n = 172)	Row total (n = 266)		Competitive runners (n = 34)	Recreational runners (n = 221)	Row total (n = 255)
1	9 (5%)	2 (2%)	11 (4%)		3 (3%)	8 (5%)	11 (4%)		1 (3%)	9 (4%)	10 (4%)
2	12 (7%)	2 (2%)	14 (5%)		5 (5%)	9 (5%)	14 (5%)		2 (6%)	10 (5%)	12 (5%)
3	2 (1%)	2 (2%)	4 (2%)		2 (2%)	2 (1%)	4 (2%)		0 (0%)	4 (2%)	4 (2%)
4	11 (6%)	5 (6%)	16 (6%)		5 (5%)	11 (6%)	16 (6%)		3 (9%)	13 (6%)	16 (6%)
5	26 (15%)	7 (8%)	33 (12%)		16 (17%)	17 (10%)	33 (12%)		1 (3%)	32 (15%)	33 (13%)
6	31 (17%)	10 (12%)	41 (15%)		9 (10%)	32 (19%)	41 (15%)		10 (29%)	30 (14%)	40 (16%)
7	20 (11%)	13 (15%)	33 (12%)		11 (12%)	22 (13%)	33 (12%)		2 (6%)	29 (13%)	31 (12%)
8	31 (17%)	26 (30%)	57 (21%)		17 (18%)	40 (23%)	57 (21%)		7 (21%)	47 (21%)	54 (21%)
9	6 (3%)	2 (2%)	8 (3%)		2 (2%)	6 (4%)	8 (3%)		1 (3%)	7 (3%)	8 (3%)
10	10 (6%)	8 (9%)	18 (7%)		7 (7%)	11 (6%)	18 (7%)		4 (12%)	13 (6%)	17 (7%)
11	2 (1%)	1 (1%)	3 (1%)		2 (2%)	1 (1%)	3 (1%)		0 (0%)	3 (1%)	3 (1%)
12	10 (6%)	5 (6%)	15 (6%)		8 (9%)	7 (4%)	15 (6%)		0 (0%)	14 (6%)	14 (6%)
13	1 (1%)	0 (0%)	1 (0.4%)		0 (0%)	1 (1%)	1 (0.4%)		0 (0%)	1 (1%)	1 (0.4%)
14	2 (1%)	0 (0%)	2 (1%)		0 (0%)	2 (1%)	2 (1%)		2 (6%)	0 (0%)	2 (1%)
15	1 (1%)	2 (2%)	3 (1%)		2 (2%)	1 (1%)	3 (1%)		0 (0%)	3 (1%)	3 (1%)
16	3 (2%)	0 (0%)	3 (1%)		2 (2%)	1 (1%)	3 (1%)		0 (0%)	3 (1%)	3 (1%)
17	0 (0%)	1 (1%)	1 (0.4%)		1 (1)	0 (0%)	1 (0.4%)		0 (0%)	1 (1%)	1 (0.4%)
18	1 (1%)	1 (1%)	2 (1%)		1 (1%)	1 (1%)	2 (1%)		1 (3%)	1 (1%)	2 (1%)
20	1 (0.6%)	0 (0%)	1 (0.4%)		1 (1%)	0 (0%)	1 (0.4%)		0 (0%)	1 (1%)	1 (0.4%)

Appendix VIII C: Training intensity. Data has been presented as number (n) and percentage (%).

Training intensity	Males runners (n = 179)	Females runners (n = 87)	Row total (n = 266)		Junior runners (n = 94)	Veteran runners (n = 172)	Row total (n = 266)		Competitive runners (n = 34)	Recreational runners (n = 221)	Row total (n = 255)
Day-to-day											
1	3 (2%)	0 (0%)	3 (1%)		3 (3%)	0 (0%)	3 (1%)		0 (0%)	3 (1%)	3 (1%)
2	10 (6%)	4 (1%)	14 (5%)		5 (5%)	9 (5%)	14 (5%)		1 (3%)	12 (5%)	13 (5%)
3	113 (63%)	52 (60%)	165 (62%)		53 (56%)	112 (65%)	165 (62%)		25 (74%)	133 (60%)	158 (62%)
4	49 (27%)	28 (32%)	77 (29%)		31 (33%)	46 (27%)	77 (29%)		8 (24%)	66 (30%)	74 (29%)
5	3 (2%)	3 (3%)	6 (2%)		2 (2%)	4 (2%)	6 (2%)		0 (0%)	6 (3%)	6 (2%)
Week before a race											
1	31 (17%)	14 (16%)	45 (17%)		16 (17%)	29 (17%)	45 (17%)		10 (29%)	32 (15%)	42 (17%)
2	70 (39%)	44 (51%)	114 (43%)		35 (37%)	79 (46%)	114 (43%)		14 (41%)	95 (43%)	109 (43%)
3	63 (35%)	21 (24%)	84 (32%)		36 (38%)	48 (28%)	84 (32%)		9 (27%)	72 (33%)	81 (32%)
4	14 (8%)	8 (9%)	22 (8%)		6 (6%)	16 (9%)	22 (8%)		0 (0%)	22 (10%)	22 (9%)
5	1 (1%)	0 (0%)	1 (0.4%)		1 (1%)	0 (0%)	1 (0.4%)		1 (3%)	0 (0%)	1 (0.4%)
Week after a race											
1	70 (39%)	33 (38%)	103 (39%)		34 (36%)	69 (40%)	103 (39%)		11 (32%)	90 (40%)	101 (40%)
2	71 (40%)	34 (39%)	105 (40%)		38 (40%)	67 (39%)	105 (40%)		16 (47%)	82 (37%)	98 (38%)
3	31 (17%)	18 (21%)	49 (18%)		18 (19%)	31 (18%)	49 (18%)		6 (18%)	41 (19%)	47 (18%)
4	4 (2%)	2 (2%)	6 (2%)		3 (3%)	3 (2%)	6 (2%)		0 (0%)	6 (3%)	6 (2%)
5	2 (1%)	0 (0%)	2 (1%)		1 (1%)	1 (1%)	2 (1%)		1 (3%)	1 (1%)	2 (1%)

Note: Intensity was rated on a scale of 1-5, where 1 = very light training 2 = easy training 3 = moderate training 4 = high intensity training 5 = very high intensity training.

Appendix VIII D: Number of recovery days required post race. Data has been presented as number (n) and percentage (%).

Recovery days post race required prior to commencing training	Males runners (n = 173)	Females runners (n = 86)	Row total (n = 259)	Junior runners (n = 91)	Veteran runners (n = 168)	Row total (n = 259)	Competitive runners (n = 34)	Recreational runners (n = 214)	Row total (n = 248)
0	2 (1%)	0 (0%)	2 (1%)	0 (0%)	2 (1%)	2 (1%)	0 (0%)	2 (1%)	2 (1%)
1	10 (6%)	13 (15%)	23 (9%)	9 (10%)	14 (8%)	23 (9%)	4 (12%)	19 (9%)	23 (9%)
2	54 (31%)	32 (37%)	86 (33%)	36 (40%)	50 (30%)	86 (33%)	10 (29%)	68 (32%)	78 (32%)
3	48 (28%)	25 (29%)	73 (28%)	21 (23%)	52 (31%)	73 (28%)	11 (32%)	60 (28%)	71 (29%)
4	14 (8%)	5 (6%)	19 (7%)	8 (9%)	11 (7%)	19 (7%)	2 (6%)	17 (8%)	19 (8%)
5	7 (4%)	3 (4%)	10 (4%)	1 (1%)	9 (6%)	10 (4%)	1 (2%)	8 (4%)	9 (4%)
6	3 (2%)	1 (1%)	4 (2%)	3 (3%)	1 (1%)	4 (2%)	0 (0%)	4 (2%)	4 (2%)
7	25 (15%)	4 (5%)	29 (11%)	9 (10%)	20 (12%)	29 (11%)	5 (15%)	24 (11%)	29 (12%)
8	1 (1%)	1 (1%)	2 (1%)	0 (0%)	2 (1%)	2 (1%)	0 (0%)	2 (1%)	2 (1%)
9	1 (1%)	1 (1%)	2 (1%)	0 (0%)	2 (1%)	2 (1%)	0 (0%)	2 (1%)	2 (1%)
10	4 (2%)	0 (0%)	4 (2%)	2 (2%)	2 (1%)	4 (2%)	0 (0%)	4 (2%)	4 (2%)
12	1 (1%)	0 (0%)	1 (0.4%)	1 (1%)	0 (0%)	1 (0.4%)	0 (0%)	1 (1%)	1 (0.4%)
14	3 (2%)	1 (1%)	4 (2%)	1 (1%)	3 (2%)	4 (2%)	1 (3%)	3 (1%)	4 (2%)

Appendix VIII E: Number of years competing in ultra-marathon running. Data has been presented as number (n) and percentage (%).

No. years running ultra-marathons	Male runners (n = 179)	Female runners (n = 87)	Row total (n = 266)		Junior runners (n = 94)	Veteran runners (n = 172)	Row total (n = 266)		Competitive runners (n = 34)	Recreational runners (n = 221)	Row total (n = 255)
1-5	75 (42%)	44 (51%)	119 (45%)		73 (78%)	46 (27%)	119 (45%)		7 (21%)	105 (48%)	112 (44%)
6-10	33 (18%)	22 (25%)	55 (21%)		16 (17%)	39 (23%)	55 (21%)		4 (12%)	49 (22%)	53 (21%)
11-15	20 (11%)	13 (15%)	33 (12%)		4 (4%)	29 (17%)	33 (12%)		3 (9%)	28 (13%)	31 (12%)
16-20	15 (8%)	6 (7%)	21 (8%)		1 (1%)	20 (12%)	21 (8%)		4 (12%)	17 (8%)	21 (8%)
21-25	15 (8%)	2 (2%)	17 (6%)		0 (0%)	17 (10%)	17 (6%)		5 (15%)	12 (5%)	17 (7%)
26-30	11 (6%)	0 (0%)	11 (4%)		0 (0%)	11 (6%)	11 (4%)		3 (9%)	8 (4%)	11 (4%)
31-35	7 (4%)	0 (0%)	7 (3%)		0 (0%)	7 (4%)	7 (3%)		6 (18%)	1 (1%)	7 (3%)
36-40	3 (2%)	0 (0%)	3 (1%)		0 (0%)	3 (2%)	3 (1%)		2 (6%)	1 (1%)	3 (1%)

Appendix VIII F: Average number of marathons and ultra-marathons completed per annum. Data has been presented as number (n) and percentage (%).

No. of marathons in one year	Male runners (n = 179)	Female runners (n = 87)	Row total (n = 266)		Junior runners (n = 94)	Veteran runners (n = 172)	Row total (n = 266)		Competitive runners (n = 34)	Recreational runners (n = 221)	Row total (n = 255)
1	14 (8%)	8 (9%)	22 (8%)		10 (11%)	12 (7%)	22 (8%)		2 (6%)	20 (9%)	22 (9%)
2	31 (17%)	14 (16%)	45 (17%)		19 (20%)	26 (15%)	45 (17%)		3 (9%)	40 (18%)	43 (17%)
3	43 (24%)	21 (24%)	64 (24%)		26 (28%)	38 (22%)	64 (24%)		12 (35%)	49 (22%)	61 (24%)
4	37 (21%)	22 (25%)	59 (22%)		14 (15%)	45 (26%)	59 (22%)		9 (27%)	47 (21%)	56 (22%)
5	27 (15%)	8 (9%)	35 (13%)		14 (15%)	21 (12%)	35 (13%)		5 (15%)	29 (13%)	34 (13%)
6	16 (9%)	4 (5%)	20 (8%)		7 (7%)	13 (8%)	20 (8%)		1 (3%)	18 (8%)	19 (8%)
7	6 (3%)	3 (3%)	9 (3%)		2 (2%)	7 (4%)	9 (3%)		1 (3%)	7 (3%)	8 (3%)
8	3 (2%)	4 (5%)	7 (3%)		1 (1%)	6 (4%)	7 (3%)		1 (3%)	6 (3%)	7 (3%)
9	1 (1%)	1 (1%)	2 (1%)		0 (0%)	2 (1%)	2 (1%)		0 (0%)	2 (1%)	2 (1%)
10	1 (1%)	0 (0%)	1 (0.4%)		1 (1%)	0 (0%)	1 (0.4%)		0 (0%)	1 (0.5%)	1 (0.4%)
12	0 (0%)	2 (2%)	2 (1%)		0 (0%)	2 (1%)	2 (1%)		0 (0%)	2 (1%)	2 (1%)
No. of ultra-marathons in one year											
1	34 (19%)	19 (22%)	53 (20%)		23 (25%)	30 (17%)	53 (20%)		2 (6%)	49 (22%)	51 (20%)
2	62 (35%)	28 (32%)	90 (34%)		25 (27%)	65 (38%)	90 (34%)		12 (35%)	74 (34%)	86 (34%)
3	58 (32%)	24 (28%)	82 (31%)		37 (39%)	45 (26%)	82 (31%)		12 (35%)	66 (30%)	78 (31%)
4	18 (10%)	13 (15%)	31 (12%)		7 (7%)	24 (14%)	31 (12%)		8 (24%)	22 (10%)	30 (12%)
5	5 (3%)	1 (1%)	6 (2%)		1 (1%)	5 (3%)	6 (2%)		0 (0%)	6 (3%)	6 (2%)
6	1 (1%)	1 (1%)	2 (1%)		1 (1%)	1 (0.6%)	2 (1%)		0 (0%)	2 (1%)	2 (1%)
7	1 (1%)	0 (0%)	1 (0.4%)		0 (0%)	1 (0.6%)	1 (0.4%)		0 (0%)	1 (0.5%)	1 (0.4%)
13	0 (1%)	1 (1%)	1 (0.4%)		0 (0%)	1 (0.6%)	1 (0.4%)		0 (0%)	1 (0.5%)	1 (0.4%)

APPENDIX IX: Detailed Comparison of Ergogenic Aid Use

Participant use of each ergogenic aid. Data has been presented as number (n) and percentage (%).

Ergogenic aid	Total participants using this aid (n = 266)	Male runners (n = 179	Female runners (n = 87)	p-value	Junior runners (n = 94)	Veteran runners (n = 172)	p-value	Competitive runners (n = 34)	Recreational runners (n = 221)	p-value
Sports drinks	213 (80%)	144 (80%)	69 (79%)	p > 0.5	81 (86%)	132 (77%)	p > 0.05	31 (91%)	174 (797%)	p > 0.05
Vitamins	181 (68%)	110 (62%)	71 (82%)	p < 0.001**	61 (65%)	120 (70%)	p > 0.1	25 (74%)	149 (67%)	p > 0.1
Carbo-loading	165 (62%)	116 (65%)	49 (55%)	p > 0.1	57 (61%)	108 (63%)	p > 0.5	28 (82%)	132 (60%)	p < 0.05*
Gels	163 (61%)	112 (63%)	51 (57%)	p > 0.5	53 (56%)	110 (64%)	p > 0.1	20 (59%)	136 (62%)	p > 0.5
Electrolytes	130 (49%)	83 (46%)	47 (53%)	p > 0.1	46 (49%)	84 (49%)	p > 0.5	20 (59%)	104 (47%)	p > 0.1
Medication	104 (39%)	67 (37%)	37 (42%)	p > 0.1	38 (40%)	66 (38%)	p > 0.5	15 (44%)	84 (38%)	p > 0.1
Caffeine	87 (33%)	57 (32%)	30 (34%)	p > 0.5	35 (37%)	52 (30%)	p > 0.1	12 (35%)	73 (33%)	p > 0.5
Protein intake	85 (32%)	57 (32%)	28 (32%)	p > 0.5	30 (32%)	55 (32%)	p > 0.5	15 (44%)	66 (30%)	p > 0.05
Amino acids	19 (7%)	9 (5%)	10 (11%)	p > 0.05	6 (6%)	13 (8%)	p > 0.5	3 (9%)	15 (7%)	p > 0.5
Antioxidants	6 (2%)	3 (2%)	3 (3%)	p > 0.1	1 (1%)	5 (3%)	p > 0.1	1 (3%)	4 (2%)	p > 0.5
Growth hormone	0 (0%)	0 (0%)	0 (0%)	-	0 (0%)	0 (0%)	-	0 (0%)	0 (0%)	-
EPO	0 (0%)	0 (0%)	0 (0%)	-	0 (0%)	0 (0%)	-	0 (0%)	0 (0%)	-
Blood doping	0 (0%)	0 (0%)	0 (0%)	-	0 (0%)	0 (0%)	-	0 (0%)	0 (0%)	-

#Note: Statistical significance: *p<0.05 ** p<0.01

APPENDIX X: Detailed Comparison of the Influential Factors Affecting Ergogenic Aid Intake Strategies.

Appendix X A: Ranking of the mean scores for the factors affecting the intake of fluids. Data is presented as mean and standard deviation (SD).

Sources influencing fluid intake	Gender				Age				Competitiveness			
	Male Mean (±SD)	Female Mean (±SD)	t-value	p-value	Junior Mean (±SD)	Veteran Mean (±SD)	t-value	p-value	Competitive Mean (±SD)	Recreational Mean (±SD)	t-value	p-value
Coach/Trainer	3.76 ± 0.66	3.57 ± 0.90	1.89	p > 0.05	3.63 ± 0.82	3.74 ± 0.71	-1.1	p > 0.1	3.66 ± 0.80	3.88 ± 0.41	-1.61	p > 0.1
Fellow runners	2.98 ± 1.09	3.11 ± 1.05	-0.98	p > 0.1	2.95 ± 1.12	3.06 ± 1.05	-0.85	p > 0.1	3.01 ± 1.08	3.06 ± 1.10	-0.25	p > 0.5
Books/Magazines	3.18 ± 1.03	3.17 ± 1.08	0.09	p > 0.5	3.20 ± 1.03	3.17 ± 1.05	0.25	p > 0.5	3.20 ± 1.01	3.06 ± 1.20	0.76	p > 0.1
Websites	3.63 ± 0.76	3.71 ± 0.68	-0.90	p > 0.1	3.55 ± 0.78	3.71 ± 0.71	-1.66	p > 0.05	3.64 ± 0.75	3.76 ± 0.61	-0.90	p > 0.1
Adverts	3.91 ± 0.36	3.91 ± 0.33	-0.07	p > 0.5	3.94 ± 0.29	3.89 ± 0.38	1.04	p > 0.1	3.90 ± 0.36	3.91 ± 0.29	-0.10	p > 0.5
Sports associations/ Athletic clubs	3.97 ± 0.18	3.87 ± 0.55	2.06	p < 0.05*	3.94 ± 0.38	3.94 ± 0.33	0.00	p > 0.5	3.93 ± 0.37	3.97 ± 0.17	-0.60	p > 0.5
Self experimentation/ Personal experience	2.23 ± 1.34	2.32 ± 1.34	-0.53	p > 0.5	2.09 ± 1.23	2.35 ± 1.39	-1.57	p > 0.1	2.24 ± 1.34	2.38 ± 1.35	-0.58	p > 0.5
Other	3.94 ± 0.36	3.91 ± 0.47	0.69	p > 0.1	3.91 ± 0.41	3.94 ± 0.40	-0.52	p > 0.5	3.94 ± 0.39	3.88 ± 0.54	0.72	p > 0.1

#Note: Statistical significance: *p<0.05

Appendix X B: Ranking of the mean scores for the factors influencing the intake of vitamins. Data is presented as mean and standard deviation (SD).

Factors influencing vitamin intake	Gender				Age				Competitiveness			
	Male Mean (±SD)	Female Mean (±SD)	t-value	p-value	Junior Mean (±SD)	Veteran Mean (±SD)	t-value	p-value	Competitive Mean (±SD)	Recreational Mean (±SD)	t-value	p-value
Coach/ Trainer	3.70 ± 0.76	3.56 ± 0.83	0.93	p > 0.1	3.54 ± 0.96	3.71 ± 0.69	-1.05	p > 0.1	3.88 ± 0.33	3.58 ± 0.86	-1.40	p > 0.1
Fellow runners	2.63 ± 1.12	2.95 ± 0.94	-1.51	p > 0.1	2.62 ± 1.14	2.82 ± 1.03	-0.94	p > 0.1	2.76 ± 1.14	2.75 ± 1.05	-0.05	p > 0.5
Books/Magazines	2.89 ± 1.07	2.92 ± 1.21	-0.15	p > 0.5	3.00 ± 1.11	2.85 ± 1.14	0.63	p > 0.5	2.64 ± 1.11	2.95 ± 1.11	1.03	p > 0.1
Websites	3.55 ± 0.88	3.58 ± 0.92	-0.18	p > 0.5	3.37 ± 0.98	3.66 ± 0.83	-1.59	p > 0.1	3.76 ± 0.75	3.51 ± 0.93	-1.04	p > 0.1
Adverts	3.80 ± 0.53	3.75 ± 0.66	0.37	p > 0.5	3.89 ± 0.39	3.72 ± 0.66	1.41	p > 0.1	3.52 ± 0.87	3.86 ± 0.43	2.41	p < 0.05*
Sports associations / Athletic clubs	3.89 ± 0.35	3.75 ± 0.66	1.37	p > 0.1	3.86 ± 0.42	3.82 ± 0.54	0.38	p > 0.5	3.94 ± 0.24	3.82 ± 0.54	-0.89	p > 0.1
Self experimentation / Personal experience	1.92 ± 1.12	1.90 ± 1.16	0.08	p > 0.5	2.00 ± 1.11	1.87 ± 1.15	0.56	p > 0.5	1.82 ± 1.01	1.92 ± 1.15	0.35	p > 0.5
Other	3.78 ± 0.71	3.80 ± 0.64	-0.15	p > 0.5	3.89 ± 0.59	3.73 ± 0.76	1.09	p > 0.1	3.64 ± 0.86	3.80 ± 0.66	0.87	p > 0.1

#Note: Statistical significance: *p<0.05

Appendix X C: Ranking of the mean scores for the factors influencing the intake of gels. Data is presented as mean and standard deviation (SD).

Factors influencing gel intake	Gender				Age				Competitiveness			
	Male Mean (±SD)	Female Mean (±SD)	t-value	p-value	Junior Mean (±SD)	Veteran Mean (±SD)	t-value	p-value	Competitive Mean (±SD)	Recreational Mean (±SD)	t-value	p-value
Coach/ Trainer	3.70 ± 0.79	3.46 ± 1.07	1.37	p > 0.1	3.55 ± 0.97	3.67 ± 0.84	-0.69	p > 0.1	3.54 ± 0.96	4.00 ± 0.00	-1.78	p > 0.05
Fellow runners	2.54 ± 1.05	2.73 ± 1.12	-0.90	p > 0.1	2.62 ± 1.10	2.59 ± 1.07	0.16	p > 0.5	2.58 ± 1.08	2.71 ± 1.20	-0.42	p > 0.5
Books/Magazines	3.11 ± 1.03	2.92 ± 1.12	0.92	p > 0.1	3.17 ± 0.93	2.99 ± 1.12	0.88	p > 0.1	3.08 ± 1.01	3.00 ± 1.24	0.28	p > 0.5
Websites	3.53 ± 0.86	3.81 ± 0.46	-1.90	p > 0.05	3.38 ± 0.96	3.75 ± 0.59	-2.54	p < 0.05*	3.60 ± 0.77	3.71 ± 0.83	-0.49	p > 0.5
Adverts	3.76 ± 0.58	3.65 ± 0.75	0.90	p > 0.1	3.83 ± 0.49	3.67 ± 0.70	1.36	p > 0.1	3.79 ± 0.54	3.50 ± 0.76	1.78	p > 0.05
Sports associations / Athletic clubs	3.98 ± 0.16	3.95 ± 0.33	0.65	p > 0.5	3.93 ± 0.34	3.99 ± 0.12	-1.35	p > 0.1	3.98 ± 0.20	3.86 ± 0.36	1.86	p > 0.05
Self experimentation / Personal experience	1.76 ± 1.05	2.00 ± 1.25	-1.07	p > 0.1	1.88 ± 1.15	1.81 ± 1.10	0.31	p > 0.5	1.83 ± 1.11	1.86 ± 1.17	-0.07	p > 0.5
Other	3.95 ± 0.27	4.00 ± 0.00	-1.12	p > 0.1	4.00 ± 0.00	3.95 ± 0.28	1.23	p > 0.1	3.99 ± 0.10	3.79 ± 0.58	3.20	p <0.005**

#Note: Statistical significance: *p<0.05 ** p<0.01

Appendix X D: Ranking of the mean scores for the factors influencing the intake of electrolytes. Data is presented as mean and standard deviation (SD).

Factors influencing electrolyte intake	Gender				Age				Competitiveness			
	Male Mean (±SD)	Female Mean (±SD)	t-value	p-value	Junior Mean (±SD)	Veteran Mean (±SD)	t-value	p-value	Competitive Mean (±SD)	Recreational Mean (±SD)	t-value	p-value
Coach/Trainer	3.63 ± 0.83	3.76 ± 0.55	-0.84	p > 0.1	3.59 ± 0.86	3.74 ± 0.65	-0.95	p > 0.1	3.61 ± 0.80	4.00 ± 0.00	-1.70	p > 0.05
Fellow runners	2.71 ± 1.08	2.53 ± 1.16	0.74	p > 0.1	2.83 ± 1.10	2.52 ± 1.11	1.29	p > 0.1	2.64 ± 1.12	2.67 ± 1.07	-0.08	p > 0.5
Books/Magazines	3.00 ± 1.04	2.91 ± 1.19	0.37	p > 0.5	3.00 ± 1.08	2.94 ± 1.11	0.23	p > 0.5	3.00 ± 1.06	2.67 ± 1.23	0.98	p > 0.1
Websites	3.60 ± 0.85	3.76 ± 0.65	-0.96	p > 0.1	3.46 ± 0.98	3.80 ± 0.59	-2.03	p < 0.05*	3.60 ± 0.85	4.00 ± 0.00	-1.63	p > 0.1
Adverts	3.63 ± 0.76	3.74 ± 0.62	-0.68	p > 0.1	3.76 ± 0.70	3.61 ± 0.71	0.99	p > 0.1	3.68 ± 0.73	3.75 ± 0.45	-0.34	p > 0.5
Sports associations / Athletic clubs	3.96 ± 0.27	3.64 ± 0.93	2.43	p < 0.05*	3.85 ± 0.62	3.83 ± 0.64	0.11	p > 0.5	3.84 ± 0.61	4.00 ± 0.00	-0.89	p > 0.1
Self experimentation / Personal experience	1.81 ± 1.10	2.15 ± 1.21	-1.33	p > 0.1	2.03 ± 1.14	1.89 ± 1.16	0.56	p > 0.5	2.01 ± 1.20	1.42 ± 0.51	1.69	p > 0.05
Other	4.00 ± 0.00	3.97 ± 0.17	1.26	p > 0.1	3.97 ± 0.17	4.00 ± 0.00	-1.26	p > 0.1	3.99 ± 0.12	4.00 ± 0.00	-0.41	p > 0.5

#Note: Statistical significance: *p<0.05 ** p<0.01

Appendix X E: Ranking of the mean scores for the factors influencing the intake of amino acids. Data is presented as mean and standard deviation (SD).

Factor influencing amino acids intake	Gender				Age				Competitiveness			
	Male Mean (±SD)	Female Mean (±SD)	t-value	p-value	Junior Mean (±SD)	Veteran Mean (±SD)	t-value	p-value	Competitive Mean (±SD)	Recreational Mean (±SD)	t-value	p-value
Coach/ Trainer	3.14 ± 1.46	3.80 ± 0.45	-0.96	p > 0.1	3.00 ± 1.41	3.63 ± 1.06	-0.87	p > 0.1	3.56 ± 1.01	2.50 ± 2.12	1.14	p > 0.1
Fellow runners	2.86 ± 1.07	2.40 ± 1.14	0.71	p > 0.1	2.75 ± 1.26	2.63 ± 1.06	0.18	p > 0.5	2.33 ± 1.00	3.50 ± 0.71	-1.54	p > 0.1
Books/Magazines	3.29 ± 0.95	3.80 ± 0.45	-1.11	p > 0.1	3.50 ± 1.00	3.50 ± 0.76	0.00	p > 1.0	3.56 ± 0.73	3.00 ± 1.41	0.85	p > 0.1
Websites	3.29 ± 1.25	3.60 ± 0.89	-0.48	p > 0.5	2.75 ± 1.50	3.75 ± 0.71	-1.61	p > 0.1	3.22 ± 1.20	4.00 ± 0.00	-0.88	p > 0.1
Adverts	3.71 ± 0.76	3.60 ± 0.89	0.24	p > 0.5	4.00 ± 0.00	3.50 ± 0.93	1.05	p > 0.1	4.00 ± 0.00	3.00 ± 1.41	2.71	p < 0.05*
Sports associations / Athletic clubs	4.00 ± 0.00	2.80 ± 1.30	2.49	p < 0.05*	3.50 ± 1.00	3.50 ± 1.07	0.00	p > 1.0	3.44 ± 1.13	4.00 ± 0.00	-0.67	p > 0.5
Self experimentation / Personal experience	2.14 ± 1.21	2.00 ± 1.41	0.19	p > 0.5	2.50 ± 1.29	1.88 ± 1.25	0.81	p > 0.1	2.11 ± 1.17	2.50 ± 2.12	-0.38	p > 0.5
Other	3.71 ± 0.76	4.00 ± 0.00	-0.83	p > 0.1	4.00 ± 0.00	3.75 ± 0.71	0.69	p > 0.5	3.78 ± 0.67	4.00 ± 0.00	-0.45	p > 0.5

#Note: Statistical significance: *p<0.05 ** p<0.01

Appendix X F: Ranking of the mean scores for the factors influencing the intake of antioxidants. Data is presented as mean and standard deviation (SD).

Factors influencing antioxidant intake	Gender				Age				Competitiveness			
	Male Mean (±SD)	Female Mean (±SD)	t-value	p-value	Junior Mean (±SD)	Veteran Mean (±SD)	t-value	p-value	Competitive Mean (±SD)	Recreational Mean (±SD)	t-value	p-value
Coach/ Trainer	4.00 ± 0.00	4.00 ± 0.00			4.00 ± 0.00	4.00 ± 0.00			4.00 ± 0.00	4.00 ± 0.00		
Fellow runners	3.67 ± 0.58	2.50 ± 0.71	2.05	p > 0.1	4.00 ± 0.00	3.00 ± 0.82	1.10	p > 0.1	3.00 ± 0.82	4.00 ± 0.00	-1.10	p > 0.1
Books/Magazines	2.33 ± 1.53	2.00 ± 1.41	0.24	p > 0.5	2.00 ± 0.00	2.25 ± 1.50	-0.15	p > 0.5	2.50 ± 1.29	1.00 ± 0.00	1.04	p > 0.1
Websites	3.67 ± 0.58	4.00 ± 0.00	-0.77	p > 0.1	3.00 ± 0.00	4.00 ± 0.00			3.75 ± 0.50	4.00 ± 0.00	-0.45	p > 0.5
Adverts	4.00 ± 0.00	4.00 ± 0.00			4.00 ± 0.00	4.00 ± 0.00			4.00 ± 0.00	4.00 ± 0.00		
Sports associations / Athletic clubs	4.00 ± 0.00	4.00 ± 0.00			4.00 ± 0.00	4.00 ± 0.00			4.00 ± 0.00	4.00 ± 0.00		
Self experimentation / Personal experience	1.67 ± 1.15	1.50 ± 0.71	0.18	p > 0.5	1.00 ± 0.00	1.75 ± 0.96	-0.70	p > 0.5	1.25 ± 0.50	3.00 ± 0.00	-3.13	p > 0.05
Other	2.67 ± 1.15	4.00 ± 0.00	-1.55	p > 0.1	4.00 ± 0.00	3.00 ± 1.15	0.77	p > 0.1	3.50 ± 1.00	2.00 ± 0.00	1.34	p > 0.1

#Note: Statistical significance: *p<0.05 ** p<0.01

Appendix X G: Ranking of the mean scores for the factors influencing the carbo-loading intake. Data is presented as mean and standard deviation (SD).

Factors influencing carbo-loading intake	Gender				Age				Competitiveness			
	Male Mean (±SD)	Female Mean (±SD)	t-value	p-value	Junior Mean (±SD)	Veteran Mean (±SD)	t-value	p-value	Competitive Mean (±SD)	Recreational Mean (±SD)	t-value	p-value
Coach/Trainer	3.73 ± 0.73	3.65 ± 0.79	0.57	p > 0.5	3.73 ± 0.66	3.69 ± 0.80	0.23	p > 0.5	3.65 ± 0.81	4.00 ± 0.00	-1.80	p > 0.05
Fellow runners	2.65 ± 1.06	2.72 ± 1.09	-0.36	p > 0.5	2.86 ± 1.07	2.55 ± 1.05	1.55	p > 0.1	2.69 ± 1.07	2.53 ± 1.07	0.59	p > 0.5
Books/Magazines	2.87 ± 1.07	2.92 ± 1.05	-0.20	p > 0.5	3.16 ± 0.99	2.72 ± 1.07	2.21	p < 0.05*	2.93 ± 1.06	2.59 ± 1.06	1.21	p > 0.1
Websites	3.56 ± 0.81	3.81 ± 0.62	-1.63	p > 0.1	3.43 ± 0.97	3.76 ± 0.57	-2.28	p < 0.05*	3.59 ± 0.82	3.88 ± 0.33	-1.45	p > 0.1
Adverts	3.82 ± 0.50	3.89 ± 0.40	-0.70	p > 0.1	3.89 ± 0.44	3.82 ± 0.49	0.77	p > 0.1	3.86 ± 0.43	3.71 ± 0.69	1.26	p > 0.1
Sports associations/ Athletic clubs	3.95 ± 0.27	3.75 ± 0.69	2.22	p < 0.05*	3.89 ± 0.54	3.89 ± 0.40	-0.01	p > 0.5	3.91 ± 0.44	3.88 ± 0.33	0.20	p > 0.5
Self experimentation/ Personal experience	1.75 ± 1.08	1.75 ± 1.05	-0.01	p > 0.5	1.61 ± 0.89	1.83 ± 1.16	-1.06	p > 0.1	1.79 ± 1.08	1.65 ± 1.06	0.50	p > 0.5
Other	4.00 ± 0.00	3.89 ± 0.52	1.90	p > 0.05	3.98 ± 0.15	3.96 ± 0.36	0.34	p > 0.5	3.96 ± 0.32	4.00 ± 0.00	-0.53	p > 0.5

#Note: Statistical significance: *p<0.05 ** p<0.01

Appendix X H: Ranking of the mean scores for the factors influencing the increase protein intake. Data is presented as mean and standard deviation (SD).

Factors influencing increased protein intake	Gender				Age				Competitiveness			
	Male Mean (±SD)	Female Mean (±SD)	t-value	p-value	Junior Mean (±SD)	Veteran Mean (±SD)	t-value	p-value	Competitive Mean (±SD)	Recreational Mean (±SD)	t-value	p-value
Coach/ Trainer	3.75 ± 0.52	3.73 ± 0.80	0.08	p > 0.5	3.71 ± 0.47	3.77 ± 0.71	-0.32	p > 0.5	3.69 ± 0.67	4.00 ± 0.00	-1.11	p > 0.1
Fellow runners	2.86 ± 1.11	3.13 ± 0.92	-0.82	p > 0.1	3.24 ± 1.09	2.77 ± 0.99	1.45	p > 0.1	3.06 ± 1.01	2.33 ± 1.21	1.58	p > 0.1
Books/Magazines	3.00 ± 1.12	2.33 ± 1.18	1.83	p > 0.05	2.94 ± 1.09	2.65 ± 1.23	0.78	p > 0.1	2.81 ± 1.19	2.67 ± 1.21	0.26	p > 0.5
Websites	3.18 ± 1.12	3.80 ± 0.56	-2.00	p > 0.05	3.18 ± 1.19	3.54 ± 0.86	-1.16	p > 0.1	3.36 ± 1.05	3.50 ± 0.84	-0.31	p > 0.5
Adverts	3.82 ± 0.48	3.93 ± 0.26	-0.84	p > 0.1	3.82 ± 0.53	3.88 ± 0.33	-0.47	p > 0.5	3.89 ± 0.40	3.67 ± 0.52	1.21	p > 0.1
Sports associations / Athletic clubs	4.00 ± 0.00	3.80 ± 0.56	1.91	p > 0.05	4.00 ± 0.00	3.88 ± 0.43	1.10	p > 0.1	3.92 ± 0.37	4.00 ± 0.00	-0.55	p > 0.5
Self experimentation / Personal experience	1.93 ± 1.18	1.67 ± 0.82	0.76	p > 0.1	2.00 ± 1.17	1.73 ± 1.00	0.81	p > 0.1	1.86 ± 1.07	1.83 ± 1.17	0.06	p > 0.5
Other	4.00 ± 0.00	3.67 ± 0.90	1.98	p > 0.05	3.82 ± 0.73	3.92 ± 0.39	-0.58	p > 0.5	3.86 ± 0.59	4.00 ± 0.00	-0.57	p > 0.5

#Note: Statistical significance: *p<0.05 ** p<0.01

Appendix X I: Ranking of the mean scores for the factors influencing the intake of caffeine. Data is presented as mean and standard deviation (SD).

Factors influencing caffeine intake	Gender				Age				Competitiveness		
	Male Mean (±SD)	Female Mean (±SD)	t-value	p-value	Junior Mean (±SD)	Veteran Mean (±SD)	t-value	p-value	Competitive Mean (±SD)	Recreational Mean (±SD)	t-value
Coach/ Trainer	3.73 ± 0.78	3.60 ± 0.97	0.42	p > 0.5	3.77 ± 0.83	3.65 ± 0.83	0.41	p > 0.5	3.70 ± 0.84	3.60 ± 0.89	0.25
Fellow runners	3.08 ± 1.06	3.50 ± 0.85	-1.13	p > 0.1	3.15 ± 1.07	3.22 ± 1.00	-0.18	p > 0.5	3.07 ± 1.05	3.80 ± 0.45	-1.53
Books/Magazines	3.00 ± 0.80	2.70 ± 1.16	0.89	p > 0.1	2.85 ± 0.80	2.96 ± 0.98	-0.35	p > 0.5	2.93 ± 0.87	2.80 ± 1.30	0.30
Websites	3.69 ± 0.68	3.60 ± 0.84	0.34	p > 0.5	3.54 ± 0.78	3.74 ± 0.69	-0.80	p > 0.1	3.73 ± 0.64	3.20 ± 1.10	1.55
Adverts	3.73 ± 0.60	4.00 ± 0.00	-1.40	p > 0.1	3.85 ± 0.55	3.78 ± 0.52	0.34	p > 0.5	3.80 ± 0.55	3.80 ± 0.45	0.00
Sports associations / Athletic clubs	3.96 ± 0.20	3.30 ± 1.16	2.87	p < 0.01**	4.00 ± 0.00	3.65 ± 0.83	1.50	p > 0.1	3.80 ± 0.66	4.00 ± 0.00	-0.66
Self experimentation / Personal experience	1.27 ± 0.67	2.20 ± 1.32	-2.82	p < 0.01**	1.46 ± 0.88	1.57 ± 1.04	-0.30	p > 0.5	1.57 ± 1.01	1.40 ± 0.89	0.35
Other	3.88 ± 0.59	4.00 ± 0.00	-0.61	p > 0.5	4.00 ± 0.00	3.87 ± 0.63	0.75	p > 0.1	3.90 ± 0.55	4.00 ± 0.00	-0.40

#Note: Statistical significance: *p<0.05 ** p<0.01

APPENDIX XI: Regression analyses detailed tables.

The sample size was too small for both amino acids and antioxidants in order to attain true reflections for a regression analysis investigating these factors.

Forward stepwise regression analysis of the descriptive factors and training and race history influencing the use of sports drinks as ergogenic aids.

Descriptive factors					
Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	4.10	$p < 0.000$			80.03
Gender		$p > 0.5$			
Age		$p > 0.05$			
Level of competitiveness		$p > 0.05$			
Training and race factors					
Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	5.27	$p > 0.000$			60.35
Training frequency ($d.wk^{-1}$)		$p > 0.1$			
Training distance ($km.wk^{-1}$)		$p > 0.1$			
Number of marathons (n)		$p > 0.1$			
Number of ultra-marathons (n)		$p > 0.1$			
Ultra-marathon experience (yr)	0.53	$p < 0.05$*	0.29	0.98	0.31

Forward stepwise regression analysis of the descriptive and race and training factors influencing the intake of vitamins.

Descriptive factors					
Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	1.64	$p < 0.005$			9.94
Gender	2.69	$p < 0.005$*	1.42	5.09	9.21
Age		$p > 0.5$			
Level of competitiveness		$p > 0.1$			
Race and training factors					
Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	1.33	$p > 0.1$			1.14
Training frequency ($d.wk^{-1}$)		$p > 0.5$			
Training distance ($km.wk^{-1}$)		$p > 0.1$			
Number of marathons (n)		$p > 0.5$			
Number of ultra-marathons (n)	1.83	$p > 0.05$	1.00	3.36	3.82
Ultra-marathon experience (yr)		$p > 0.5$			

Forward stepwise regression analysis of the descriptive and race and training factors influencing gel use.

Descriptive factors					
Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	1.64	$p < 0.005$			9.94
Gender	2.69	$p < 0.005$*	1.42	5.09	9.21
Age		$p > 0.5$			
Level of competitiveness		$p > 0.1$			
Race and training factors					
Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	1.33	$p > 0.1$			1.14
Training frequency ($d.wk^{-1}$)		$p > 0.5$			
Training distance ($km.wk^{-1}$)		$p > 0.1$			
Number of marathons (n)		$p > 0.5$			
Number of ultra-marathons (n)	1.83	$p > 0.05$	1.00	3.36	3.82
Ultra-marathon experience (yr)		$p > 0.5$			

Forward stepwise regression analysis of the descriptive and race and training factors influencing electrolyte consumption.

Descriptive factors					
Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	0.66	$p > 0.5$			0.19
Gender		$p > 0.1$			
Age		$p > 0.5$			
Level of competitiveness		$p > 0.1$			
Race and training factors					
Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	0.96	$p > 0.5$			0.14
Training frequency ($d.wk^{-1}$)		$p > 0.5$			
Training distance ($km.wk^{-1}$)		$p > 0.1$			
Number of marathons (n)		$p > 0.5$			
Number of ultra-marathons (n)		$p > 0.5$			
Ultra-marathon experience (yr)		$p > 0.05$			

Forward stepwise regression analysis of descriptive and race and training factors influencing the use of carbo-loading.

Descriptive factors					
Steps	Exp(B)	p-value	95% CI Lower	95% CI Upper	Wald
Constant	4.67	$p < 0.001$*			11.73
Gender		$p > 0.5$			
Age		$p > 0.5$			
Level of competitiveness	0.32	$p < 0.05$*	0.13	0.80	5.94
Race and training factors					
Steps	Exp(B)	p-value	95% CI Lower	95% CI Upper	Wald
Constant	1.63	$p < 0.000$			15.09
Training frequency ($d.wk^{-1}$)		$p > 0.5$			
Training distance ($km.wk^{-1}$)		$p > 0.1$			
Number of marathons (n)		$p > 0.5$			
Number of ultra-marathons (n)		$p > 0.1$			
Ultra-marathon experience (yr)		$p > 0.5$			

Forward stepwise regression analysis of the descriptive, race and training factors influencing the use of increased protein intake.

Descriptive factors					
Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	0.47	p < 0.000			32.31
Gender		p > 0.5			
Age		p > 0.5			
Level of competitiveness		p > 0.05			

Forward step regression analysis of the descriptive, race and training factors influencing the use of medication.

Descriptive factors					
Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	0.64	p < 0.000			12.52
Gender		p > 0.5			
Age		p > 0.5			
Level of competitiveness		p > 0.1			
Race and training factors					
Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	0.64	p < 0.000			12.44
Training frequency ($d.wk^{-1}$)		p > 0.1			
Training distance ($km.wk^{-1}$)		p > 0.5			
Number of marathons (n)		p > 0.1			
Number of ultra-marathons (n)		p > 0.5			
Ultra-marathon experience (yr)		p > 0.5			

Forward stepwise regression analysis of the descriptive, race and training factors influencing the use of caffeine.

Descriptive factors					
Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	0.50	$p < 0.000$			27.23
Gender		$p > 0.5$			
Age		$p > 0.1$			
Level of competitiveness		$p > 0.5$			
Race and training factors					
Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	0.49	$p < 0.000$			30.47
Training frequency ($d.wk^{-1}$)		$p > 0.1$			
Training distance ($km.wk^{-1}$)		$p > 0.5$			
Number of marathons (n)		$p > 0.5$			
Number of ultra-marathons (n)		$p > 0.5$			
Ultra-marathon experience (yr)		$p > 0.1$			

APPENDIX XI: Medication Dosage Patterns

Dosage patterns of medication. Data has been presented as number (n).

Number of pills per dose					
	1 per dose	2 per dose	3 per dose	Min-Max	Median
Analgesics	4	12	0	1-2	2
NSAIDS	18	7	0	1-2	1
Muscle relaxants	1	1	0	1-2	1.5
Combo meds	1	0	0	1-1	1

Number of doses per day							
	1	2	3	N/A	Only when necessary	Min-Max	Median
Analgesics	6	4	2	1	2	1-3	2
NSAIDS	10	6	1	0	8	1-3	2
Muscle relaxants	0	0	0	1	0	0	0
Combo meds	0	0	0	0	1	0	0

Number of days one would continue consuming the medication					
	1 Day	2-3 Days	1 Week	Only on the race or training day	As long as I need to
Analgesics	0	2	0	12	1
NSAIDS	2	11	2	7	3
Muscle relaxants	0	0	0	2	0
Combo meds	1	0	0	0	0