

TRAINING, TAPER AND RECOVERY STRATEGIES FOR EFFECTIVE COMPETITION PERFORMANCE IN JUDO

by

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Abstract

Post-exercise carbohydrate-protein consumption and tapering periods during training periodisation have been proposed as effective recovery strategies in several sports; however, limited attention has been given to judo. Apart from training and recovery, effective competition performance can also be influenced by several stimuli on the competition day, which may be manifested as distinct endocrine responses. The main objective of this thesis was to influence effective competition performance in judo, through examining strategies that can aid recovery from intense exercise/training and examining endocrine responses to competition. Three experimental studies on recovery were completed (chapters 3-5) followed by an observational study on a judo competition day (chapter 6) in elite, national level, male judo athletes. Studies 1 and 2 examined the effects 1000 ml of post-exercise chocolate milk (CM) consumption compared with water (W) following an intense judo training session (chapter 3) and five days of intense judo training with concomitant weight loss (chapter 4) on the recovery of salivary cortisol (sC), salivary testosterone (sT), salivary testosterone:cortisol (sT/C) ratio, salivary secretory IgA (SIgA) absolute concentrations and secretion rate, muscle soreness, mood state and judo-related performance. Study 1 (n=10) did not show any beneficial effects of acute CM consumption on aspects of recovery of any of the measured variables, except for a lower perception of soreness ($p<0.05$) and a tendency for better push-up performance ($p=0.09$). Study 2 (n=12) showed that post-exercise CM consumption resulted in significantly lower sC levels, a tendency for higher sT/C ratio ($p=0.07$), better judo-related performance, lower muscle soreness and reduced mood disturbance ($p<0.05$) with W. In addition, post-exercise consumption of CM resulted in a 1.1% decrease in body weight, indicating that CM is an effective recovery beverage during periods of intense judo training without affecting intentional weight loss. Study 3 (n=11) examined the effects of a 2-week exponential taper following 2 weeks of intense judo training on recovery of the aforementioned variables. Within 12 days of tapering there were evidence of enhanced performance, lower sC, higher sT and higher sT/C ratio, higher SIgA secretion rate, lower muscle soreness and reduced mood disturbance, indicating that a tapering period of ~10 days is an effective recovery strategy for optimising judo performance. Study 4 observed the responses of sC, sT, SIgA absolute concentrations and SIgA secretion rate and self-measured anxiety state in the winners (n=12) and losers (n=11) of a judo competition. Winners presented significantly higher morning sC levels and higher cognitive anxiety in anticipation of the competition,

as well as a tendency for higher SIgA secretion rate ($p=0.07$) and significantly higher saliva flow rate mid-competition. These findings indicate that winners experienced higher arousal levels and that anticipatory sC might have some predictive value for winning performance in judo. This thesis concludes that nutrition and tapering are both important aspects of effective recovery; CM can be an effective nutritional recovery aid during periods of intense judo training and tapering for 7-12 days can optimise judo performance and can be implemented prior to competitions. In addition, elevated sC levels in anticipation of a judo competition and higher levels of arousal could have some predictive value for winning performance in judo. Further research could focus on strategies to increase levels of arousal in anticipation of competition.

Keywords: salivary cortisol, salivary testosterone, SIgA, saliva flow rate, chocolate milk, nutrition, intense judo exercise, winning performance, psychophysiological anxiety, competition

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List of Abbreviations

ACSM	American College of Sports Medicine
ANOVA	Analysis of variance
AU	Arbitrary units
bpm	beats per minute
C	Cortisol
cm	centi
cal	calories
CHO	Carbohydrate(s)
CI	95% confidence intervals of relative differences
CK	Creatine kinase
CM	Chocolate milk
CSAI-2R	Revised competitive anxiety inventory-2 questionnaire
DOMS	Delayed-onset muscle soreness
ELISA	Enzyme-linked immunoassay
g	grams
h	hour(s)
HR	Heart rate
HRmax	Maximum heart rate
IJF	International Judo Federation
INT	Intensified training
k	kilo
l	litre
LSD	Fisher's least significant differences
m	milli
min	minute(s)
MSFT	Multistage fitness test
nmol	nanomoles
NORM	Normal training
p	Level of significance
pmol	picomoles
POMS	Profile of mood state

ES	Effect size
<i>r</i>	Intra-class correlation coefficient
RER	Respiratory exchange ratio
ROS	Reactive oxygen species
RPE	Rate of perceived exertion
sC	Salivary cortisol
SD	Standard deviation
sec	second(s)
SIgA	Salivary secretory immunoglobulin A
SJFT	Special judo fitness test
T	Testosterone
T/C	Testosterone:cortisol
sT	Salivary testosterone
sT/C	Salivary testosterone:cortisol
TAP1	Tapering days 1-2
TAP2	Tapering days 3-4
TAP3	Tapering days 5-6
TAP4	Tapering days 8-10
TAP5	Tapering days 11-13
TAPER	Tapering
URTI	Upper respiratory tract infections
VAS	Visual analogue scale
W	Water
μ	micro
%	Percentage
°C	Degree Celsius

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CHAPTER 1: GENERAL INTRODUCTION

The main aim of each competitive athlete is to enhance training process for optimising competition performance. Judo is a physically demanding combat sport that incorporates repeated short bouts of anaerobic activity and intensive training periods with eccentric loading so the multi-directional needs of training are optimised prior to the competition period. However, maintaining high training loads with insufficient recovery periods has been proven to lead to the onset of non-functional overreaching (Meeusen et al., 2013); therefore, promoting adequate and sufficient recovery is particularly important during training periodisation. Proper recovery in athletes is accomplished through several strategies and methods to alleviate the accumulated levels of fatigue, in order to prevent excessive training stress and facilitate the optimal adaptations for sport performance. Effective competition performance can also be influenced by several stimuli on the competition day, which may be manifested into the endocrine responses. Therefore, the main objective of this thesis was to influence effective competition performance in the sport of judo, through identifying strategies that could aid recovery from intense exercise/training and examine whether psychophysiological responses to competition could be related to winning performance.

Effective training periodisation depends upon achieving the right balance of intense training and recovery cycles. Incorporating a tapering phase following periods of intensive training allows the athlete greater recovery which in turn can prevent the detrimental effects of overtraining and super-compensate physical performance (Mujika and Padilla, 2003). Tapers are associated with enhancements in performance capacity, increases in muscular strength and power, enhanced mood state, reduced circulating cortisol (C) and creatine kinase (CK) responses and increased testosterone (T) and peak post-exercise blood lactate values (Mujika et al., 2004). Mucosal immunity is known to be suppressed during periods of intensive training (Walsh et al., 2011), yet studies assessing its response during tapering are scarce. However, no studies to date have described the time course of change of some of the above variables during tapering in judo athletes.

Coingestion of carbohydrate (CHO) and protein is vital during recovery from exercise, as the induced hyperinsulinaemia and hyperaminoacidaemia respectively can stimulate glucose uptake and glycogen storage as well as promote a positive muscle protein turnover. Chocolate milk (CM) is a natural whole food that contains CHO, protein, fluid and electrolytes; therefore, it can be characterised as a practical and straightforward nutritional aid to provide the required nutrients during recovery for effective refuelling and

rehydration. However, evidence is limited regarding the efficacy of CM on performance, endocrine responses and mucosal immunity during recovery from intense judo exercise and training.

Apart from exercise training and recovery, a major concern of a competitive athlete is effective competition performance. Performance on the competition day may be affected by other internal or external stimuli, some of which could be manifest in the athletes' endocrine responses. C and T are two steroid hormones that may have the possibility to influence the competition outcome. Although chronic elevations in cortisol can be debilitating for health and performance (Sapolsky et al., 2000), acute C elevations can be euphorogenic, increasing motivation and promoting arousal and focused attention (Duclos, 2010a). Circulating T levels are associated with dominant and competitive aggression behaviours (Mazur, 1985; Booth et al., 1989) which may indirectly influence performance during judo competition.

To try and achieve proper recovery strategies and examine effective competition performance in judo, three experimental studies on recovery were completed, followed by an observational study that has examined psychophysiological responses during an international judo competition. The main aims of the research studies were:

1. To examine whether post-exercise CM consumption following a single intensive judo training session can limit the disturbances in salivary hormones, mucosal immunity and sleep, attenuate the exercise-induced muscle soreness and improve the subsequent judo-specific performance during acute recovery.
2. To examine whether post-exercise CM consumption during 5 days of intense judo training with concomitant weight loss can limit the disturbances in salivary hormones, mucosal immunity and mood state, attenuate the exercise-induced muscle soreness and improve the subsequent judo-specific performance, without affecting intentional weight loss.
3. To examine the changes in performance, salivary cortisol (sC) and salivary testosterone (sT), mood state, mucosal immunity and muscle soreness during two weeks of intensive judo training and a subsequent two-week period of tapering.

4. To assess the responses of sC, sT, salivary secretory immunoglobulin A (SIgA) before, during and after a judo competition and to determine whether the levels of these salivary variables may differentiate winners and losers of the competition.

CHAPTER 2: LITERATURE REVIEW

2.1. Judo as an Olympic combat sport

Judo is a full-contact martial art originating from ancient Japan and has developed into an Olympic sporting event. It is a representative Japanese combat sport which throughout the decades has become popular worldwide with international character. Judo was previously considered as a sport in which only Japanese athletes could excel; however, the philosophic and pedagogic nature of judo has seen it develop into an international sporting event, engaged in by millions of people throughout the world. The international spread of Judo has influenced the creation of other martial arts such as the Brazilian jiu-jitsu and Russian sambo. The founder of judo is *sensei* Jigoro Kano who adopted the best techniques from Japanese jiu-jitsu and created a new and improved competitive martial art in 1882 that is referred as Kodokan Judo. “Ju-do” in Japanese translates as the “gentle way”, illustrating the culture of the sport itself as it promotes respect, friendship and peace.

The International Olympic Committee accepted Judo as an Olympic sport at the Tokyo Olympic Games in 1964, with athletes participating in only 4 weight categories (<68, 68-80, >80 kg and open category) and was primarily a men’s sport. Nowadays, judo is one of the most popular Olympic sports with 7 weight categories in men (<60, 60-66, 66-73, 73-81, 81-90, 90-100, >100 kg) and women (<48, 48-52, 52-57, 57-63, 63-70, 70-78, >78 kg). *Judokas* (judo practitioners) train and compete wearing the *judogi* (judo uniform) in colours of white (the traditional Japanese *judogi*) or blue (modern/European style *judogi*) to distinguish the two competitors. The International Judo Federation (IJF) has 200 National Judo Federation members with approximately 20 million registered athletes worldwide. The ranking in judo level according to skill and knowledge of the art is indicated by a system of coloured belts which denotes into *kyū* and *dan* grades. The progression of belt colours differentiates to the national judo organization but usually includes a progression series from white, yellow, orange, green, blue to brown belts with increasing *kyū* grades. Subsequently, there are the black belt, the white-red belt and the red belt according to the numbers of *dan* grades.

2.1.1. Physiology of judo

Judo is a physically demanding, high-intensity, intermittent exercise which involves use of the entire body and full body contact. Judo can be described as a power combat sport, involving frequent and high-intensity bursts of activity throughout the short duration of the

combat in order to succeed over the opponent. It has been previously reported that the most important aspects for successive performance in judo are a combination of highly developed physical fitness and technical/tactical skills (Franchini et al., 2011; Krstulović, 2012; Krstulović and Sekulic, 2013).

The energy contribution in judo is similar to intermittent-type sports; thus relying mostly on repeated short bursts of anaerobic metabolism in order to release maximal power while applying the techniques several times during the match. Judo can be characterised as an intermittent sport, and like football, rugby, tennis etc, there is an utilisation of both alactic and lactic mechanisms; although anaerobic metabolism contributes primarily and to a great extent to the total energy requirements, there is an increasing contribution of aerobic metabolism as the match progresses. It has been reported that energy substrate utilization during a judo match involves mobilisation of both glucose and lipids (Degoutte et al., 2003), emphasising the fact that judo play involves energy contribution from both aerobic and anaerobic energy sources. Subsequently, judoists repeatedly work at or above their anaerobic threshold throughout the course of training and competition, with reported values of average heart rate during judo match at 92% of maximal heart rate (HR_{max}) and blood lactate concentrations three min after a judo match at 12.3 mmol·l⁻¹ (Degoutte et al., 2003). The contribution of aerobic metabolism gradually increases as the match progresses; aerobic contribution helps to sustain effort for the multiple bursts of intermittent work, the rapid recovery process during the short intervals of reduced effort during the match as well as during rest periods between matches. It has been shown that judo athletes with high aerobic capacity perform better in intermittent, high-intensity judo-related tasks (Franchini et al., 2007), which is believed to be derived from faster creatine phosphate resynthesis and lactate removal (Gariod et al., 1995). One could argue that the metabolic profiles of judo athletes are similar to those of intermittent-type sports, with maximal oxygen uptake ($\dot{V}O_2\text{max}$) reported at 50-60 ml·kg⁻¹·min⁻¹ for men and 40-50 ml·kg⁻¹·min⁻¹ for women (Franchini et al., 2007; Franchini et al., 2011).

Production of muscular power is also an important factor for judo performance during the execution of techniques. Considering that power represents the product of strength and velocity, judo athletes perform their throwing techniques using high speed over a great resistance of the opponent. In their review, Franchini and colleagues (2011) have concluded that muscular power of the lower extremities seems to be more important for judo performance than power of the upper body, whereas maximal strength and muscular

endurance appears to be better developed in the upper body. Studies have used jump tests to measure lower-extremities muscular power (vertical jump, countermovement jump) and it has been reported that the power of the lower extremities measured by vertical jump is associated with winning outcomes ($r=0.69$) during the European and World Cup competitions (Franchini et al., 2011). Measuring maximal strength in judo has been assessed using tests for both isometric strength (handgrip strength) and dynamic strength (1 repetition maximum) of different muscle groups, whereas muscular endurance has been evaluated using sit-ups and push-ups (Franchini et al., 2011).

2.1.2. Judo training

Kano's vision for Judo was to preserve the philosophy of Japanese martial arts and to utilize it within the principle of "maximum efficiency, minimum effort", thus emphasising the importance of effectiveness in the execution of techniques. The evolution of the sport of judo throughout the years has led to the development of specific training methods so that most of the moves could be done with full speed and power to create a victory without injury. Judo training can be very hard and demanding as it involves dynamic and frequent eccentric activity bouts; training for judo involves several repetitions of high intensity attacks and defences through a variety of throwing and choking grips, in addition to several free practice combats aiming to throw the opponent's back segment into the ground. Therefore, training for judo should be multi-directional in order to achieve high levels of physical fitness along with substantial knowledge of technical and tactical skills.

Training for judo typically involves judo practice at the *dojo* (judo practice area) where athletes perform several sets of *randori* (free practice sparring), in addition to several high-intensity repetitions of judo-specific skills and drills and mat training. Judo training in the *dojo* is usually divided into two directions; standing training and groundwork training. Standing judo training begins with repetitive technical training (*uchi komi*), then multiple executions of throwing techniques (*nage komi*) followed by the standing *randoris* (*tachi randori*); whereas groundwork training begins with several repetitions of ground techniques (*uchi komi*) followed by the ground *randoris* (*newaza randori*). Judo training in the *dojo* lasts for over 2 h where athletes train at 60-85% of $\dot{V}O_2\text{max}$ and $HR\text{max}$, resulting in high total energy expenditure during specific judo exercises (273 kJ) and high levels of blood lactate ($14.4 \text{ mmol}\cdot\text{l}^{-1}$) (Franchini et al., 2014). In addition to judo-specific exercises,

training also includes enhancement of physical fitness. Training involves enhancement of speed and aerobic endurance by continuous and/or intermittent running (over distances of 50-800 m, according to the season) to optimise alactic and lactic metabolic systems function, as well as work on muscle-related power strength and endurance which is usually performed via resistance training.

2.1.2.1. Biochemical, immunological and endocrine responses to judo training

Maintaining such strenuous and intense training loads for prolonged periods of time with insufficient recovery periods has been proven to lead to the onset of overreaching in several sports. The most conspicuous consequence of this during intense training periods appears to be the impaired physical performance along with training-induced immunosuppression (Walsh et al., 2011), poor psychological state and exercise-induced damage of muscle tissue (Meeusen et al., 2013). In judo, interest is increasing regarding the effects of the intense training on athletes' state. Mochida et al. (2007) observed decreased post-exercise neutrophil phagocytic activity and elevated post-exercise serum CK levels after 64 days of judo training as well as lower post-exercise reactive oxygen species (ROS) production following a subsequent 7-day of intense training. Similarly, Yaegaki et al. (2007) observed reduced neutrophil phagocytic activity and increased ROS production as well as muscle damage manifested by elevated serum CK levels after a 7-day training camp in a group of male and female judoists. Umeda et al. (2008) reported that one week of intense training resulted in decreased blood leukocyte counts and phagocyte activity, increased neutrophil oxidative burst activity, deterioration of mood state and accumulation of myogenic enzymes in the circulation in a group of female judoists. Although many studies have focused on the blood immune responses to assess physical stress during judo training, no studies have used salivary immunoendocrine markers to measure training stress (and recovery) in judo athletes.

2.1.3. Judo competition

Judo competitions are usually organised at a regional, national and international level and according to the athletes' weight, there are 3 prize winners (first, second, third place) at each category. During judo fights the athlete tries to throw the opponent's back segment into the ground by a variety of throw techniques and choking grips. A competitive judo match is officially of 5 min duration; however, it can vary from a few seconds (when *ippon*

is scored) to a maximum of 8 min by adding an extra 3-min period after a match that ends in a tie (Miarka et al., 2012). Athletes competing in official judo competitions fight several times during the same day with a variable time schedule for qualifying, semi-final and final matches. Consequently, an athlete may compete 5-7 times in one day, interspersed by 20-30 sec of activity and 5-10 sec of interval during each combat in international tournaments, with an average of 10-15 min rest periods between matches (Franchini et al., 2011). Therefore, judo players require excellent physiological profiles and proper weight management to ensure they can cope with the demands of intensive training and successive combats during competition.

The competition day usually begins with registrations of the athletes in the morning, around 1.0 - 1.5 h before their first scheduled fight. Before January 2013 the weigh-ins were assessed in the morning of the competition day; new regulations state that weigh-ins are scheduled in the evening, the day before the competition (IJF, 2012). Then, athletes are divided into weight categories and draws determine the opposing dyads within each category. When an athlete loses the fight, he/she is disqualified, except when they compete in an additional fight called “repechage”. Consequently, repechage rounds often determine the third place.

2.1.3.1. “Making weight”

Judo is a sport with weight categories, where in all official competitions judo athletes compete within a single weight class against competitors of similar body weight. It was reported that when changing a weight class the athlete should go through complex adaptation processes in order to face heavier opponents with different fighting styles (Franchini et al., 2012); therefore, intentional weight loss or “making weight” cycles are a common strategy during judo periodisation. Like most sports classed by weight, judo athletes often engage in rapid weight loss (<7 days) in the days preceding competition, mainly by severe fluid and food restriction. A study examining the magnitude of weight loss practices in 822 male and female judo athletes showed that 80-90% of athletes had engaged in weight loss practices 2-5 times a year and many athletes reduced their weight 6-10 times annually; the average weight reduction has been reported at 2-5% of body weight in 47% of athletes and 5-10% in 39% of athletes (Artioli et al., 2010b). This study also highlighted several unorthodox and aggressive rapid weight loss methods that are followed by judo competitors, such as intensive exercising, skipping meals, restricted fluid

intake, gradual dieting, exercising with rubberized suits or in heated rooms, use of saunas, laxatives, diuretics, diet pills, and even self-induced vomiting, which may have detrimental effects on their performance and health. Following such intense body weight reduction practices may impair performance and induce high physiological strain on the athletes. In some extreme cases deaths have been reported associated with rapid weight loss, which occurred from heart attacks, hyperthermia and dehydration (Franchini et al., 2012). Possible reported consequences of rapid weight loss were dehydration, poor psychological state, impaired aerobic and anaerobic performance (Koral and Dosseville, 2009; Artioli et al., 2010b; Tsai et al., 2011b; Franchini et al., 2012) and immunosuppression (Kowatari et al., 2001; Ohta et al., 2002; Yaegaki et al., 2007; Tsai et al., 2011a; Tsai et al., 2011b). Degoutte et al. (2006) reported that 4 weeks of judo training followed by a 7-day weight loss after the training period led to deterioration of left handgrip strength, increased scores of tension, fatigue, anger and decreased vigour, decreased blood T concentrations and T/C ratio and increases in blood C, urea and uric acid. Therefore, proper nutrition and weight management are vital for effective training and competition performance in judo. However, field studies to assess “real-time” immunoendocrine responses of judo athletes during an actual competition do not exist.

Controversy exists regarding the effects of rapid weight loss on performance. A number of studies have shown that rapid weight loss does not appear to markedly affect performance, especially when athletes have enough time to recover, rehydrate and re-feed before the combat (Finn et al., 2004; Artioli et al., 2010b; Artioli et al., 2010c; Mendes et al., 2013). According to the previous regulations of IJF, the weigh-ins were assessed in the morning of competition day and the time schedule leading up to the first combat was 2-4 h, and it was during this time that athletes aimed to rehydrate and increase their energy levels to reverse their previously dehydrated state and low-glycogen stores. During this brief recovery period athletes ingested high amounts of CHO, which has been shown to return performance to pre-weight loss levels (Artioli et al., 2010b), in addition to fluids and electrolytes for rapid rehydration. However, with increasing awareness of the detrimental effects of rapid weight loss on athletes' performance and health, scientists proposed a weight management control program in judo (Artioli et al., 2010a) that the IJF has recently implemented. The new regulations for weigh-ins in judo have been modified to allow more time for the athletes to recover from rapid weight loss and refuel before the competition day. Thus, as of January 2013, the official weigh-in of the athletes is completed in the

evening before the competition, analogous to other combat sports like wrestling and taekwondo. The official statement of IJF (2012) regarding the regulations of weigh-ins procedure is shown below:

“IJF: 16.3. Weigh-in times

The athletes weigh in will be scheduled the day before the competition at 19:00h. A weigh in will be operated the morning of the competition, during the Judogi control, prior to the first fight in order to assess the impact of this new decision on the weight of the athletes during the competition. If the collected data require further experimentation, then it will be maintained. A procedure will be implemented when a fighter has a weight over a certain weight tolerance percentage. Within his category (weight to be determined with sport doctors) a medical check may be done. The official weigh-in control period shall be between 30 – 60 minutes. Competitors shall be allowed to check their weight on the official weigh-in scales (that will be used for the official weigh-in) during the 1 hour before the official weigh-in commences. There is no limit to the number of times each athlete may check his weight during this time of the unofficial weigh in.”

2.1.3.2. Acute psychophysiological responses to competition

Participating in competition is associated with acute rather than chronic stress. Anticipation of competition exerts physical and mental stress on the participating athletes, manifested by endocrine changes that may indirectly affect competition outcome. C is an adrenal glucocorticoid and is considered the main hormone responsible for catabolic processes, with main actions to promote gluconeogenesis, attenuate muscle protein synthesis and increase degradation (Viru and Viru, 2004). Chronic or persistent elevated C levels can be debilitating for performance and health as they could result in adrenal exhaustion and dysfunction; elevated circulating C levels have been reported to lead to uncertainty, inability to respond to stress and volatile decision-making (Coates and Herbert, 2008) and inhibit the inflammatory process and immunity (Sapolsky et al., 2000). On the other hand, if C elevation is acute and moderate, this glucocorticoid can have ergogenic effects; acute C elevations can be euphorogenic, increase motivation and promote arousal and focused

attention (Duclos, 2010b). T is major steroid hormone that exerts anabolic actions upon muscle tissue; T contributes to a great extent to muscle growth, by stimulating muscle protein synthesis and decreasing degradation, thus promoting muscular hypertrophy and enhancing muscle strength-related performance (Wood and Stanton, 2012). T can also have behavioural effects; according to Mazur's (1985) theory of the biosocial model of status, circulating T levels are associated with dominant and competitive aggression behaviours along with increases and decreases in T levels in winners and losers, respectively. Winning can also lead to subsequent elevations in T, which further stimulate competitiveness described as the "winner's effect" (Booth et al., 1989). Concentrations of sT in males were reported to be associated with situation-specific aggression and willingness to engage in competitive task (Carre and McCormick, 2008), traits that could positively influence judo competition performance.

SIgA is the most abundant antimicrobial protein found in mucus secretions, including saliva in the mouth. Together with α -amylase, lactoferrin and lysozyme, SIgA acts as the first line of defence by neutralizing and preventing viral pathogens entering the body via mucosal surfaces. SIgA has been considered as a strong indicator of susceptibility to upper respiratory tract infections (URTI). Low levels of salivary SIgA concentration and/or secretion rate have been associated with increased risk of URTI and strenuous, chronic training has been associated with falls of SIgA which may leave the athlete susceptible to common upper respiratory infections (Walsh et al., 2011). The overall intensity of the exercise bout appears to influence the post-exercise SIgA response; generally, increases are seen in response to short bouts (<30 min) of high intensity exercise (>80% $\dot{V}O_{2max}$), whereas no change or falls are seen with very prolonged exercise (>2 h) (Bishop and Gleeson, 2009). Sympathetic nervous system activity promotes the transportation of SIgA through epithelial cells and into saliva (Bishop and Gleeson, 2009), which can be related to the acute physiological demands of the competition.

The association between arousal and performance has been demonstrated in an inverted U-shaped relationship, illustrating that optimal performance is accomplished at a moderate level of arousal; thus poor performance is related to very low levels of arousal, progressively enhances at moderate levels of arousal until it deteriorates at very high arousal levels (Hardy and Parfitt, 1991). Arousal is closely interrelated to anxiety, whereas in athletic population it could be interpreted as the perception of the athletes'

physiological/somatic response or psychological/cognitive response to a stressor, which is usually a subsequent competition. A meta-analysis by Woodman and Hardy (2003), have suggested that a negative linear relationship exist in men ($r=-0.22$) between cognitive anxiety and performance; thus low levels of cognitive anxiety were observed in the athletes that performed better. However, these authors showed that the relationships between cognitive anxiety and performance are inconsistent, with 60% of studies showing a negative relationship, 23% showing a positive relationship and 16% reporting no significance. In judo, Filaire et al., (2001a) observed that interregional judo competitions elicit higher levels of somatic and cognitive anxiety and lower self-confidence compared with regional competitions. In addition, these authors reported that somatic and cognitive anxiety was correlated with sC levels, suggesting that neuroendocrine response and anxiety is related in judo athletes. Judo is a combat sport with high body contact where the athlete should “read” the moves of the opponent; thus the mental/psychological capacity and arousal of the athletes is especially important to the combat outcome. However, evidence are lacking to whether anxiety measures and self-confidence could influence the outcome of a judo competition.

Judo competition has been reported to lead to high psychophysiological strain on the athletes, manifested by elevated cognitive and somatic anxiety, low self-confidence and high sC and sT levels (Filaire et al., 2001a; Filaire et al., 2001b). Although C concentrations appear to be more sensitive to the acute psychophysiological stress of the competition, T responses to competition appear less consistent.

Anticipatory responses

Anticipatory increases in serum (Suay et al., 1999) and saliva (Salvador et al., 2003) C concentrations were observed before judo competitions, elevations in plasma C were found prior to karate fights (Parmigiani et al., 2009) and rises in saliva C were presented in anticipation of Brazilian jiu-jitsu matches (Moreira et al., 2012a). Serum T was reported to rise in anticipation of a competitive match in wrestlers (Fry et al., 2011), but not in judo athletes (Filaire et al., 2001b). According to the outcome, Suay et al. (1999) observed that winners of a judo competition had higher serum C levels throughout the competition, despite no differences in T and prolactin and similar physical effort of the athletes. The findings of this study confirm the results of Balthazar et al. (2012) that higher early-morning anticipatory C levels were associated with winning performance during a triathlon

competition. However, no differences in anticipatory sC levels between winners and losers were observed in relation to judo fights (Salvador et al., 2003). On the other hand, serum T was reported to rise in anticipation of a wrestling competitive match, with larger increases during the pre-fight anticipatory values in those who won the fight (Fry et al., 2011).

Exercise responses

Increased sC levels from baseline were observed throughout regional and interregional judo competitions which were associated to anxiety components, however without changes in sT levels (Filaire et al., 2001b). Acute elevations in post-exercise sC concentrations have been observed after a basketball match (Gonzalez-Bono et al., 1999), after a weightlifting competition (Le Panse et al., 2010), after simulated and actual karate fights (Parmigiani et al., 2009), after a youth taekwondo competition (Chiodo et al., 2011) and following a judo competition (Suay et al., 1999). SIgA responses to acute exercise are not consistent, with some studies reporting increases and some decreases of SIgA after acute exercise bouts (Bishop and Gleeson, 2009). Studies that have examined SIgA responses to competition are limited, showing no changes in SIgA levels in response of the competition (Moreira et al., 2010; Moreira et al., 2012a; Moreira et al., 2013a); however, currently, no evidence on SIgA responses during judo competitions exist. According to the outcome, increases in post-competition T were observed in those who won a badminton game (Jimenez et al., 2012), which illustrates the winner-loser effect (Booth et al., 1989). Similar results were found in judo athletes illustrating a positive relationship between serum T levels and offensive behaviours of threats, fights and attacks during a judo match (Salvadora et al., 1999). Conversely, Suay et al. (1999) did not find different serum T levels in winners, despite higher C values and better mood state after the fight in those who won. Therefore, the lack of strong evidence of an association between endocrine levels, psychophysiological anxiety and competition outcome highlights the need for further research in the area.

2.2. Strategies to promote recovery

Promoting adequate and sufficient recovery has particular importance in the design of a training program. Proper recovery in athletes is being attained through several strategies and methods in order to alleviate the accumulated levels of fatigue, as to provide the

optimal adaptations for sport performance and prevent excessive training fatigue. The current part of this chapter will discuss recovery strategies for optimising and enhancing the recovery process, with particular attention on the benefits of tapering and nutrition.

2.2.1. Training periodisation and tapering

In competitive sports the intention of every athlete, elite or novice, is to enhance performance capacity which is achieved through exercise training. During training periodisation, periods or cycles (microcycles, mesocycles, macrocycles) of high volumes of intensive training provide the required loading or stimulus for adaptations; these are interspersed by recovery periods in order to enhance physical performance (Whyte, 2006; Figure 2.1). This reduction in the training load allows the recovery of physiological capacities that were impaired by the previous training phase and should restore the tolerance to training which results in further training adaptations and performance enhancements (Mujika and Padilla, 2003), formally known as the supercompensation phase. Typically, the higher the training load is the need for recovery intensifies in order to achieve the training-induced adaptations. In judo, the multi-directional requirements of training can often compromise the equilibrium of the training:recovery ratio, resulting in high levels of accumulated fatigue. Under-recovery by maintaining high training loads with insufficient recovery periods (Figure 2.1) has been proven to lead to the onset of non-functional overreaching and overtraining, accompanied by impaired performance, low psychological preparedness, high levels of muscle damage, and immunosuppression (Meeusen et al., 2013).

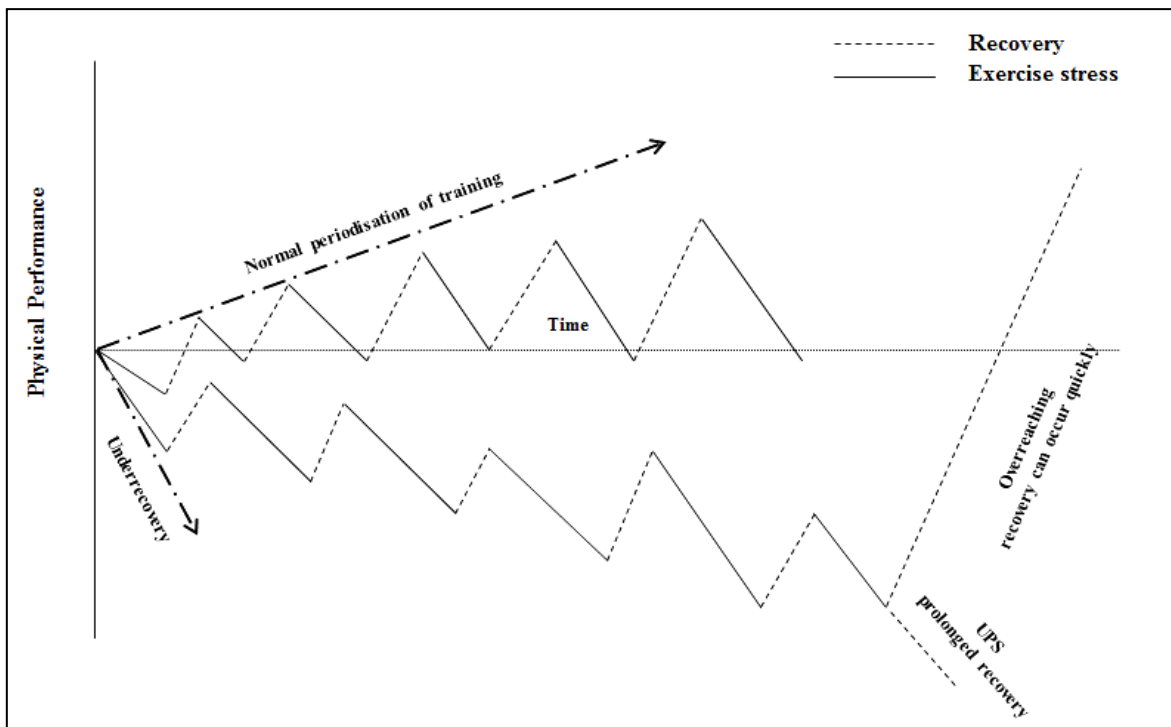


Figure 2.1. Schematic representation of training periodisation showing the relationship of exercise stress and recovery. Adequate/normal recovery is related to supercompensation of physical performance and underrecovery is related to overreaching and unexplained underperformance syndrome (UPS) (adapted from Whyte, 2006).

This systematic, progressive reduction in the training load during training periodisation, known as the taper, aims to achieve optimal performance and is usually performed for several days prior to competition. Performance optimization during tapering periods is not gained by additional training-induced fitness gains; rather, it results by significant reductions on the accumulated levels of fatigue. In general, the improvements in performance can range from 0.5-6.0 % (Mujika and Padilla, 2003), which often can make a substantial difference to the outcome of competition performance. The term “taper” has been given several definitions, as “a period of reduced training volume to enhance performance” (Trappe et al., 2001), and “an incremental reduction in training volume for 7–21 days before a championship race” (Houmard and Johns, 1994). More recently, Mujika and Padilla (2003) have redefined the taper as “a progressive, non-linear reduction of the training load during a variable amount of time that is intended to reduce the physiological and psychological stress of daily training and optimise sport performance”. However, reducing the training load imposes the danger of detraining; without a sufficient training stimulus, reducing the training load may be detrimental to training-induced adaptations (Izquierdo et al., 2007).

Judo athletes engage in substantial loads of high-intensity training, therefore the need for recovery is vital in order to perform at optimal capacity during training and competition. Especially in judo, since performance is also dependant on the opponent, the adverse effects of overtraining may be linked to further consequences that impair training capacity such as injuries and inability to practice the techniques with full speed and power.

2.2.1.1. Reduction of the training load

The reduction in the training load can be designed by modification of the different components of training, including training volume, intensity, frequency and duration (Mujika et al., 2004). The method or pattern as well as the duration of taper are also important elements for the efficacy of the taper. However, no studies have examined the effects of modification of the different components of training during recovery in the sport of judo.

Training intensity

It has been demonstrated that sustaining training intensity during the taper had preferable gains on sport performance (Hickson et al., 1985; Mujika and Padilla, 2003; Bosquet et al., 2007). Hickson et al. (1985) investigated the effects of decreasing training intensity on performance enhancements; subjects trained aerobically for 10 weeks, and for the successive 15 weeks training intensity was reduced by one- or two-thirds, whereas training volume and frequency remained unaltered. Gains in aerobic power and endurance as well as cardiac enlargement were not maintained when training intensity was reduced by one-third and even decreased when training intensity was reduced by two-thirds, highlighting the importance of sustaining training intensity during the taper. Similar results come from Shepley et al. (1992), who investigated physiological and performance measures during three different 7-day tapers in trained middle distance runners; a high intensity-low volume taper, a low intensity-moderate volume taper and a rest-only taper. Only the high intensity-low volume taper improved muscle strength and running time to exhaustion which was probably attributed to the increased citrate synthase activity, muscle glycogen levels, red cell and blood volume. Similarly, it has been shown that in a group of middle-distance runners, the high-intensity training during the taper promoted anabolic activity and recovery process, whereas conversely, the low intensity-high volume taper resulted in low total T levels and increased CK activity (Mujika et al., 2000). The majority of studies

assessing the effects of training intensity during the taper are in agreement, whereas high intensity training during tapering is vital for maintaining training adaptations and optimising performance; a meta-analysis of the tapering literature by Bosquet and colleagues (2007) provided enlightenment to whether the reduction in the training load should or should not be decreased at the expense of training intensity. In accordance with the cohort of studies it was concluded that not decreasing training intensity had a significant overall effect size, thus suggesting that maintaining training intensity is the key requirement during periods of reduced training for maintenance of training-induced adaptations during the taper.

Training volume

Analysis of the accumulated evidence showed that reductions in the training volume were more sensitive to performance gains, thus suggesting that reductions in training load should be achieved primarily through reductions in training volume (Bosquet et al., 2007). Shepley et al. (1992) reported that a 3-week low-volume taper enhanced performance and physiological adaptations in swimmers compared with a moderate-volume taper. Similarly, Mujika et al. (2000) showed that a higher reduction (75%) of the training volume enhanced performance and training-induced adaptations, compared with a lower reduction of the training volume (50%). In their meta-analysis Bosquet and colleagues (2007) concluded that maximal performance gains were achieved with reductions of 41% to 60% to pre-taper training volumes, as computed by the area under the training volume-time curve. Nevertheless, it has been observed that training-induced adaptations can be maintained with lower or higher reductions of the training volume.

Training frequency

Mujika et al. (2002) observed that in a group of trained runners not decreasing training frequency resulted in a 1.9% enhancement of 800-m performance, whereas a 33% reduction in training frequency resulted in 0.4% non-significant enhancements in performance. According to the meta-analysis of Bosquet and colleagues (2007), decreases in training sessions' frequency has not been shown to provide significant performance enhancements, especially in sports like swimming, running and cycling. Nonetheless, the different fitness levels of individuals may affect training adaptations during tapering; it has been recommended that in order to maintain training adaptations, highly trained

athletes should maintain their training frequencies (>80%), whereas moderately trained individuals may decrease frequency just 30-50% of pre-taper values (Mujika and Padilla, 2003).

Duration of taper

Appropriate duration of the taper should result in optimising sport performance and inducing positive physiological and psychological adaptations. However, being able to establish the chronic period that separates the positive adaptations of taper from the negative consequences of detraining still remains a challenge. According to Mujika and Padilla (2003), most performance, psychological and physiological enhancements have been reported to occur in taper programs lasting 4-14 days in cyclists and triathletes, ~7 days in middle and long distance runners and 10-35 days in strength trained athletes. Bosquet et al. (2007) concluded that a dose-response relationship exists between taper duration and performance enhancements; optimal taper duration has been reported at 8-14 days, which distinguishes the time frame between positive training-induced adaptations and detraining. Nevertheless, the duration of the taper has been widely varied in the literature, where performance enhancements have also been observed in 1-, 3- and 4-week tapers, given that variations in the previous training load and intensity might influence the efficacy of the taper; thus athletes who complete high volumes of high intensity training require longer time to recover.

Taper mode

There are four types or patterns of reduction of the training load: linear taper, exponential taper with slow or fast time constant of decay of the training load and step taper (Figure 2.2). During the linear taper the training load is reduced in a systematic, linear manner and usually this type of taper implies a higher total training load than other types of tapers (Mujika and Padilla, 2003). During the exponential taper the training load is reduced in a systematic, exponential order, where the rate of training load reduction can be achieved either in a slow (slow decay taper) or fast rate (fast decay taper). In contrast to the tapers that reduce training load progressively, the step taper implies that the training load is reduced suddenly at a steady level, and this is often described as a reduced training procedure. Banister et al. (1999) examined the effectiveness of a 10-day exponential and step taper in triathletes following one month of intensive training. The exponential taper

resulted in a significant ~4.0% improvement in 5000-m maximal run time and a 5.4% increase in peak power output measured by a cycling test to exhaustion, whereas the step taper resulted in non-significant enhancements of 1.2% and 1.5%, respectively. Furthermore, the same study investigated which type of exponential taper was the most effective; following 6 additional weeks of intensive training, triathletes performed a 13-day exponential taper in which training load was reduced fast (time constant of decay=4 days) or slow (time constant of decay=8 days). The fast decay exponential taper resulted in a 6.3% enhancement in 5000-m run time and a 7.9% increase in peak power output, whereas the slow decay taper resulted in 2.4% and 3.8% enhancements, respectively. In their meta-analysis, Bosquet et al. (2007) analysed the outcomes of progressive (linear and exponential) tapers and step tapers; in agreement with the results of Banister et al. (1999), it was concluded that maximal gains were obtained when the tapering intervention involved reduction of the training load in a progressive manner. Taking the evidence collectively it may be suggested that exponential tapers with a fast time constant of decay may have result in more marked enhancements of performance.

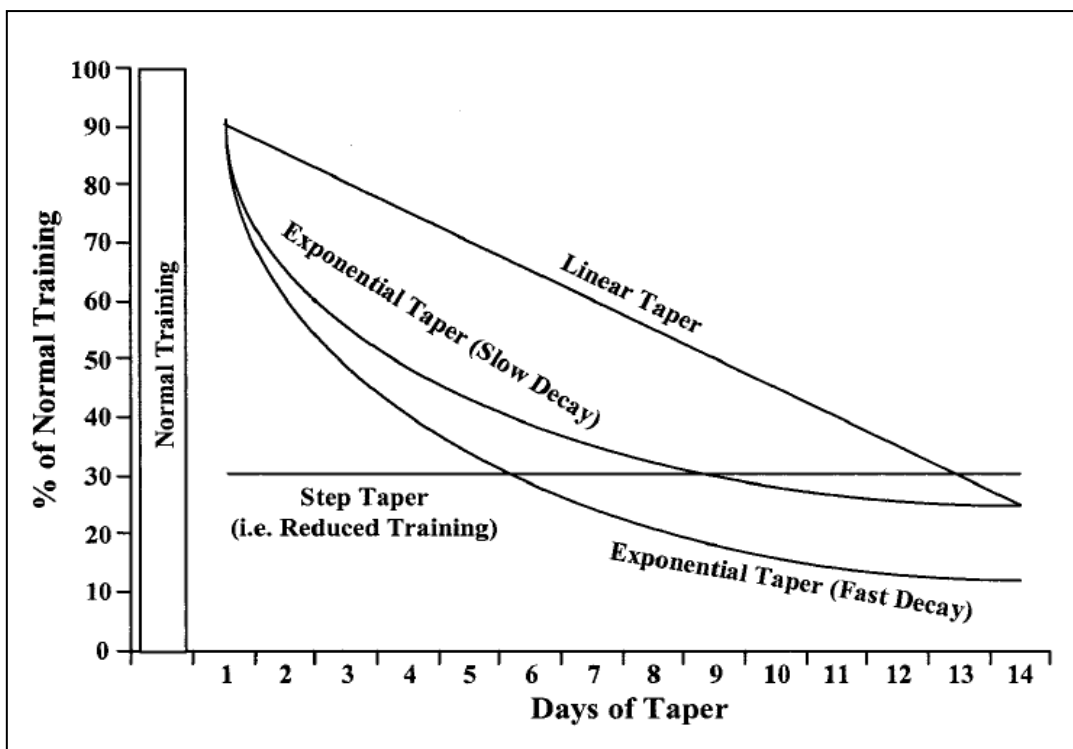


Figure 2.2. Schematic representation of the reduction of the training load during the different types of tapers, including linear taper, exponential taper with slow or fast constant of decay and step taper (described as reduced training) (adapted from Mujika and Padilla, 2003).

2.2.1.2. Taper-associated changes

Aerobic capacity

In highly trained athletes, $\dot{V}O_2\text{max}$ has been shown to increase or remain unchanged following tapers (Mujika et al., 2004). Improved $\dot{V}O_2\text{max}$ by 4.5% has been reported in cyclists at the end of a 2-week step taper, and was concomitant with a 7.2% enhancement in 8500-m outdoor time trial (Jeukendrup et al., 1992). Similarly, a 9.1% increase in $\dot{V}O_2\text{max}$ and enhancements in 5000-m maximal run time (1.2 - 6.3%) and cycling power (1.5 - 7.9%) have been reported in triathletes following a 2-week taper (Banister et al., 1999). However, several studies have reported no change in $\dot{V}O_2\text{max}$ levels, but this did not prevent enhancements in performance capacity. Unchanged $\dot{V}O_2\text{max}$ levels were evident in distance runners following a 7-day taper; however, with 3.0% improvements in 5000-m time trial performance (Houmard et al., 1994). Similar findings were presented by Shepley et al. (1992) in middle-distance runners, with unchanged $\dot{V}O_2\text{max}$ levels but improved treadmill running time (22.0%). In intermittent-type sports improvements in endurance capacity were also evident. In rugby league players there were increases in $\dot{V}O_2\text{max}$ values and $\dot{V}O_2\text{max}$ peak running speed as well as enhancements in the multi-stage running test performance following 7-day tapers (Coutts et al., 2007a; Coutts et al., 2007c). Collectively, it appears that $\dot{V}O_2\text{max}$ can increase or remain stable following tapers; however, an increase in $\dot{V}O_2\text{max}$ during the taper does not seem to be a requirement for increased endurance performance capacity, since performance may still be improved when no changes in $\dot{V}O_2\text{max}$ levels are evident. Judo requires high aerobic capacity for effective training and competition; however, no studies examined the efficacy of a taper in the aerobic capacity of judo athletes.

Muscle function and Strength performance

Muscular strength and power are also enhanced following tapers in several sports. Shepley et al. (1992) reported increased maximal voluntary isometric strength and evoked contractile properties of knee extensors following a 7-day taper. Similar results were observed in swimmers, where a 7.0 – 20.0 % increase in swim bench arm power and

competition performance were evident following a 3-week taper (Trappe et al., 2001). Interestingly, Trinity and colleagues (2006) observed a biphasic response in the increases in maximal arm power after a 3-week taper in swimmers; when the trends of power enhancements were grouped based on individual responses, the majority of the swimmers displayed a biphasic increase in power, with the first peak at 7 days of tapering and second peak at 21 days; in this study there were also some early and late responders who increased power at 14 days and 21 days, respectively. Additionally, rugby league players performing a 7-day taper also increased their speed, strength and muscle function in terms of vertical jump, sprint running, 3-repetition maximum squat and bench press, chin-ups, peak isometric quadriceps and hamstrings torque and total work at a set movement velocity (Coutts et al., 2007a). Muscle strength performance is an important component of training in judo. The high rate of body contact during judo training and competition demands for all throws and movements to be performed in full speed and power. Callister et al. (1990) reported that increasing the training load by 100% resulted in significant decreases in isokinetic peak torque of elbow and knee flexion and extension; however, no studies examined the efficacy of a subsequent taper on muscle strength/function performance.

Markers of muscle damage

Creatine kinase: Strenuous or unaccustomed eccentric physical activity often results in inflammation and damage of the affected muscles and subsequent feelings of sore and weak muscles. The exercise-induced muscle fibre breakdown induces leakage of myogenic enzymes into the bloodstream, one of the most important ones being CK. CK comprises one of the most widely used biomarkers utilised to assess muscle-related training stress and recovery. The majority of studies report a decrease in circulating CK levels during tapers, nonetheless a few studies reported no change (Mujika et al., 2004). Child et al. (2000) reported lower CK levels following a half-marathon compared to pre-taper values in trained runners after a 7-day taper; however, performance time did not improve. Lower CK values were also evident following a 3-week taper in middle-distance runners without enhancements in performance capacity (Houmard et al., 1990). In rugby league players, Coutts et al. (2007a) reported decreased CK activity following a 7-day taper which coincided with enhancements in aerobic performance. On the contrary, no changes in CK levels were found in triathletes after a 2-week taper (Coutts et al., 2007c) and in runners

after a 6-day taper (Mujika et al., 2000), even when performance enhancements were evident.

Delayed onset muscle soreness (DOMS): Muscle soreness is another important measure of muscle damage, as high ratings of soreness can negatively influence the athletes' capacity for optimal performance for training and competition and several strategies have been proposed to attenuate muscle soreness during training and recovery (Cheung et al., 2003; Barnett, 2006). Judo is an explosive contact sport that incorporates several eccentric actions with high impact forces involving full use of the entire body; subsequently athletes often experience sore muscles, bruises and light muscle injuries. DOMS is a rather subjective measure of the sensation of aching muscles, usually manifested 1-2 days after the initial muscle damage and it is mostly attributed to the exercise-induced inflammation which limits range of motion and production of maximal power. However, evidence on muscle soreness during training and tapering in judo are scarce. Muscle soreness is commonly measured using a visual analogue scale, with a subjective rating of the athlete's level of soreness on a scale of 1-10. This approach is frequently used in the field as it is fast and easily comprehensible by the athletes.

Endocrine responses

Testosterone, cortisol and the testosterone:cortisol ratio: Overreaching and overtraining are often accompanied by hormonal changes, including lower than normal T concentrations and elevated C levels at rest (Halson and Jeukendrup, 2004). Elevated C levels at rest have been suggested as an approach to assess excessive training fatigue or the onset of overreaching (Urhausen et al., 1995). Conversely, in already overreached athletes, an adrenocortical dysfunction or "exhaustion" of the hypothalamic-pituitary-adrenal axis to exercise is reported, which is manifested by a markedly lower than normal C response post-exercise. The use of testosterone:cortisol (T/C) ratio has been proposed to provide an indication of the anabolic/catabolic balance response to training, where a decrease in the T/C ratio by >30% may indicate "insufficient regeneration" and the onset of overreaching (Meeusen et al., 2013). However, the efficacy of the T/C ratio as a method to assess overreaching is controversial; a depressed T/C ratio has been found in athletes showing no declines in performance, whereas no change in T/C ratio has been found in overreached athletes (Halson and Jeukendrup, 2004). Therefore, the evidence suggests that monitoring the T/C ratio could indicate the chronic state of fatigue and recovery, but may not serve as

a sole indicator for overreaching and tapering. The literature regarding T and C responses to tapering is inconsistent (Mujika et al., 2004). A recent study by Zehsaz et al. (2011) reported increased plasma total T concentrations and T/C ratio and decreased plasma C following a 1- and 3-week taper in cyclists, which coincided with improvements in performance capacity. Similarly, increased T/C ratio was evident following a 1-week taper in rugby league players (Coutts et al., 2007a) and after a 2-week taper in triathletes (Coutts et al., 2007c). Conversely, no changes in T, T/C ratio and C were observed after a 6-day taper in middle-distance runners (Mujika et al., 2000) and following a 4-week taper in strength-trained subjects (Izquierdo et al., 2007), even when enhancements in performance capacity were evident. Saliva measurements of T and C can provide a reference for their respective blood concentrations at rest and after exercise. Assessment of C (Gozansky et al., 2005) and T (Morley et al., 2006) in saliva has been suggested to reflect the free concentration of steroid hormones in blood and thus, the biologically active portion of the hormone. Therefore, saliva measurements of C and T can serve as a useful, stress-free and non-invasive tool to assess endocrine responses to training; however, there are currently no studies that have examined these endocrine responses during judo training and recovery. Monitoring T and C responses in saliva during a period of intense training and tapering in judo athletes could aid identifying the exercise stress associated with training.

Immune function

SIgA: Prolonged intensive training can compromise aspects of immunity, including the “first line” of defence against common URTI infections; this is described in the “open window theory” which makes the athletes vulnerable to picking up common infections or reactivation of a previous virus (Walsh et al., 2011). Engaging in long-term, strenuous training resulted in decreased SIgA concentrations and/or secretion rate in triathletes, (Libicz et al., 2006), swimmers (Gleeson et al., 1999a; Gleeson et al., 1999b), kayakers (Mackinnon et al., 1993), distance runners (Mackinnon and Hooper, 1994) and football players (Fahlman and Engels, 2005). Although a large cohort of studies examined SIgA responses to intense exercise and training, there is limited evidence regarding the responses of SIgA in response to recovery training or tapering. One study by Moreira and colleagues (2013b) examined SIgA responses and URTI severity during a period of intense training and tapering in futsal athletes; no changes in SIgA concentrations and secretion rate were

found, despite a significant decrease in URTI symptom severity during the taper. However, no reports of SIgA concentrations and secretion rate responses to tapering in judo exist.

Leukocytes: Leukocytes comprise one of the body's immune defences against infectious diseases and foreign invading microorganisms. Leukocytes can indirectly influence performance in sports, keeping the athletes healthy (illness-free) to keep up with their training regimens. A study in female judo athletes showed reduced blood leukocyte and neutrophil counts as well as compromised monocyte oxidative burst and phagocytic activity following a 1-week training camp (Umeda et al. 2008). Generally, it appears that chronic intensive training with insufficient recovery can negatively affect the function but not necessarily the numbers of circulating leukocytes, leading to depression of acquired immune function (Walsh et al., 2011).

Mood disturbance

Excessive training-induced stress and fatigue are usually associated with psychological disturbances and negative affective state (Halson and Jeukendrup, 2004; Meeusen et al., 2013), whereas tapering can enhance psychological measures which will positively affect competitive performance (Mujika et al., 2004). The Profile of Mood State questionnaire (POMS) has been widely used in the literature as a means to measure states of mood (McNair et al., 1971) and has been validated to assess athletes' mood condition (Terry et al., 2003). The questionnaire quantifies negative measures of tension, anger, confusion, fatigue, depression, and positive measure of vigour as well as a measure of global mood disturbance. Zehsaz et al. (2011) assessed global mood disturbance in cyclists during intense training and tapering of 1- and 3-week duration; POMS scores increased during intensive training, whereas significant declines in mood disturbance were evident after 1 week tapering with further declines following 3 weeks tapering. Similarly, acute decreases in total mood disturbance were found in young competitive swimmers following a 7-day pre-competition taper, along with declines in scores of depression, confusion and tension (Berger et al., 1997). Contrasting results come from Martin and colleagues (2000) who reported no change in global mood disturbance or specific mood scores following 6 weeks of heavy training and a 1-week taper in cyclists; however, in this study a large inter-individual variation in POMS scores was evident. Taking the evidence together, it appears that tapering is accompanied with enhancements in mood state in several sports as measured by the POMS (Mujika et al., 2004). Mood state is extremely important in judo,

since judo a sport with high body contact; therefore the psychological state of the athlete is often detrimental to winning or losing.

2.2.2. Nutrition

Proper nutrition is a crucial aspect of effective recovery and a necessary aid for optimising exercise quality. Nutritional practices aim to compensate for the increased needs for energy and hydration that is lost through intensive training and enhance muscle-related recovery as to aid the athlete recover and subsequently prevent the onset of overreaching.

2.2.2.1. Hydration

During recovery from exercise it is necessary to effectively restore body fluids to prevent the well-recognised detrimental effects of dehydration and subsequently maintain optimal performance (Shirreffs et al., 2004). Common strategies include adequate fluid consumption before, during and after the training session, especially when it is performed in the heat and humidity. The American College of Sports Medicine (ACSM) advocates in their position stand that during recovery, athletes should consume approximately 1.0 - 1.5 l of fluid for every kg of body weight lost during exercise (Rodriguez et al., 2009). However, ingestion of plain water is not recommended since it lowers plasma osmolality and sodium concentrations, decreases sensation of thirst and reduces fluid retention by increasing urine production (Maughan, 1991). The ingestion of drinks with added electrolytes (primarily sodium and chloride) can help prevent hyponatraemia and successfully restore hydration. Maughan and Shirreffs (2004) emphasize the importance of restoring sodium along with water especially during exercise, highlighting the increased needs for electrolyte and fluid intake after exercise in heat and humidity. This is especially important in judo, where a typical judo training session lasts 2.0 - 2.5 h indoors, whilst during this time the athletes are required to wear the *judogi*; these facts along with the high training intensity increase core temperature and reduce heat loss due to limited evaporation through the skin. Replacing fluids and electrolytes lost in sweat can adequately be accomplished by consumption of rehydration beverages in addition to salty foods/snacks, or by consuming a sports beverage with added electrolytes (Rodriguez et al., 2009). Therefore, effective rehydration using fluids and electrolytes is essential during and after judo training for optimal recovery.

2.2.2.2. Carbohydrate

CHO is the main substrate for both muscle action and the central nervous system, whereas CHO availability can become a limiting factor for performance especially during prolonged (>90 min) and intermittent high-intensity exercise sessions (Burke et al., 2004). It is evident that CHO consumption is important before and during the exercise session as to provide fuel for exercise, whilst CHO ingestion after training or competition is crucial for facilitating muscle glycogen resynthesis and restore energy levels during recovery. It is well accepted that immediate (within 60 min) CHO intake during recovery from exercise at a rate of 1.0 - 1.5 g⁻¹·kg body weight⁻¹·h⁻¹ for up to 6 h can sufficiently replenish glycogen stores (Rodriguez et al., 2009). The most rapid rate of muscle glycogen resynthesis post-exercise is reported to occur during the initial, insulin-independent phase of recovery and lasts 30-60 min; it is reported that the immediate consumption of CHO and the low levels of muscle glycogen after exercise maximises the rate of glycogen resynthesis during this initial phase of recovery (Jentjens and Jeukendrup, 2003). Recommendations for daily CHO intake for athletes focus on high-CHO diets, with CHO levels ranging from 6 - 10 g⁻¹·kg⁻¹·day⁻¹ for maintaining energy levels and replacing muscle glycogen (Rodriguez et al., 2009). Intake of CHO for refuelling during recovery mainly concerns strategies that focus on dietary CHO with moderate-high glycaemic index foods in order to reach the threshold of muscle glycogen storage, without differences in rates of glycogen storage whether CHO is given in large meals or frequent smaller snacks (Burke et al., 2004). However, high-CHO diets are often impractical in judo where athletes undergo weight reduction by reducing their energy intake in the days/weeks preceding the competition. It has been reported that a typical judo training session elicits energy expenditure of ~1800 kcal, adding up to 3350 kcal of daily energy expenditure; moreover, when the average CHO intake was calculated in these judo athletes, it was below the French recommended daily allowance even though their daily energy intake was equivalent to their daily energy expenditure (Degoutte et al., 2003). This study highlights the general common view of judo athletes towards their nutrition and CHO consumption, thus engaging in moderate/low CHO diets even during periods of intensive training. It has been reported that moderate/low CHO diet during intensive training resulted in deterioration of performance and increased mood disturbance, both characteristic symptoms of overreaching (Achten et al., 2004; Halson et al., 2004). Judo athletes usually fail to take the required amount of CHO via their diets, therefore practices should focus on the immediate post-exercise CHO

consumption as to replenish energy stores and muscle glycogen resynthesis. Therefore, the early consumption of CHO after intensive exercise in judo could serve as a nutritional aid for initiating the recovery process by taking advantage of the insulin-independent phase for optimising glycogen resynthesis and restoring energy levels.

2.2.2.3. Protein

Protein intake is essential for athletes during recovery from exercise for aiding the repair of exercise-induced muscle damage, promoting hypertrophy through training-induced anabolic adaptations of muscle tissue, and more sparingly, replenishing energy stores that have occurred during glycogen-depleting exercise (Phillips, 2011). The ACSM suggests that daily requirements of protein intake are higher in athletes than sedentary individuals, with values at 1.2 to 1.4 g⁻¹·kg⁻¹·day⁻¹ for endurance athletes and 1.6 to 1.7 g⁻¹·kg⁻¹·day⁻¹ for resistance and strength-trained athletes (Rodriguez et al., 2009). Normally, these requirements can be met through diet alone with sufficient energy intake to maintain body weight (Rodriguez et al., 2009). It is evident that unaccustomed exercise or exercise that includes eccentric loading can often lead to muscle tissue disruption leading to muscle soreness and impairment of muscle function. In the absence of amino acids during recovery from exercise, the rate of muscle protein breakdown exceeds that of synthesis resulting in net protein loss. Consumption of protein during the acute post-exercise period is the optimal time to achieve hyperaminoacidaemia, which stimulates muscle protein synthesis and diminishes protein degradation; these mechanisms will sequentially attenuate levels of muscle damage and soreness and optimise the recovery of muscle function (Phillips, 2014). A systematic review by Pasiakos et al. (2014) concluded that when supplemental protein is ingested after daily training sessions there are beneficial effects on the muscles such as attenuated levels of muscle soreness and reduced muscle damage, and that these effects are greatest in athletes with negative nitrogen and/or energy balance. However, in their review they indicate that evidence is inconsistent, with great variability between individuals and in surrogate markers of muscle damage. Casein protein (40 g) ingested just before sleep (~30 min) has also been reported to be effective in stimulating muscle protein synthesis and improving whole-body protein balance during the post-exercise 7.5 h of overnight recovery (Res et al., 2012). Judo is a combat sport that engages several eccentric and isometric movements with high levels of exercise-induced muscle damage, which often lead to muscle soreness and deterioration of muscle function and

subsequently compromise performance of consecutive training sessions. Therefore, consumption of protein during recovery from a judo training session could be vital for maintaining muscle mass and managing exercise-induced muscle damage.

2.2.2.4. Co-ingestion of carbohydrate and protein

Co-ingestion of CHO and protein post-exercise has been proposed as an effective means to promote muscle glycogen resynthesis and muscle-related recovery (Jentjens and Jeukendrup, 2003). The mechanism behind the CHO-protein supplements relies on the synergistic action of CHO and protein to stimulate a marked hyperinsulinaemia and hyperaminoacidaemia respectively, mechanisms that stimulate glucose uptake and glycogen storage as well as promoting muscle protein synthesis and suppressing muscle protein breakdown. Previous studies have shown that when CHO is co-ingested with protein during the early hours of recovery is more beneficial than CHO or protein intake alone in maximizing the rates of glycogen resynthesis (Tarnopolsky et al., 1997; Ivy et al., 2002; Berardi et al., 2006) and simultaneously reducing the post-exercise protein degradation and increasing post-exercise protein synthesis manifested by reduced levels of muscle damage and/or soreness (Saunders et al., 2004; Millard-Stafford et al., 2005; Romano-Ely et al., 2006; Rowlands et al., 2008). The ACSM states that glycogen synthesis rates are similar when isocaloric amounts of carbohydrates or carbohydrates plus protein and fat are provided after endurance or resistance exercise; therefore including protein (in addition to CHO) in a post-exercise meal, may provide the required amino acids for muscle protein repair and promote a more anabolic hormonal profile (Rodriguez et al., 2009). However in reality, appetite is usually suppressed immediately after exercise, thus drinking fluids than eating whole foods is preferable by most athletes.

Sport beverages: Commercially available sport recovery drinks are designed to contain both CHO and protein as to restore hydration, replenish energy needs and provide the required amounts of amino acids. Ivy et al. (2002) found that a CHO-protein beverage can more effectively replenish muscle glycogen post-exercise than can a CHO beverage equivalent to total CHO or total caloric content. Similarly, Williams et al. (2003) showed that a CHO-protein-electrolyte beverage vs. a CHO-electrolyte beverage taken after glycogen-depleting exercise resulted in 17% higher plasma glucose, 92% greater insulin response, and 128% greater muscle glycogen storage. However, this study has a major limitation since the CHO-electrolyte beverage provided less CHO ($0.3 \text{ g}\cdot\text{kg}^{-1}$) than the

CHO-protein-electrolyte beverage ($0.8 \text{ g}\cdot\text{kg}^{-1}$), thereby the results could have simply occurred due to greater glucose availability. Jentjens et al. (2001) examined the effects of two beverages, one containing only CHO (ingested at a rate of $1.2 \text{ g}\cdot\text{kg}^{-1}\cdot\text{h}^{-1}$) and the other containing the same amount of CHO with added protein ($0.4 \text{ g}\cdot\text{kg}^{-1}\cdot\text{h}^{-1}$). These authors observed that muscle glycogen resynthesis was similar between beverages, even though the CHO-protein beverage resulted in higher insulin concentrations. This study suggests that it is substrate availability rather than insulin concentration that is the limiting factor in glycogen resynthesis. Consequently, it might be impractical for athletes to consume such large amounts of CHO ($1.2 \text{ g}\cdot\text{kg}^{-1}\cdot\text{h}^{-1}$) and alternatively co-ingestion of moderate amounts of CHO ($0.8 \text{ g}\cdot\text{kg}^{-1}\cdot\text{h}^{-1}$) with some protein may induce similar glycogen resynthesis rates and at the same time to aid the recovery of muscle damage and soreness. Studies have consistently shown that when protein was co-ingested with CHO there was an attenuation of muscle soreness and/or markers of muscle damage albeit performance on the next training session was not enhanced (Saunders et al., 2004; Millard-Stafford et al., 2005; Romano-Ely et al., 2006). However, sports drinks are relatively expensive, not easily available and the artificial substances contained raise the question as to whether they would be healthy in the long term.

Chocolate milk: Milk-based beverages are increasing in popularity as post-exercise recovery aid since they are commercially available, relatively inexpensive and a natural whole food. CM includes CHO and protein, as well as electrolytes and fluids and accordingly can provide the required nutrients for refuelling (Wilkinson et al., 2007; Ferguson-Stegall et al., 2011; Lunn et al., 2012) and rehydration (Shirreffs et al., 2007; Watson et al., 2008) during post-exercise recovery. In addition, CM contains cocoa which has antioxidant properties. Therefore, for the needs of the current thesis the CM chosen would provide the athletes with at least 1 g of CHO per kg body weight, 35 g of protein and 1000 ml of total fluid; the ingredients of the CM are presented in Table 2.1. This composition of the CM ingredients is similar to the literature using milk-based beverage as a post-exercise recovery beverage (Table 2.2), thus providing at least 1 g of CHO per kg body weight (90-110 g per 1000 ml), 30-40 g of protein per 1000 of fluid, and 500-2300 ml of total fluid (according to the post-exercise rehydration needs). Milk-derived proteins such as whey and casein are rich in leucine, a key amino acid which serves as a metabolic trigger for hypertrophy, being a regulatory activator of skeletal muscle protein synthesis (Phillips, 2014). It has been suggested that milk-based proteins are superior to soy-based

proteins in promoting muscle protein accretion and synthesis when consumed after resistance exercise (Wilkinson et al., 2007). Table 2.2 shows all previous studies that have examined the effects of CM (or whole milk) on recovery; only a few have utilised measures of muscle function (shown as part a) whereas many studies have utilised tests of endurance performance capacity (shown as part b). Generally, from this Table it appears that milk consumption during recovery was more or equally beneficial to CHO-sports drinks in enhancing subsequent strength or endurance exercise performance. Only a few studies have examined the effects of CM on responses of markers of muscle damage and muscle soreness during recovery from damaging eccentric exercise; these studies have consistently showed lower CK responses after CM consumption (Cockburn et al., 2008; Pritchett et al., 2009; Cockburn et al., 2010; Gilson et al., 2010) but only one of these studies demonstrated lower DOMS ratings (Cockburn et al., 2010). The studies of Cockburn et al., (2008) and Cockburn et al., (2010) have shown that the attenuated CK responses after muscle damaging exercise were accompanied with enhancements of subsequent strength performance; however, the lower DOMS ratings were only observed when the CM was compared with W (Cockburn et al., 2010). C and T responses were measured in only a couple of studies involving acute exercise bouts, however with no differences between post-exercise consumption of CM, CHO or Placebo (Wojcik et al., 2001; Ferguson-Stegall et al., 2011). However, both these studies used blood measurements of C and T and involved a glycogen depletion trial prior to a standardised endurance (Ferguson-Stegall et al., 2011) or muscle function (Wojcik et al., 2001) exercise protocol. However, no evidence on the salivary responses of C and T with CM consumption after an actual training session are reported in the literature. Regarding exercise training, Gilson et al. (2010) observed no differences in soccer-specific performance and muscle function between post-exercise consumption of CM and an isocaloric CHO-replacement beverage during short-term intensified soccer training; however, the consumption of CM attenuated serum CK concentrations compared with the CHO-replacement beverage at the end of the intensified training period (day 4). Post-exercise milk consumption was also reported to be more or equally beneficial to CHO-electrolyte drinks during post-exercise rehydration. Post-exercise consumption of whole milk in exercise-induced dehydrated active males provided better net fluid balance during recovery compared with a CHO-electrolyte beverage (Watson et al., 2008), whereas CM was as beneficial as a CHO-drink in the rehydration of trained subjects after endurance exercise bouts (Karp et al., 2006). However, from Table 2.1, it appears that most studies

involved laboratory-based testing endurance performance (b) and a few studies examined laboratory-based strength performance or muscle function (a) using standardised exercise protocols; subsequently evidence on the possible beneficial effects of post-exercise CM consumption during “real-life” training and field-based studies are currently lacking. Although many studies utilised populations of trained athletes, there are no evidence on the effects of CM in populations of elite judo athletes. Judo training involves eccentric loading and muscle tissue micro-trauma in addition to the high training loads. However, judo athletes do not tend to consume any CHO-containing beverages because they are cautious about caloric content. It would be interesting to assess whether post-exercise consumption of a CM beverage that contains the required amounts of CHO and protein could aid recovery from intense judo exercise and training in an applied sport setting, especially during pre-competition weight loss periods.

Table 2.1. Ingredients of the chocolate milk beverage.

Energy (kcal·L ⁻¹)	870.0
Carbohydrates (g·L ⁻¹)	107.0
of which sugars	105.0
Protein (g·L ⁻¹)	35.0
Fat (g·L ⁻¹)	33.0
of which saturates	19.0
Sodium (g·L ⁻¹)	0.7
Calcium (g·L ⁻¹)	0.9
Phosphorus (g·L ⁻¹)	1.3
Vitamin B2 (mg·L ⁻¹)	1.5
Cocoa (g·L ⁻¹)	13.5

values supplied by manufacturer (Lanitis Dairy, Ltd)

Table 2.2. Studies utilising tests of (a) strength performance and muscle function and (b) endurance exercise performance, showing the effects of milk-based beverages during recovery on exercise performance, markers of muscle damage and delayed-onset muscle soreness (DOMS) and post-exercise rehydration.

Reference	Subjects	Design	Exercise and recovery	Timing of supplementation	Type of supplementation	Effects on exercise performance	Effects on muscle damage and soreness	Effects on rehydration
<i>(a) Strength and muscle function</i>								
(Cockburn et al., 2010)	Trained athletes Males (n=32)	Crossover and placebo-controlled	6x10 eccentric reps of both legs – 24 h, 48 h, 72 h – 6 concentric reps of both legs	- Before exercise, - Immediately post-exercise, - 24 h post-exercise	Chocolate milk (1000 ml) Water (1000 ml)	↑ peak torque at 48 h ↑ reactive strength index at 48 h	↓ CK at 48 h ↓ DOMS at 48 h	
(Gilson et al., 2010)	Soccer players Males (n=13)	Crossover	4 days of intensive soccer training – 48 h, 96 h – isometric quadriceps force, agility t-drill test and vertical jump tests	After each training session	Chocolate milk (672 ml) CHO drink (672 ml)	~ isometric quadriceps force ~ agility test ~ vertical jump	↓ CK ~ Mb ~ DOMS	
(Cockburn et al., 2008)	Team sports athletes Males (n=24)	Crossover and placebo-controlled	6x10 eccentric reps of both legs – 24 h, 48 h – 6 concentric reps of both legs	Immediately post-exercise	Chocolate milk (1000 ml) CHO drink (1000 ml) Milk (1000 ml) Water (1000 ml)	↑ total work of set at 48 h ↑ peak torque at 48 h	↓ CK at 48 h ↓ Mb at 48 h ~ DOMS	

(b) Endurance capacity

(Lunn et al., 2012)	Runners Males (n=8)	Crossover	45-min run at 65% $\dot{V}O_2$ peak – 4.5 h – running at $\dot{V}O_2$ peak until exhaustion (duration not reported)	Immediately post-exercise	Chocolate milk (480 ml) ————— CHO drink (480 ml)	↑ time to exhaustion	
(Spaccarotella and Andzel, 2011)	Soccer players Males and females (n=13)	Crossover	Morning soccer session – 15-18 h – Afternoon soccer session and shuttle run to exhaustion (6-8 min)	Immediately post-exercise	Chocolate milk (514 – 716 ml) ————— CHO drink (514 – 716 ml)	↑ time to exhaustion (n=5 men)	
(Ferguson-Stegall et al., 2011)	Endurance athletes Males and females (n=10)	Crossover and placebo-controlled	1.5 h cycling or running (70% $\dot{V}O_2$ max) and 10x1- min intervals (45%- 90% $\dot{V}O_2$ max) – 4 h – 40-km time trial	Immediately and 2 h post-exercise	Chocolate milk (1000 – 1400 ml) ————— CHO drink (1000 – 1400 ml) ————— Water (1000 – 1400 ml)	↓ time trial time ↑ total work	~ cortisol ~ Mb ~ CK ~ IL-6 ~ IL-8 ~ IL-10 ~ IL-1Ra ~ TNF-a

(Thomas et al., 2009)	Trained cyclists Males (n=9)	Crossover	2-min cycling intervals at 90-50% peak power output until exhaustion – 4 h – cycling at 70% $\dot{V}O_2$ max until exhaustion (21-32 min)	Immediately and 2h post-exercise	Chocolate milk (460 ± 53 ml) <hr/> CHO drink (527 ± 60 ml) <hr/> Fluid replacement drink (527 ± 60)	↑ time to exhaustion by ~50%	
(Pritchett et al., 2009)	Trained cyclists and triathletes Males (n=10)	Crossover	6 sets of 3x10-s sprints – 15-18 h – cycling at 85% $\dot{V}O_2$ max until exhaustion (~13 min)	Immediately post-exercise	Chocolate milk (1.0 g CHO kg ⁻¹ ·h ⁻¹)* <hr/> CHO drink (1.0 g CHO kg ⁻¹ ·h ⁻¹)*	~ time to exhaustion	↓ CK ~ DOMS
(Watson et al., 2008)	Recreationally active Males (n=7)	Crossover	Several bouts of 10-min intermittent cycling (55% $\dot{V}O_2$ max) until mild dehydration – 3 h – cycling at ~61 % $\dot{V}O_2$ max until exhaustion (~40 min)	30 min post-exercise	Milk (2263 ± 241 ml) <hr/> CHO-electrolyte drink (2280 ± 249 ml)	~ time to exhaustion	↓ urine volume ~ electrolyte balance ↑ serum osmolality

(Karp et al., 2006)	Trained cyclists Males (n=9)	Crossover	2-min cycling intervals at 90-50% peak power output until exhaustion – 4 h – cycling at 70% $\dot{V}O_2$ max until exhaustion (25-40 min)	Immediately and 2h post-exercise	Chocolate milk (509 ± 36 ml)	Fluid replacement drink (509 ± 36 ml)	↑ time to exhaustion ↑ total work	~ body weight ~ total body water
(Wojcik et al., 2001)	Untrained Males (n=27)	Crossover and placebo-controlled	40-min cycling at 70% $\dot{V}O_2$ peak and 5x1-min maximal cycling sprints – overnight rest – 10x10 eccentric reps of dominant leg at 120% 1RM	Immediately and 2h post-exercise	Strawberry milk (1.25 g CHO kg ⁻¹ ·h ⁻¹)*	CHO drink (1.25 g CHO kg ⁻¹ ·h ⁻¹)*	~ peak torque ~total work	~ CK (p=0.08) ~ IL-6 ~ cortisol ~testosterone ~ DOMS
					Water (1.25 g CHO kg ⁻¹ ·h ⁻¹)*			

↑ and ↓ indicates significantly higher or lower (p<0.05) respectively vs placebo and/or CHO drink; ~ indicates no significant difference (p>0.05) vs placebo and/or CHO drink; * volume not reported

2.2.2.5. Dietary antioxidants

When exercise sessions are strenuous, prolonged and intensified there is an increase in oxidative reactions within muscle cell that are associated with increased production of free radicals or ROS. This exercise-induced increase in ROS has been linked to the increased energy demands of exercise training as the elevated aerobic metabolism involves increased mitochondrial respiration; this promotes superoxide radical leakage whereas muscle disruption results in activation of infiltrating phagocytic cells which release pro- and anti-inflammatory cytokines (Peake et al., 2007). Although the cellular appearance of oxidants is important for cell function and physiological adaptations (Powers et al., 2011b), high production of ROS promotes oxidative damage and dysfunction to cellular proteins and DNA, lipid peroxidation and muscle fatigue which could have detrimental effects on immune function and health (Peake et al., 2007). This imbalance of ROS to antioxidants in favour of the oxidants has been defined as “oxidative stress” (Powers et al., 2011b). Antioxidants have received great interest in favour of their ability to scavenge and neutralise ROS and are accordingly proposed to protect skeletal muscles against exercise-induced oxidative damage as well as to delay muscle fatigue (Powers et al., 2011a). Hence, a particular interest has arisen within sport population for antioxidant supplements especially in athletes that do not have well-balanced diets and may be deficient in antioxidant intake, as are judo athletes during pre-competition weight loss periods. However, the arguments of antioxidant supplementation in athletes remain equivocal; on one hand, antioxidant supplementation protects against oxidative damage and muscle fatigue, on the other hand, excessive antioxidant supplementation may impair some important exercise-induced muscular adaptations that are, at least in part, mediated by ROS and consequently blunt the training adaptations to exercise (Powers et al., 2011a). Generally, it is recommended that there is no need for exogenous antioxidant supplementation as long as the athlete follows a well-balanced diet including a variety of fruit and vegetables (Peake et al., 2007; Rodriguez et al., 2009). However, this is not always feasible, mostly in sports with weight categories (judo, taekwondo, wrestling) or when a low body weight is required (figure skating, gymnastics) or when athletes eliminate selected food groups from their diets (Muslims, vegetarians). Judo athletes may be more vulnerable to micronutrient deficiencies as they undergo several cycles of energy restriction for weight loss during a competitive season.

Vitamin C: Ascorbic acid or vitamin C is a powerful water-soluble antioxidant and found in most bright-coloured fruit and vegetables. Studies *in vitro* and in animals have shown that vitamin C acts as an effective antioxidant by scavenging ROS in intracellular and extracellular fluids and by aiding the regeneration of α -tocopherol; however, evidence from clinical studies in humans is weak (Padayatty et al., 2003). Vitamin C has also been proposed to act as an immunostimulant by reducing symptoms and severity of common cold, enhancing iron absorption, reducing cardiovascular disease risk and protecting against certain cancers (Schlueter and Johnston, 2011). Supplementation with vitamin C for 3 weeks preceding an ultramarathon has been shown to reduce URTI incidence in the post-race period (Peters et al., 1993), and was as effective in reducing respiratory infection symptoms as a vitamin cocktail containing vitamins C, E and A (Peters et al., 1996). Requirements of vitamin C may be higher in athletes as prolonged, strenuous exercise may leave the athlete more susceptible to vitamin C deficiency; Gleeson et al., (1987) observed a 20% decrease in plasma ascorbic acid after a 21-km race which remained low for the next 2 consecutive days. Even though the general belief on vitamins is “the more, the better”, the effects of vitamin C supplementation on enhancing recovery from exercise in relation to the oxidative stress and muscle soreness are equivocal (Peake et al., 2007). Although there is some evidence to show that vitamin C consumption in the weeks preceding the exercise could attenuate the rise in inflammatory and and/or endocrine markers and/or soreness (Nieman et al., 2000; Davison and Gleeson, 2005), other studies have not been able to show any beneficial effects of vitamin C supplementation (Nieman et al., 1997; Thompson et al., 2003; Davison and Gleeson, 2006). Moreover, it has been observed that in some cases, supplementation with vitamin C could serve as a pro-oxidant rather than antioxidant, especially if taken after the exercise bout (Childs et al., 2001; Close et al., 2006). Taking the evidence together, it appears that the question whether vitamin C supplementation is beneficial to athletes remains unanswered. Therefore, it can be concluded that a well-balanced diet with abundance of antioxidant fruit and vegetables could provide the required amounts of vitamin C.

Vitamin E: Vitamin E (α -tocopherol, γ -tocopherol) is a lipid-soluble antioxidant vitamin and mostly found in oils, nuts and seeds. Vitamin E is the major antioxidant in almost all cell membranes which serves to chain-break ROS-induced reactions; its antioxidant abilities include the conversion of peroxy radicals into less reactive forms as well as to scavenge and break down the products of lipid peroxidation to protect cell membranes

(Powers et al., 2004). The effects of vitamin E on exercise-induced inflammatory responses are again variable. Although some studies show enhanced recovery of oxidative markers and soreness with vitamin E supplementation, especially when combined with other antioxidants (Cannon et al., 1990; Fischer et al., 2004), other studies report no effect (Singh et al., 1999; Mastaloudis et al., 2006) or even increases (Nieman et al., 2004; McAnulty et al., 2005) in markers of oxidative damage. A review by Evans (2000) suggests that supplementation with vitamin E may be beneficial in skeletal muscle repair after muscle-damaging exercise, as illustrated by decreases in circulating CK levels and enhanced neutrophil response to eccentric exercise.

Flavonoids: Flavonoids are the largest group of polyphenolic compounds and are found widely distributed in plants with many attributed antioxidant capacities (Malaguti et al., 2013). There are several antioxidant substances within the flavonoids family with the most important of which being flavonols (including quercetin), flavanols (including catechins) and anthocyanins. Flavonoid varieties are distributed in abundance among berries, nuts, tea, wine and some vegetables, and have been proposed to have strong immunomodulatory, antioxidant and anti-inflammatory functions and thus may help to protect against the effects of exercise-induced muscle disruption and oxidative stress (Malaguti et al., 2013).

Cherries are widely known as highly antioxidant foods attributed to their high content of polyphenolic compounds, mainly anthocyanins. During the last 10 years, numerous investigations have studied their effects on exercise-induced oxidative stress and recovery. Cherries have received great interest regarding their ability to assist athletes recover quickly and efficiently from intense exercise/training. Tart Montmorency cherry juice supplementation before and after a marathon race has been found to attenuate post-exercise inflammatory response, induce faster recovery of isometric strength and increase total antioxidant status compared with placebo (Howatson et al., 2010). Consistent evidence supports the high antioxidant capacity of cherries for attenuating exercise-induced inflammation and muscle soreness, enhancing muscle function and reducing oxidative stress after prolonged intense exercise, which are all crucial aspects of recovery (Bell et al., 2014). In addition to their antioxidant capacities, tart cherries include melatonin which is highly associated with sleep management. Enhancement of sleep quality and quantity is of particular importance to the recovering athlete and cherry supplementation presents

promising effects on sleep regulation (Bell et al., 2014). Studies have shown that tart Montmorency juice improves sleep time and efficiency in asymptomatic patients (Howatson et al., 2012), whereas modest effect sizes were found on severity of symptoms in insomniacs (Pigeon et al., 2010). Therefore, there is strong evidence in support the use of cherry supplementation for assisting recovery in athletes especially when they are engaged in prolonged and strenuous bouts of exercise.

Cocoa has generated increasing interest in the field of exercise science attributable to its high content of antioxidant flavonoids. Dark chocolate bars contain $\geq 70\%$ cocoa and are considered one of the richest sources of dietary polyphenols. The majority of investigations have supported the antioxidant capacity of flavonol-containing dark chocolate showing attenuations in markers of oxidative stress post-exercise (Rein et al., 2000; Wang et al., 2000; Wiswedel et al., 2004; Allgrove et al., 2011; Davison et al., 2012). Allgrove et al. (2011) showed that daily dark chocolate consumption for 2 weeks and 2 h prior to exhaustive cycling exercise resulted in attenuated oxidative stress response (lower plasma F₂Isoprostanes and oxidised-LDL levels) and higher free fatty acid mobilisation during the recovery period, despite no effects on inflammatory cytokines and exercise performance. Davison et al. (2012) supported these findings by showing a small but significant increase in antioxidant capacity and a marked insulinaemia following a prolonged submaximal cycling bout after dark chocolate bar consumption. Therefore, there is some evidence to support the use of cocoa/dark chocolate for enhancing antioxidant capacity after intense exercise.

Green tea originates from Asia (mainly China and Japan) from leaves that have undergone minimal oxidation during fermentation and contains a large amount of catechins of which are epicatechin, epicatechin gallate, epigallocatechin and epigallocatechin gallate and small amounts of caffeine (Graham, 1992). Consumption of green tea has received increasing interest attributable to its antioxidant and anti-inflammatory effects on health promotion (Tipoe et al., 2007). In addition, green tea has been proposed to have promising effects on fat metabolism (Jeukendrup and Randell, 2011) as well as considerable antimicrobial properties (Reygaert, 2014). A study by Haramizu and colleagues (2013) reported that green tea administration for 3 weeks in mice hastened the recovery of running performance, attenuated the exercise-induced decrease in muscle contractile force and suppressed the increases in exercise-induced inflammation and oxidative stress markers.

The cohort of studies that have examined the anti-inflammatory and anti-oxidative effects of green tea during recovery from exercise reported attenuation of post-exercise oxidative stress markers (Panza et al., 2008; Jowko et al., 2011; Jowko et al., 2014) and post-exercise CK responses (Jowko et al., 2011) when green tea was administered for 1-4 weeks prior to the strenuous exercise bout. However, the antioxidant effects of green tea catechins appear to have an accumulating effect, as a single dose of green tea consumed before exercise resulted in only a small increase in plasma catechins and had no effect on markers of oxidative stress and muscle disruption in soccer players (Jowko et al., 2012). Green tea consumption has also been recently attributed to exert antimicrobial and antiviral actions (Reygaert, 2014). Ahmed et al. (2014) have shown that long term consumption of a polyphenol-rich protein beverage protected against viruses *in vitro* by delaying the exercise-induced virus replication in the serum of long-distance runners. Similar findings were shown in 22 taekwondo athletes who ingested green tea after a 2-h training session and reported increased salivary antibacterial capacity and increases in α -amylase activity during recovery (Lin et al., 2014). Therefore green tea consumption appears to be beneficial in enhancing antioxidant capacity and could show promising effects on the enhancement of mucosal immunity after intense exercise.

Quercetin is the most widespread flavonol substance in nature found in most fruit and vegetables and proposed to have extensive health benefits such as antioxidant, anti-inflammatory and psychostimulatory functions, as well as protection against viruses, cancer, heart disease and neurodegenerative diseases (Bjelakovic et al., 2007; Davis et al., 2009). Accumulating evidence in athletes shows that quercetin supplementation does not have strong influence as an antioxidant to prevent exercise-induced muscle damage and inflammation following prolonged intensive endurance exercise (McAnulty et al., 2008; Nieman et al., 2009; Konrad et al., 2011); however, it appears to be more effective for improving exercise performance. A meta-analysis by Kressler and colleagues (2011) concluded that quercetin supplementation can enhance endurance exercise capacity and $\dot{V}O_2$ max, however with trivial to small effect sizes (~3.0%). In mice, short-term ingestion of quercetin (7 days) has been reported to enhance muscle and brain mitochondrial biogenesis, which were accompanied by increases in maximal running performance and increased exercise tolerance (Davis et al., 2009). However, mitochondrial biogenesis with quercetin supplementation has not been evidenced in humans, even though Nieman et al. (2010) showed an insignificant modest increase in relative mitochondrial DNA copy

number and messenger RNA levels of four mitochondrial biogenesis-related genes following a 2-week quercetin supplementation. Therefore, further investigations are required to validate the ergogenic and/or antioxidant effects of quercetin.

2.2.3. Other recovery strategies

To enhance muscle recovery during intense training periods, athletes engage in several recovery strategies for alleviation and management of DOMS as part of their training and post-competition regimens. Various recovery strategies are used by athletes, with the most popular being cryotherapies, contrast water immersion, sports massage, intake of non-steroidal anti-inflammatory drugs, stretching and electrical stimulation. However, these strategies have been found to have no effect or provide only a small contribution to DOMS management. The most effective recovery intervention appears to be massage for reducing soreness 24 h post-exercise, whereas inconsistent evidence appear for other strategies such as cryotherapies and stretching (Cheung et al., 2003; Barnett, 2006; Torres et al., 2012).

Sleep and rest are rather important aspects of recovery, as sleep can prepare the body for subsequent functioning and facilitates many important physiological and cognitive purposes. Sleep deprivation (<6 h) has been reported to have adverse effects upon performance and health, such as to impair mood and cognitive function, glucose metabolism and appetite regulation and have detrimental effects on immune function (Halson, 2014). Extension in sleep time or napping during daytime may aid athletes increase their total sleep hours (Halson, 2014), whereas some nutritional interventions, such as consumption of high glycaemic index meals, diets high in carbohydrates and protein and low in fat, adequate caloric intake, small doses of tryptophan and the herb valerian (Halson, 2014) and tart cherry juice supplementation (Bell et al., 2014) may have beneficial effects on optimising sleep quality and quantity.

2.3. Summary

Summarising the literature it appears that judo is a sport that has not been studied extensively, despite its demanding training requirements and complex sporting nature. Judo athletes undergo very high volumes of strenuous training each season, and the

additional physical (and psychological) stress of “making weight” cycles may result in athletes becoming overreached. Therefore, proper and effective recovery strategies are essential for enhancing performance and reduce the risk of overreaching/overtraining; however, no evidence in the literature focused in enhancing recovery and optimising competition performance in the sport of judo. Tapering strategies by modification of the different aspects of training (intensity, frequency, volume and type of taper) have been broadly studied in other sports; however, less attention has been given to judo regarding how a tapering period after an intensive training microcycle may enhance aspects of recovery and optimise performance. Consumption of CM as a post-exercise recovery aid has been examined in several studies, and shows beneficial effects on recovery. However, most of the studies utilised standardised, laboratory-based tests, whereas no studies examined field-based judo-related performance. In addition, no studies so far examined the effects of post-exercise consumption of CM when athletes are “making weight” before competitions. Lastly, effective competition performance is related to a high degree on the psychophysiological stress of the athletes on the day of the competition. Although there is a number of studies that has examined C and T responses in relation to the outcome of the competition, the evidence in the literature are inconsistent, and there are only a few studies in judo athletes. Therefore, this thesis will try to address the above gaps in the literature with an aim to provide further scientific knowledge on proper recovery strategies and effective competition performance in the sport of judo, utilising research in a “real-life” field-based sporting scenario.

**CHAPTER 3: STUDY 1. Acute effects of a
chocolate milk beverage during post-exercise
recovery on salivary hormones, salivary IgA, sleep
quality, muscle soreness and performance indices
in judo athletes.**

3.1. Abstract

This study examined the acute effects of post-exercise CM and water (W) consumption during recovery from a single intensive judo training session on salivary hormones, mucosal immunity, sleep quality, muscle soreness and judo-related performance. Ten male judo athletes (mean \pm SD, age 19 ± 4 years; $\dot{V}O_2\text{max}$ 56.6 ± 3.4 ml·kg⁻¹·min⁻¹; training experience 7 ± 3 years) engaged in an intensive judo training session on two separate occasions. Immediately post-exercise and within the first h of recovery the athletes consumed in a crossover design 1000 ml of either CM or W. Performance tests and assessment of sleep quality and muscle soreness were assessed pre-exercise and again 24 h later. Saliva was collected in frequent times during recovery throughout the study. Ratings of perceived exertion were 16 ± 1 for each training session. Subsequent performance at 24 h of handgrip strength and judo-specific test were similar after the consumption of CM and W ($p > 0.05$), whereas push-up performance in the tended to improve after the consumption of CM ($p = 0.09$). Self-reported ratings of general muscle soreness increased post-exercise and remained high until the next day ($p < 0.01$), with higher ratings of soreness in the W condition ($p < 0.05$). Responses of sC, sT and SIgA over the 4-h recovery period and sleep quality were similar after the consumption of both beverages ($p > 0.05$). This study indicates that the consumption of CM after an acute judo training session did not facilitate better recovery than W, apart from a lower perception of muscle soreness which could be related to the tendency for better push-up performance.

Keywords: CHO-protein beverage, DOMS, mucosal immunity, sC, sT, SJFT

3.2. Introduction

Judo is a dynamic combat sport that incorporates several eccentric-type, high-intensity attacks and defences through a variety of throwing and choking grips. Empirical evidence show that the brief and eccentric efforts sustained during intensive judo training sessions can often lead to glycogen depletion and tissue trauma, muscle soreness and metabolic stress, manifested by inflammation, aches and deterioration in production of maximal force. Subsequently, judo training-induced stress can often impair the consequent training sessions, mainly by preventing the next training session from being performed at an optimal volume and/or intensity.

C and T are two steroid hormones that have been frequently measured to assess training stress and/or training adaptations to exercise (Halson and Jeukendrup, 2004). C is measured as a marker of the body's response to stress, whereas T may contribute to muscle growth by enhancing net protein synthesis by the muscles. The T/C ratio is frequently proposed as a method to assess the anabolic/catabolic equilibrium to training, whereas it has been proposed that decreases in the T/C ratio may indicate insufficient regeneration (Meeusen et al., 2013). SIgA has been reported to increase, decrease or remain stable following acute exercise bouts (Bishop and Gleeson, 2009), whereas high intensity exercise increases and prolonged strenuous exercise decreases SIgA post-exercise. A possible decrease post-exercise could compromise mucosal immunity post-exercise, leaving the athlete's immune response an "open window" for picking up infections. Milk-based beverages are increasing in popularity as post-exercise recovery aid, since they are practical, palatable, commercially available and relatively inexpensive. CM contains CHO and protein, as well as electrolytes and fluids and thus can serve as a post-exercise beverage to promote recovery. CM has been shown to be an effective recovery beverage to enhance post-exercise rehydration (Shirreffs et al., 2007), whereas the dairy proteins found in fluid milk have been reported to be beneficial in muscle related recovery (Phillips, 2011). Studies have shown that CM consumption after exercise is an effective nutritional recovery aid during repeated bouts of exercise sessions (Karp et al., 2006; Pritchett et al., 2009; Thomas et al., 2009; Gilson et al., 2010; Ferguson-Stegall et al., 2011; Spaccarotella and Andzel, 2011). Studies in cyclists (Karp et al., 2006; Thomas et al., 2009) have shown that time to exhaustion during a cycling trial is improved (40-80%) after the consumption of CM versus a fluid replacement beverage. Ferguson-Stegall et al. (2011) observed that

CM consumption during recovery from sprint and endurance exercise was more effective in improving subsequent time-trial cycling performance compared with an isocaloric CHO-replacement beverage and placebo in a group of cyclists and triathletes. Milk is also natural source of tryptophan, whereas tryptophan loading has been proposed to be effective in improving mood and sleep quality (Silber and Schmitt, 2010). The combination of carbohydrate and protein, can stimulate tryptophan uptake by the brain (Halson, 2014), therefore CM could be beneficial in promoting sleep quality.

The milk proteins found in CM have been proposed to enhance muscle-related recovery (Phillips, 2011) whereas CM consumption during recovery has been found to elicit acute rises in muscle protein synthesis following resistance exercise (Wilkinson et al., 2007). Acute consumption of CM post exercise has been shown to attenuate markers of muscle damage, accompanied by enhancements in muscle function and performance capacity (Cockburn et al., 2008; Cockburn et al., 2010). Similarly, Gilson et al. (2010) showed that the consumption of CM attenuated DOMS and serum CK responses during 5 days of intensified soccer training compared with the CHO-replacement beverage, despite similar influences on exercise performance. Prichett et al. (2009) supports these findings by showing no increase in plasma CK when consuming CM compared with a CHO-replacement beverage after multiple bouts of sprint and endurance exercise, despite similar changes in muscle soreness and cycling performance.

The majority of investigations have included endurance-type sports and examined performance during multiple exercise bouts using laboratory-based tests. Judo is a power sport that incorporates eccentric-type exercises that often lead to performance deterioration, tissue disruption and muscle damage. Therefore, the purpose of this study was to examine whether post-exercise CM consumption following a single intensive judo training session can limit the disturbances in salivary hormones, mucosal immunity and sleep, attenuate the exercise-induced muscle soreness and improve the subsequent judo-specific performance during acute recovery.

3.3. Methods

Subjects

Ten trained, male judo athletes volunteered to participate in the current investigation. (mean \pm SD, age 19 ± 4 years; body height 175 ± 7 cm; body weight 77.7 ± 14.0 kg; body fat 11.1 ± 5.3 %; HRmax 195 ± 11 bpm; $\dot{V}O_2$ max 56.6 ± 3.4 ml·kg⁻¹·min⁻¹; training experience 7 ± 3 years.). All subjects had competed in judo for at least five years and trained a minimum of 4 times per week. Subjects were lactose tolerant, non smokers, not taking any form of medication, refrained from alcohol consumption and remained free from illness for the total duration of the study. Prior to the study, all subjects completed an informed consent and a health screening questionnaire. The Cyprus National Bioethics Committee approved all procedures undertaken.

Experimental design

The study took place in Cyprus in February during pre-season preparations. Subjects were initially reported to the laboratory for the determination of their $\dot{V}O_2$ max, body weight, body fat by skinfold thickness and body height. Following at least one week, the subjects participated in two consecutive weekends of measurements, during which they performed 4 sets of performance tests and engaged in two intensive training sessions. On each occasion, on day 1 the subjects reported at the *dojo* at 16:00 and provided resting saliva samples and completed questionnaires for assessments of DOMS and sleep quality. After warming-up they performed three performance tests and then they engaged in an intensive judo training session by 17:00. Immediately after training and after the collection of the post-exercise saliva samples (~19:30), the subjects consumed, in a randomised counterbalanced order, either 1000 ml CM or W of equivalent volume.. Subjects' body weight ranged 55-90 kg, therefore the amount of CM provided at least 1 g of CHO per kg body weight. The ingredient composition of the CM is presented in Table 2.1. Both beverages were given within 15 min after training and the subjects were instructed to consume the drink within 1 h post-exercise. Saliva samples were collected every h post-exercise for 4 h until bed-time. On day 2 (24 h later) the subjects reported at the *dojo* at the same time and provided resting saliva samples and completed the same questionnaires.

After warming up they performed the same tests. Subjects have had their last meals at least 2 h prior to testing and were instructed to avoid beverages with caffeine and high-CHO content at least 2 h before testing. Subjects were also instructed to avoid additional milk-based beverages (apart from their prescribed beverage) during the duration of the study. The study design is illustrated in Figure 3.1. The study was in the form of a training camp, and all activities of the first trial were replicated on the second trial, by notes in training diaries. Training was performed indoors (*dojo*) and consisted of judo-specific skills and drills and mat work. The training program followed in this study was based on previous weeks, whilst increasing the training load, so as to induce higher physical stress on the athletes and monitor changes in markers of (over)training and recovery. On both occasions all subjects stayed together in the same hotel, trained together in the same *dojo* under the supervision of the same coach and had the same meals at the same times. Subjects did not train or exercise for 2 days before each training session. Care was taken as to try to control for all daily activities.

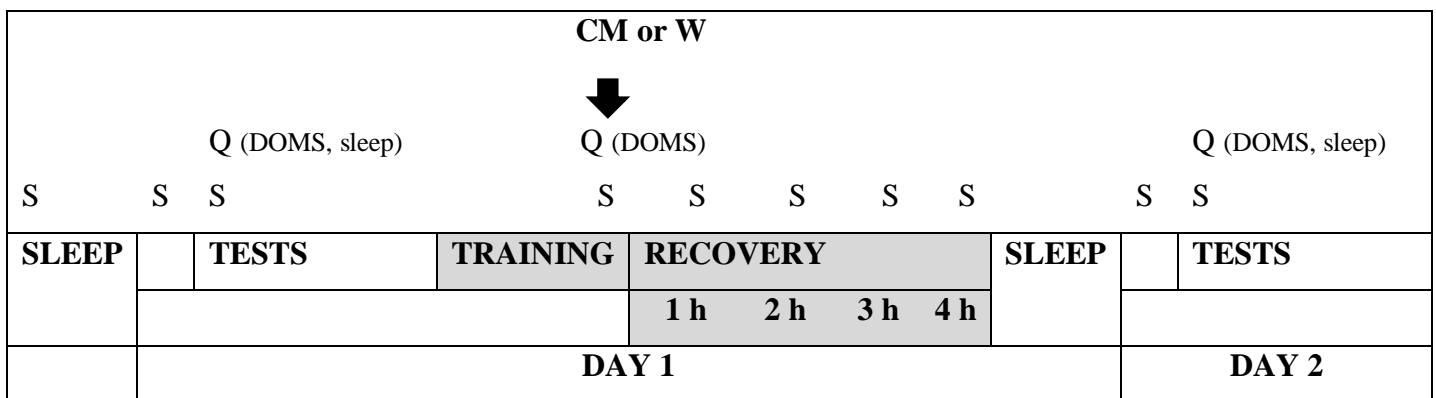


Figure 3.1. Schematic representation of experimental study design. CM indicates chocolate milk consumption, W indicates water consumption, S indicates saliva collection, Q indicates questionnaire assessments.

Training quantification

On both occasions the judo training sessions lasted 2.0 - 2.5 h. The training consisted of a warm-up (~20 min), judo-specific skills and drills and mat work (~40 min), several sets of ground Randoris (~40 min) and standing Randoris (~40 min) and cool-down (~10 min). Specific judo exercises were identical on both training sessions. To quantify exercise intensity, each subject wore a Polar heart rate (HR) monitor (Polar Electro Oy, Kempele,

Finland) during the training sessions, with HR sampling frequency in 5 s intervals. Records of HR for both training sessions were then downloaded to a computer using Polar Team System and %HRmax, average HR and time spent in each training zone were then individually calculated based on each subject's HRmax. Furthermore, ratings of perceived exertion using Borg's 6-20 scale (Borg, 1982) were recorded 30 min following each training session. The training volume was calculated by multiplying the time spent in each training zone by heart rate as a percentage of HRmax (time x %HRmax). Training load was calculated as suggested by Foster et al. (2001) by multiplying session RPE by session duration.

Dietary control

The prescribed beverage was given to the athletes within 15 min post-exercise and was consumed within 1 h post-exercise. Subjects were instructed not to consume any other drinks or foods other than their prescribed beverage for 1.5 h post-exercise. On both occasions, care was taken as to try to control for all types and timings of meals. All meals (breakfast, lunch, dinner) were prepared at the hotel and prescribed to be identical and to be served at the same times during the two occasions. Subjects tried to stay as close to the first treatment period regarding the amount of food they consumed. The subjects recorded the type and amount of foods and drinks they consumed for 3 days during each occasion in personalised food diaries [the day before treatment, day 1 (training day) and day 2] and were encouraged to replicate the same dietary habits during both treatment periods. Dietary records for each treatment period were analysed using Comp-Eat Pro (version 5.7).

Preliminary measurements

At least one week prior to the beginning of the study, preliminary anthropometric measurements and $\dot{V}O_{2\max}$ assessments were made. After reporting to the laboratory, each participant had his body weight (Seca 703, Vogel & Halke, Germany) and body height (Teraoka DI-28B, Digi) measured. In addition 4-site skinfold measurements (Harpندن, Baty Intl, West Sussex, UK) to estimate body fat were made. Percentage of body fat was calculated using the equation of Jackson and Pollock (1978). Then each subject performed a $\dot{V}O_{2\max}$ assessment. Following a short warm-up (5-10 min) at a low speed (6-8 km·h⁻¹),

subjects began running on a motorized treadmill at a constant speed of 10 km·h⁻¹. The treadmill inclination was increased by 1% every 2 min, until volitional fatigue. At the end of each 2-min stage, RPE and HR (Polar Beat, Polar Electro, Kempele, Finland) were recorded. Oxygen consumption was monitored breath by breath continuously throughout the test (Quark b², Cosmed SRL, Italy). The $\dot{V}O_2$ max test was completed within 9-15 min for all subjects, as recommended by Cooke (2009). To confirm that subjects reached their $\dot{V}O_2$ max, it was ensured that the following criteria were assessed and met: subjects reached within 10 bpm of age-predicted HRmax, post-exercise respiratory exchange ratio (RER) was >1.15 and RPE was >19.

Performance testing

For each treatment period, subjects performed three performance tests two times, before and after the consumption of the beverage. The tests were performed before training on day 1 to record baseline measurements and again 24 h later on the same time (day 2). The tests were performed at the *dojo* after warming-up. On this order on all occasions, the subjects performed a handgrip strength test, a timed push-up test and a Special Judo Fitness test (SJFT). All subjects had familiarised themselves with the tests on the previous weeks. Relative humidity and temperature (mean \pm SD) during the tests were 61 \pm 2 % and 21 \pm 1 °C, respectively.

Handgrip strength

Handgrip strength of both hands was measured twice using an analogue handgrip dynamometer (Jamar, Sammons Preston, IL, USA). The subjects stood up in the anatomical reference position, with the testing hand bended at the elbow at 90° and the other hand straight at the anatomical position. Then subjects closed their grip using maximal force. The best of the two trials was recorded. Eight out of the ten subjects were right handed.

Timed push-ups

Push-ups were performed in a prone position, by lowering and raising the whole body using the arms. The subjects performed their maximal number of push-ups in a timed 30-s period. The number of completed push-ups in 30 s was recorded as the score of the test.

Special Judo Fitness Test

The SJFT was conducted as described by Sterkowitz (1995). The test was conducted in series of 3 bouts lasting 15 s, 30 s and 30 s interspersed by 10-s intervals. During the test, the judoka throws the two opponents as many times as possible using the ippon-seoi-nage technique. HR was measured immediately at the end of the test and after 1 min using a HR monitor to calculate the performance index as:

$$SJFT\ index = (HR\ immediately\ post + HR\ one\ minute\ post) / total\ number\ of\ throws$$

A lower SJFT index indicates better performance.

Questionnaires

Throughout the study, subjects completed questionnaires to assess sensation of muscle soreness and sleep quality. A DOMS questionnaire were completed pre-exercise and after 20 min post-exercise on day 1, and again on day 2, thus 24 h later. DOMS was rated on a visual analogue scale rating from 1 (not sore) to 10 (extremely sore) for overall body soreness, soreness on front thigh muscles and soreness of upper body muscles (arms, chest, trapezoids). Subjects rated their subjective feeling of soreness while lightly palpating their muscles in a standing position. In addition, the Groningen's Sleep Quality scale (Mulder-Hajonides van der Meulen et al., 1980) was completed pre-exercise on day 1 again 24 h later. Subjects rated their subjective quality of last night's sleep by answering positively and negatively 15 questions. Then a total score is calculated where a high score indicates bad sleep quality. Scores above 6 indicate high sleep disturbances and scores of 0-2 indicate good sleep quality.

Saliva collection and analysis

Saliva samples were collected 10 times in total on each treatment period. Saliva was collected before sleep on the previous day of training, in the morning of the training day (day 1) within ~20 min after waking up (~7:30), pre-exercise, immediately post-exercise, at 1 h, 2 h, 3 h, 4 h (before sleep) of post-exercise recovery, on the next morning (day 2) within ~20 min after waking up, and again pre-exercise at day 2 (Figure 3.1).

Subjects were instructed to swallow to empty their mouth before an unstimulated saliva sample was collected. Saliva collections were made with the subject seated, head leaning slightly forward with eyes open, and making minimal orofacial movement while passively dribbling into a sterile vial (Sterilin, Caerphilly, UK). The collection time was 2 min at least or until an adequate volume of saliva (~1.5 ml) had been collected. Saliva was then stored in the same vials at -30°C and were transported frozen to the Loughborough University laboratories for analysis. Concentrations of sC, sT and SIgA were determined in duplicate using commercially available enzyme-linked immunoassay (ELISA) kits (Salimetrics, PA, USA). Mean intra-assay coefficients of variation were 2.9%, 2.3% and 2.7% for sC, sT and SIgA, respectively.

Saliva volume was estimated by weighing the vial immediately after collection and assuming that saliva density was $1.00\text{ g}\cdot\text{ml}^{-1}$ (Cole and Eastoe, 1988). Saliva flow rate was then calculated by dividing the total saliva volume collected in each sample (in ml) by the time taken to produce the sample (in min). The SIgA secretion rate ($\mu\text{g}\cdot\text{min}^{-1}$) was calculated by multiplying the absolute SIgA concentration ($\mu\text{g}\cdot\text{ml}^{-1}$) by the saliva flow rate ($\text{ml}\cdot\text{min}^{-1}$).

Statistical analysis

Data was checked for normality, homogeneity of variance and sphericity before statistical analysis. If Mauchly's test indicated that assumption of sphericity was violated the degrees of freedom were corrected using Greenhouse-Geisser estimates. For statistical analysis the results of the performance tests and questionnaires, body weight and responses of sC, sT and SIgA between the two drinks were analysed using a two-way analysis of variance (ANOVA) for repeated measures (drink x time) with Bonferroni adjustments. Nutrient intake and data from training sessions were compared between treatments using dependent

paired t-tests. The 95% confidence intervals (CI) for relative differences and size effects (ES) from simple planned contrasts were calculated to confirm meaningful significant differences. Statistical significance was set at $p \leq 0.05$. All data are presented as mean \pm SD. Data was analysed using SPSS (SPSS v. 19.0; SPSS Inc, Chicago, IL, USA).

3.4. Results

Training load, ratings of perceived exertion and dietary intake

Mean training load, RPE, training volume and time spend in each training zone did not present significant differences between the two training sessions ($p > 0.05$). Mean training load was 2892 ± 230 AU and 2770 ± 253 AU during the first and second training session, respectively. Mean RPE for each training session was 16 ± 1 . No significant differences ($p > 0.05$) were found for dietary intake (total energy, CHO, protein, fat) between treatments. The mean 3-day energy intake was 2676 ± 314 kcal (CHO 49.0 ± 8.3 %, protein 24.3 ± 4.5 %, fat 26.7 ± 7.0 %) during the CM treatment, and 2726 ± 302 kcal (CHO 45.7 ± 9.0 %, protein 24.0 ± 3.8 %, fat 30.3 ± 7.4 %) during the W treatment. The mean energy intake for the training day was 2880 ± 538 kcal, (CHO 48.3 ± 10.4 %, protein 26.6 ± 4.7 % and fat 25.1 ± 5.6 %) and 2795 ± 455 kcal (CHO 46.6 ± 11.2 , protein 25.7 ± 5.5 and fat 27.7 ± 6.3 %) for the CHO and W conditions, respectively.

Performance tests

Handgrip strength

A significant effect of time showed that mean performance of the right handgrip strength tended to deteriorate on the second day ($p = 0.06$, ES = 0.59, CI -3 to -197%) without significant effect of drink or interaction ($p > 0.05$). No significant effects of drink or interaction ($p > 0.05$) were found for left handgrip strength. No changes across time or between drinks were found for left handgrip strength ($p > 0.05$). Data is shown on Table 3.1.

Timed push-ups

A significant effects of drink showed that number of push-ups on the second day tended to be higher with the CM compared with the W treatment ($p=0.09$, $ES=0.47$). From the 10 subjects, 4 had improved performance in the W condition (CI -353 to 153%) and all 10 had improved performance in the CM condition (CI 28 to 172%). No significant effect of time or interaction were found ($p>0.05$). Data is shown on Table 3.1.

Special Judo Fitness Test

A significant effect of time ($p=0.02$), without significant effects of drink or interaction ($p>0.05$) showed that performance in the SJFT index significantly deteriorated on the second day for both beverages ($ES=0.66$, CI -21 to -179%). No significant effects of time, drink or interaction were found for total number of throws ($p>0.05$). Data is shown on Table 3.1.

Muscle soreness

Significant effects of time ($p<0.005$) and interaction ($p<0.001$) showed that sensation of general DOMS increased post-exercise ($ES=0.60$, CI W: 12 to 188%; CM: 35 to 164%) and remained high until the next day for both drinks. A significant effect of drink ($p<0.01$, $ES=0.70$, CI 29 to 173%) showed that by day 2 the CM treatment attenuated the sensation of general soreness (CI -253 to 453%), whereas muscle soreness in the W condition kept developing (CI 415 to 815%). The soreness was located on the upper body muscles with similar pattern to general soreness. Data is shown on Table 3.2.

Sleep quality

Significant effect of time showed that quality of sleep significantly deteriorated after the intensive training session ($p<0.01$, $ES=0.75$, CI 37 to 163%); however no significant effects of drink or interaction ($p>0.05$) showed no differences between beverages (Table 3.2).

Table 3.1. Performance tests before (day 1) and after (day 2) water (W) and chocolate milk (CM) consumption (Mean \pm SD).

Performance test		day 1		day 2	
		W	48.2	\pm 7.0	47.1
Handgrip strength R (kg)	CM	47.3	\pm 7.0	45.3	\pm 6.5
	W	46.5	\pm 6.0	46.7	\pm 5.5
Handgrip strength L (kg)	CM	46.2	\pm 5.8	45.8	\pm 5.3
	W	37	\pm 9	37	\pm 11
Push-ups in 30 s (no.)	CM	37	\pm 7	41	\pm 7
	W	28	\pm 5	31	\pm 4
Special Judo Fitness test (throws)	CM	28	\pm 4	29	\pm 4
	W	11.8	\pm 3.4	12.4	\pm 2.7 *
Special Judo Fitness test (index)	CM	10.6	\pm 1.8	11.2	\pm 2.7 *

R indicates right hand; L indicates left hand; * indicates significantly different ($p < 0.05$) from day 1.

Table 3.2. Muscle soreness and sleep quality during the water (W) and chocolate milk (CM) conditions (Mean \pm SD).

		day 1		day 2	
		PRE	POST	PRE	
General muscle soreness	W	2.2	\pm 1.0	4.2	\pm 1.6 *
	CM	1.8	\pm 1.1	3.7	\pm 1.4 * #
Front thigh soreness	W	2.2	\pm 1.0	4.2	\pm 2.4
	CM	1.8	\pm 1.7	2.6	\pm 2.1
Upper body soreness	W	1.6	\pm 0.7	2.5	\pm 1.7 *
	CM	1.5	\pm 0.9	2.5	\pm 1.6 * #
Sleep quality	W	0.8	\pm 1.5	5.0	\pm 5.4 *
	CM	0.8	\pm 2.1	3.5	\pm 3.9 *

PRE indicates pre-exercise; POST indicates post-exercise; * indicates significantly different ($p < 0.05$) from pre-exercise; # indicates significantly different ($p < 0.05$) than W.

Salivary hormones

Data on sC, sT and sT/C ratio is presented in Figure 3.2 A, B and C, respectively. A significant effect of time ($p < 0.005$) showed that average sC concentrations increased post-exercise (CI 44 to 156%) and then decreased during the 4 h of recovery (CI -62 to -138%), until they reached baseline levels on day 2. No significant effects of drink or interaction ($p > 0.05$). A significant effect of time ($p < 0.001$) showed that average sT concentrations decreased during the 4 h of recovery (CI -67 to -133%), without significant effects of drink or interaction ($p > 0.05$). A significant effect of time ($p < 0.05$) showed that average sT/C ratio increased at 4 h post-exercise compared with morning (CI 1 to 200%) and 1 h post-exercise levels (CI 33 to 167%), without significant effects of drink or interaction ($p < 0.05$).

Salivary IgA

Data of SIgA absolute concentrations and secretion rate is shown in Figure 3.3 A and B, respectively. A significant effect of time ($p < 0.001$) showed that average SIgA concentrations decreased from the morning values (CI -67% to -133%), from pre-exercise (CI -63% to -137%) and from post-exercise (CI -58% to -142%) during the first 2 h of recovery. A significant effect of drink ($p = 0.03$; $ES = 0.61$) but not interaction ($p > 0.05$) showed that SIgA concentrations decreased during acute recovery, with slightly higher values in the CM treatment immediately post-exercise (CI 0% to 39%). A significant effect of time ($p < 0.001$) showed that average SIgA secretion rate fell during the 2 h of post-exercise recovery compared with before-sleep (CI -12% to -188%) and early-morning (CI -22% to -178%) without significant effects of drink or interaction ($p > 0.05$).

Saliva flow rate

No significant effects of drink, time and interaction ($p > 0.05$) showed that saliva flow rate was similar throughout the study period and between both treatments (Figure 3.3 C).

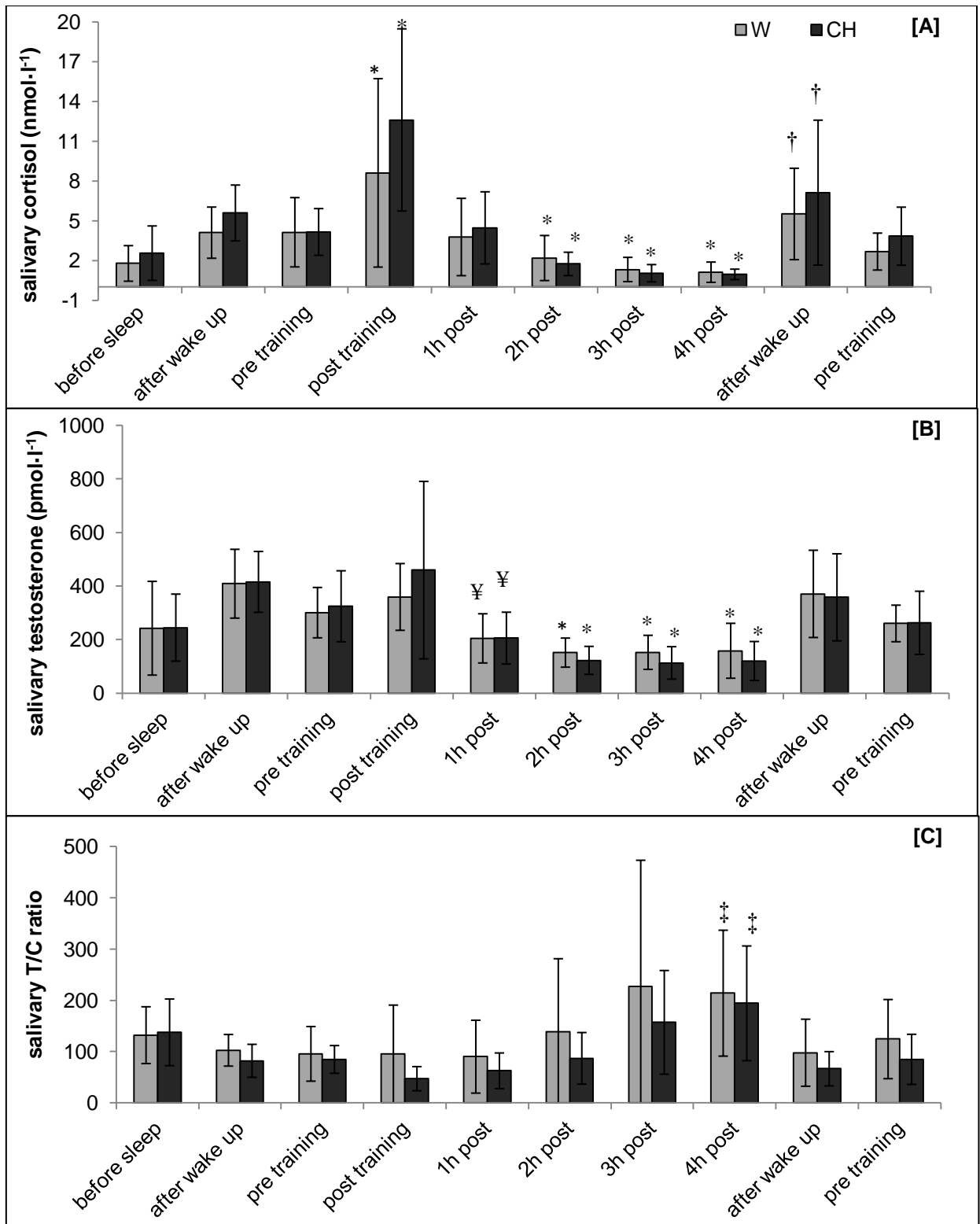


Figure 3.2. Mean (\pm SD) concentrations of [A] salivary cortisol, [B] salivary testosterone and [C] T/C ratio during the water (W; grey columns) and chocolate milk (CM; black columns) conditions. * indicates significantly different ($p < 0.05$) from all; † indicates significantly different ($p < 0.05$) from before sleep; ¥ indicates significantly different ($p < 0.05$) from after wake up (day 1), pre training (day 1) and post training; ‡ indicates significantly different ($p < 0.05$) from after wake up and 1 h post training.

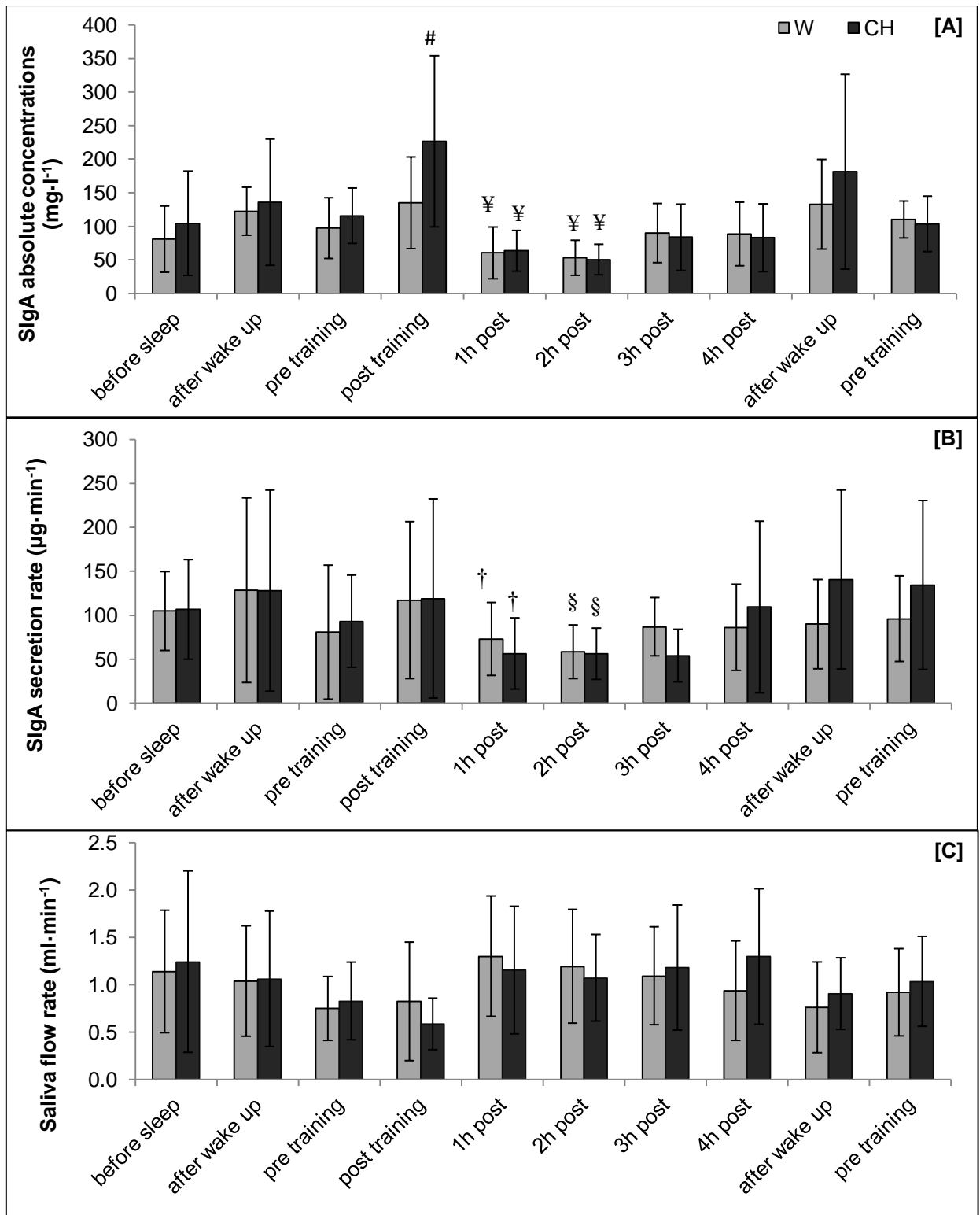


Figure 3.3. Mean (\pm SD) concentrations of [A] SigA absolute concentrations, [B] SigA secretion rate and [C] saliva flow rate during the water (W; grey columns) and chocolate milk (CM; black columns) conditions. # indicates significantly different ($p < 0.05$) than W; ¥ indicates significantly different ($p < 0.05$) from after wake up, pre training and post training; † indicates significantly different ($p < 0.05$) from before sleep; § indicates significantly different ($p < 0.05$) from after wake up (both days).

3.5. Discussion

This study examined the acute effects of chocolate milk ingested immediately after an intensive judo training session on measures of recovery, in elite national level judo athletes. This study indicated that the consumption of CM post-exercise did not facilitate better recovery of salivary hormones and mucosal immunity or promote better sleep quality in judo athletes. However, the CM consumption post-exercise was beneficial in reducing subjective feelings of muscle soreness. Although no significant differences were found in the performance tests, there was a tendency for better push-up performance on the second day, which could be related to the lower sensation of DOMS.

In this study, the consumption of CM or W during recovery from an intensive judo training session did not facilitate better recovery of handgrip strength or judo-specific performance 24 h later. Previous studies reported improvements in performance using measures of aerobic exercise (Lunn et al., 2012), multiple exercise sessions (Karp et al., 2006; Pritchett et al., 2009; Thomas et al., 2009; Gilson et al., 2010; Ferguson-Stegall et al., 2011; Spaccarotella and Andzel, 2011) and muscle damaging exercise (Cockburn et al., 2008; Cockburn et al., 2010), whereas some reported no change in subsequent performance capacity (Wojcik et al., 2001; Pritchett et al., 2009; Gilson et al., 2010; Spaccarotella and Andzel, 2011). However, the findings of our study are not truly comparable with previous reports, as in our study the tests utilised were acute strength, power and judo-specific measures after a judo training session. Our findings show that the consumption of CM was not effective for enhancing performance when consumed during acute recovery from a single intensive judo training session. Although subsequent judo-specific performance significantly deteriorated and right handgrip strength tended to deteriorate after the intensive training session, it is possible that an acute training session was not stressful enough to induce changes in other measures of performance.

The ratings of general DOMS were lower for the CM condition compared with W, with soreness mainly located on the upper part of the body. These results are comparable with the findings of previous investigations (Cockburn et al., 2008; Pritchett et al., 2009; Gilson et al., 2010) which demonstrated attenuated rise in markers of muscle damage after the consumption of CM; however, no change in perception of muscle soreness was observed in these studies. Cockburn et al. (2010) presented attenuation in sensation of DOMS in addition to decreased CK activity and enhanced functional performance after

CM consumption during acute recovery, findings comparable to our study. Ferguson-Stegall et al. (2011) showed that CM consumption during recovery from glycogen-depleting aerobic exercise increased the activation status of signalling proteins associated with increased mRNA translation and protein synthesis compared with an isocaloric carbohydrate-replacement beverage and placebo; they concluded that consumption of CM during recovery was associated with attenuation of muscle protein degradation and faster tissue repair. This may explain the lower rate of plasma CK elevations and lower muscle soreness ratings in previous studies. In the present investigation, the lower levels of soreness indicate that CM could have aided in muscle-related recovery.

The hormonal responses during recovery from the training session presented robust increases of sC and sT immediately post-exercise, followed by a progressive decrease during the 4 h of recovery, until they returned to baseline levels on the next day, without differences between treatments. The rises of sC to the high-intensity training session support the view that moderate-high intensity endurance exercise provokes increases in circulating C levels (Hill et al., 2008). The sT/C ratio increased at 4 h post-exercise in a similar rate in both conditions, possibly indicating that anabolic activity was higher before sleep than during the first few h post-exercise. The results indicate that endocrine responses were not affected by the acute consumption of CM.

Responses of SIgA absolute concentrations and secretion rate were similar during recovery between both beverages. SIgA concentrations and secretion rate fell during the first 2 h of recovery, indicating possible suppression of mucosal immunity; this may illustrate the “open window” period of immunosuppression associated with intense exercise (Walsh et al., 2011). However, the acute consumption of CM after a single training session did not enhance recovery by preventing the acute fall in SIgA levels.

In this study it has been observed that the intensive training session deteriorated the quality of the night's sleep; sleep quality was deteriorated by 525% in the CM condition and 337% in the W condition. Although no significant differences on sleep quality were noted between the CM and W consumption, the change in sleep quality between drinks could be meaningful from a physiological perspective, thus CM consumption post-exercise could be related lower sleep disturbance. It has been proposed that the combination of CHO and protein could stimulate tryptophan availability to the brain, which could serve as a sleep aid (Silber and Schmitt, 2010; Halson, 2014). However, CM

did not facilitate better sleep quality in our study. Sleep data was captured with subjective ratings of the subjects' quality of the night's sleep, but used a validated questionnaire. Perhaps use of objective tools, like sleep actigraphs could be used to explore any possible differences on sleep quality between drinks.

It is possible that a single intensive training session was not stressful enough to induce significant differences in performance, salivary immunoendocrine responses and sleep quality in the present study. Further research examining CM consumption during multiple consecutive days of intensive judo training could have possibly shown beneficial effects of CM on aspects of recovery.

A limitation of this study was the lack of placebo control, as it was impossible to disguise the colour and flavour of the two beverages. Therefore, one could argue that the lower ratings of muscle soreness were mainly associated with a placebo-effect rather than actual attenuation of muscle damage. However, the tendency of improved functional performance with CM consumption could suggest enhanced muscle-related recovery. In real life, enhanced subsequent performance along with lower perception of soreness could translate into better training quality. However, further research to study the effects of CM consumption post-exercise during multiple days of intensive training could confirm these findings.

3.6. Conclusions

This study has identified that the consumption of CM compared with W after an intensive judo training session did not facilitate better recovery of immunoendocrine markers, sleep quality or judo-related performance. However, this study has shown that the consumption of CM post training was beneficial in reducing the subjective feeling of muscle soreness. Although no significant differences were found in the performance tests, there was a tendency for better functional performance after the consumption of CM, which could be related to the lower feelings of soreness. Therefore, it is concluded that the consumption of CM is not beneficial for enhancing recovery when consumed after a single intensive judo training session; however it may facilitate better muscle-related recovery, highlighting the need for further research in this area.

CHAPTER 4: STUDY 2. Effects of acute post-exercise chocolate milk consumption during short-term intensive judo training with concomitant weight loss on the recovery of salivary hormones, salivary IgA, mood state, muscle soreness and performance.

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4.1. Abstract

This study examined the effects of post-exercise CM or water W consumption during 5 days of intensive judo training with concomitant weight loss on salivary hormones, mucosal immunity, muscle soreness and judo-related performance. Twelve male judo athletes (mean \pm SD age 19 ± 4 years; $\dot{V}O_2\text{max}$ 56.8 ± 3.2 ml \cdot kg $^{-1}\cdot$ min $^{-1}$; training experience 7 ± 3 years) engaged in 5 days of intensive judo training on two separate training weeks, followed by simulated competition. During both weeks, subjects were instructed to “make weight” for the upcoming competition, following their usual weight loss practices. Immediately post-exercise and within the first h of recovery the subjects consumed 1000 ml of W on week 1 and the equivalent volume of CM on week 2. Performance tests were assessed pre-exercise on the first and last day of each training week and questionnaires of mood state and muscle soreness were assessed 3 times during each week. Body weight and body fat measurements were assessed frequently, at the same time of day, throughout the study. Morning resting saliva samples were collected daily during the study. Performance in the timed push-ups and the SJFT improved significantly ($p < 0.001$) at the end of the training week with CM consumption (both $p < 0.001$). Decreased sC ($p < 0.01$) and a trend for increased sT/C ratio ($p = 0.07$) were also observed mid-week in the CM condition. Saliva flow rate was higher during the week with CM intake compared with W ($p < 0.001$). Self-reported ratings of muscle soreness ($p < 0.001$) and mood disturbance ($p < 0.0001$) increased after the first day of training in the W but not in the CM condition. Responses of sT and SIgA were similar between treatments ($p > 0.05$). Body weight decreased by 1.9% in the W condition (78.2 to 76.6 kg) and by 1.1% in the CM condition (78.3 to 77.5 kg), with no significant differences between drinks ($p = 0.08$). This study indicated that post-exercise CM consumption during short-term intensive judo training was beneficial for reducing accumulated fatigue, maintaining mood state, attenuating muscle soreness and enhancing performance, without affecting weight loss as no significant differences between CM and W drinks were noted in the reduction of weight loss.

Keywords: CHO-protein beverage, making weight, sC, sT, mucosal immunity, SJFT

4.2. Introduction

Training for judo can be very hard and demanding as it incorporates frequent, high intensity bouts of eccentric intermittent exercise. The multiple bursts of intermittent work with high rates of body contact utilises both aerobic and anaerobic energy sources (Degoutte et al., 2003), which often lead to glycogen depletion and tissue micro-trauma. Intense training periods with insufficient recovery has been proven to overreaching in several sports (Halson and Jeukendrup, 2004). Therefore, effective nutritional interventions that aid recovery are essential during intense training periods to avoid the risk of developing non-functional overreaching, which will negatively affect performance and health (Meeusen et al., 2013).

C and T have been frequently used to measure adaptations to training and recovery; elevated resting morning C and suppressed T levels may indicate insufficient regeneration and often used as an indicator of overreaching (Meeusen et al., 2013). Prolonged and intensive training has been reported to suppress aspects of immunity, including SIgA. Resting concentrations of SIgA have been reported to be lower than normal during periods of intensive training, supporting the use of SIgA as an indicator of training stress and recovery (Walsh et al., 2011). Chocolate milk contains carbohydrates (CHO) and protein, in addition to fluid and electrolytes and could potentially serve as a post-exercise recovery drink. Studies show that CM consumption after exercise can enhance subsequent endurance performance during repeated bouts of exercise (Karp et al. 2006; Thomas et al. 2009; Ferguson-Stegall et al. 2011; Spaccarotella and Andzel 2011; Lunn et al. 2012) and speed up recovery during intensive soccer training (Gilson et al. 2010; Spaccarotella and Andzel 2011). In addition, post-exercise consumption of whole milk has been shown to be beneficial in restoring sweat losses in dehydrated subjects (Shirreffs et al. 2007; Watson et al. 2008). Dairy proteins found in fluid milk have been reported to elicit acute rises in muscle protein synthesis following endurance (Ferguson-Stegall et al. 2011) and resistance exercise (Wilkinson et al. 2007) and could potentially be effective in attenuating markers of exercise-induced muscle damage (Cockburn et al. 2008; Pritchett et al. 2009; Gilson et al. 2010) and DOMS (Cockburn et al. 2010). Attenuated ratings of DOMS and serum CK responses were reported when CM was consumed immediately after muscle-damaging exercise (Cockburn et al. 2010); however, other studies report no change in DOMS despite attenuated increases in circulating CK responses during recovery (Cockburn et al. 2008;

Pritchett et al. 2009; Gilson et al. 2010). During a brief period of intensified soccer training period, Gilson et al. (2010) reported that post-exercise CM consumption compared with a CHO-replacement beverage attenuated serum CK responses, despite similar changes between drinks on exercise performance, serum myoglobin concentrations, DOMS and muscle function. Mucosal immunity appears to deteriorate during periods of intensive training (Walsh et al. 2011); however, the effects of post-exercise CM consumption during intensive training on SIgA responses have not been investigated.

Judo is a sport with weight categories, where athletes often engage in periods of weight loss in the days preceding a competition. Most usual practices involve rapid weight loss (>5 days) procedures, mainly by food and fluid restriction. Usual reductions in the majority of judo athletes are 2-5% of body weight, however in some cases the weight loss can be up to 10% of body weight (Artioli et al., 2010b). Several unorthodox and aggressive rapid weight loss methods are followed by judo athletes, such as intensive exercising, skipping meals and limiting CHO intake, restricting fluid intake and positively promoting sweat losses which can have detrimental effects on their competition performance and health (Artioli et al., 2010b). The combination of rapid weight loss practices and intense exercise training in the week preceding the competition could have adverse effects on athletes' competition performance.

The majority of investigations that have assessed the effects of CM included endurance-type sports and examined aspects of laboratory-based endurance performance and muscle function tests. Judo is a power sport that incorporates intense eccentric loading and often lead to performance deterioration, tissue disruption and muscle damage. Judo athletes do not usually consume carbohydrates during recovery from training, especially in the week preceding a competition, as they are conscious about any increases in body weight. Therefore, the purpose of this study was to examine whether post-exercise CM consumption during 5 days of intense judo training can limit the disturbances in salivary hormones, mucosal immunity and mood state, attenuate the exercise-induced muscle soreness and improve the subsequent judo-specific performance, without affecting intentional weight loss.

4.3. Methods

Subjects

Twelve trained, male judo athletes volunteered to participate in the current investigation (mean \pm SD age 19 ± 4 years; height 175 ± 7 cm; body weight 77.4 ± 7.9 kg; body fat 11.1 ± 4.2 %; HRmax 195 ± 11 bpm; $\dot{V}O_2$ max 56.8 ± 3.2 ml·kg⁻¹·min⁻¹; training experience 7 ± 3 years.). All subjects had competed in judo for at least five years and trained a minimum of 4 times per week. Subjects were lactose tolerant, non smokers, not taking any form of medication, refrained from alcohol consumption and remained free from illness for the total duration of the study. No overt signs of overreaching (as described by Meeusen et al., 2013) were observed in the subjects before commencing the study; thus subjects in the weeks preceding the study did not present any deterioration in performance, disturbances in mood, reported no recent illness (upper respiratory symptoms) and were generally in good form physically and psychologically. Prior to the study, all subjects completed an informed consent and a health screening questionnaire. The national ethics committee approved all procedures undertaken. For the subjects under 18 years old (17 years at the time of study) informed consent was given by their guardians.

Experimental design

This was a field study that took place in Cyprus in January during pre-season preparations. Subjects were initially reported to the laboratory for the preliminary measurements of their $\dot{V}O_2$ max, body weight, body fat and body height, as they were described in chapter 3. Following at least one week, subjects began their programmed training routine. The training for each individual was controlled and monitored for two weeks in total, interspersed by a 14-day washout period. In week 1, subjects initially engaged in 5 days of intensive judo training (days 1-5, Mon-Fri) followed by a simulated competition (day 6, Sat), whereas the subjects consumed 1000 ml of W immediately post-exercise. Following a period of 14 days, the same procedures were repeated; in week 2, the same subjects engaged in 5 days of intensive judo training (days 1-5, Mon-Fri) followed by a simulated competition (day 6, Sat), whereas the subjects consumed 1000 ml of CM immediately post-exercise (Figure 4.1). During both weeks, subjects were instructed to “make weight” as to reach the body weight required to compete within their weight category during the simulated competition at the end of each week. The first week served as the observation

week to obtain baseline measurements and the second week as the intervention. The simulated competition was organised by the National Judo Federation and, to try to be as close to real-time sporting scenarios, it was organised as to motivate subjects' weight loss and assess any effect of the drink on the changes in body weight. Subjects' body weight ranged 65-95 kg, therefore the amount of CM provided at least 1 g CHO per kg body weight (for CM ingredients see Table 2.1). Training was performed indoors (*dojo*) in the evening (~18:00) and consisted of judo-specific skills and drills and mat work. The training program followed in this study was based on previous weeks, whilst increasing the training load. Athletes engaged in their usual volume of training during the 14-day washout period. Subjects trained together in the same *dojo*, under the supervision of the same coach. The training program followed in this study was based on previous weeks, whilst increasing the training load. Subjects engaged in their usual, previous volume of training during the 14-day washout period. Performance tests, questionnaires to assess DOMS and mood state and morning resting saliva samples to assess salivary hormones, salivary SIgA and saliva flow rate were collected frequently throughout the study. Subjects have had their last meals at least 3 h prior to testing and were instructed to avoid beverages with caffeine and high-CHO content at least 3 h before testing. Subjects were also instructed to avoid milk-based beverages during the duration of the study. Subjects did not train or exercise for 2 days before and after each training week. The reason for not choosing a crossover design was to eliminate bias within subjects' nutritional practices; hence should the subjects' did not manage to lose weight during the CM treatment due to higher caloric content it was possible to reduce their total energy intake on the W treatment; this could result in different energy intake between the two treatment periods and affect the results.

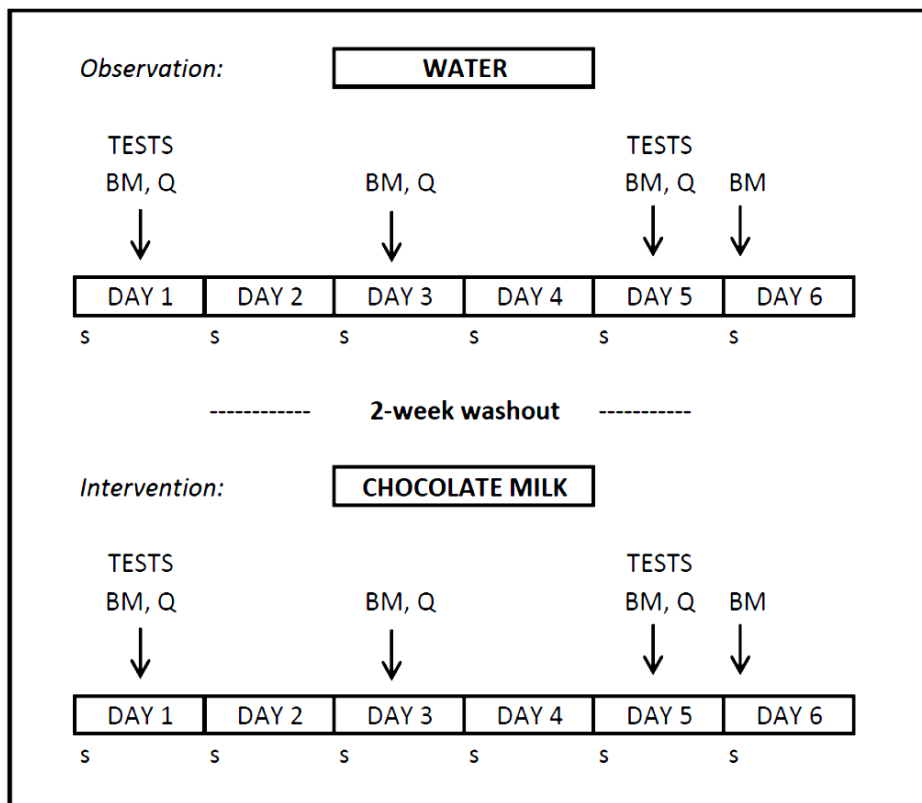


Figure 4.1. Schematic representation of experimental study design. BM indicates body weight and body fat measurements; Q indicates questionnaire assessments; s indicates saliva collection.

Training quantification

On both training weeks the judo training sessions lasted 2.0 - 2.5 h. Every day on each training week, all subjects reported at the dojo for judo training at 18:00 until ~20:30. The training consisted of a warm-up (~20 min), judo-specific skills and drills and mat work (~50 min), several sets of ground *Randori* (~40 min) and standing *Randori* (~40 min) and cool-down (~10 min). Specific judo exercises were identical on both training weeks. Quantification of training intensity, calculation of training volume and calculation of training load were made as described in chapter 3.

Dietary control

In week 1, the subjects consumed 1000 ml of W, whereas in week 2 they consumed 1000 ml of CM during post-exercise recovery. Both drinks were given within 10 min post-

exercise and were consumed within 1 h of recovery. Subjects were instructed not to consume any other drinks or foods other than their prescribed beverage for 1.5 h post-exercise. For the needs of simulated competition, subjects were asked to “make weight” for the upcoming simulated competition following their usual nutritional practices during the first week; they were instructed to replicate the same weight loss practices on the following week. On week 1, the subjects completed a personalised food diary with the type, amount and timing of foods and drinks they consumed. Food diaries were given back to the subjects on week 2 and they were instructed to replicate the same dietary habits. Subjects were instructed to stay as close to the first treatment period regarding the amount, type and timing of food and drinks they consumed. Subjects would decrease their body weight until they reached the body weight required for their weight category; this would suggest decreasing their body weight by 1.5 - 2.0 % on both weeks. Days 1, 3 and 5 had been chosen for body weight assessments as to examine the differences of CM or W on changes in body weight and body fat at mid-week (day 3) and at the end of the training week (day 5) compared to baseline (day 1; before CM or W was ingested). Dietary records for each treatment period were analysed using Comp-Eat Pro (version 5.7).

Body weight and body fat

Measurements of body weight and body fat were made 4 times in total each week, before training (~17:30) at days 1,3,5 and in the morning (~8:30) of day 6. Measurements of body weight were assessed by recording the subjects’ weight in shorts (Seca 703, Vogel & Halke, Germany). Body fat was assessed as described previously via 4-site skinfold measurements (chapter 3) and percentage of body fat was calculated using the equation of Jackson and Pollock (1978).

Performance testing

All subjects performed three performance tests, at the beginning and end of each training week; the tests were performed before training on day 1 to obtain baseline measurements and again at the same time on day 5. The tests were performed at the dojo after warming-up and following body weight measurements. On this order on all occasions, the subjects performed a counterbalanced horizontal jump test, a timed push-up test and a SJFT. All

subjects had familiarised themselves with the tests previously. Relative humidity and temperature (mean \pm SD) during the tests were 59 ± 2 % and 20 ± 2 °C, respectively.

Countermovement horizontal jump

For the measurement of the horizontal jump distance, subjects used a free countermovement jump protocol; subjects stood at the anatomical position and after lowering the knees at 90° angle they performed a jump forwards using the arms. They performed two jumps and the best of the two jumps was recorded.

Timed push-ups

Push-up test was performed as described in chapter 3. The number of completed push-ups in 30 s was recorded as the score of the test.

Special Judo Fitness Test

The SJFT was conducted as described in chapter 3. Calculation of SJFT index is described in chapter 3.

Questionnaires

Throughout the study, subjects completed questionnaires to assess subjective ratings of DOMS and mood state using the POMS questionnaire. Questionnaires were given before training, 3 times during each training week (days 1,3,5). DOMS was measured for overall body soreness, soreness on front thigh muscles and soreness of upper body muscles (arms, chest, trapezoids), as described in chapter 3. Mood state was assessed by the POMS short form questionnaire (McNair et al., 1971).

Saliva collection and analysis

Saliva samples were collected daily in the morning after an overnight fast at 07:00 within 10 min after waking up during all occasions (Figure 4.1). The procedures for saliva collection and saliva analysis were made as described in chapter 3. Mean intra-assay coefficients of variation were 2.8%, 2.4% and 2.5% for sC, sT and SIgA, respectively. Estimation of saliva volume and calculation of saliva flow rate and SIgA secretion rate were made as described in chapter 3.

Statistical analysis

Data was checked for normality, homogeneity of variance and sphericity before statistical analysis. If Mauchly's test indicated that assumption of sphericity was violated the degrees of freedom were corrected using Greenhouse-Geisser estimates. For statistical analysis data were analysed using a two-way ANOVA for repeated measures (drink x time) with Bonferroni adjustments. The 95% confidence intervals (CI) for relative differences and size effects (ES) from simple planned contrasts were calculated to confirm meaningful significant differences. Mean nutrient intake and training volume of each training week were compared using dependent paired t-tests. Statistical significance was set at $p \leq 0.05$. All data are presented as mean \pm SD. Data was analysed using SPSS (SPSS v. 19.0; SPSS Inc, Chicago, IL, USA).

4.3. Results*Training load, ratings of perceived exertion and dietary intake*

Mean training load, RPE, training volume and time spend in each training zone did not present significant differences between the two weeks ($p > 0.05$). Mean training load was 2805 ± 190 AU and 2769 ± 196 AU during the week with the CM and W treatment, respectively. Mean RPE for each training week was 16 ± 1 . No significant differences ($p > 0.05$) were found for dietary intake between treatments. The mean 5-day energy intake was 2387 ± 255 kcal (CHO 49.2 ± 8.5 %, protein 25.8 ± 5.5 %, fat 25.0 ± 6.3 %) during the W treatment, and 2575 ± 315 kcal (CHO 51.7 ± 8.9 %, protein 23.0 ± 3.2 %, fat 25.3 ± 7.4 %) during the CM treatment.

Body weight and body fat

Body weight decreased from baseline ($p < 0.001$, ES=0.55) on days 5 and 6 in W treatment and on day 6 in CM treatment. Main effect for drink approached significance ($p = 0.08$) with the decrease in body weight reaching 1.9% in the W treatment in the W treatment (CI -82 to -191%) and 1.1% in the CM treatment (CI -48 to -152%). Body fat percentage increased by the end of each training week ($p < 0.001$, ES=0.64) by ~1% in both the W (CI 30 to 197%) and CM conditions (CI 61 to 206%) with slightly higher values during the CM week ($p = 0.003$, ES=0.75). However, no significant interaction effect suggests that the

increase in body fat was to the same extent in both treatments ($p>0.05$). Mean data is presented on Table 4.1. Individual data of the subjects' absolute and percentage body weight changes is illustrated in figure 4.2.

Table 4.1. Changes in body weight and body fat during the water (W) and chocolate milk (CM) treatments (Mean \pm SD).

% indicates percentage change in body weight from day 1 to day 6; * indicates significantly different ($p<0.05$) from day 1; § indicates significantly different ($p<0.05$) from day 3.

		DAY 1	DAY 3	DAY 5	DAY 6	% change	% range
Body weight (kg)	W	78.2 \pm 7.4	77.8 \pm 7.5	77.4 \pm 7.5*	76.7 \pm 7.3*§	-1.09	-0.41 to -3.78
	CM	78.3 \pm 8.0	78.3 \pm 8.0	78.4 \pm 8.1	77.5 \pm 8.0*§	-1.94	1.83 to -5.63
Body fat (%)	W	12.4 \pm 3.8	12.6 \pm 3.5	13.6 \pm 4.5*§	13.0 \pm 4.1		
	CM	13.3 \pm 4.8	13.3 \pm 3.4	14.1 \pm 3.1*§	13.7 \pm 3.8		

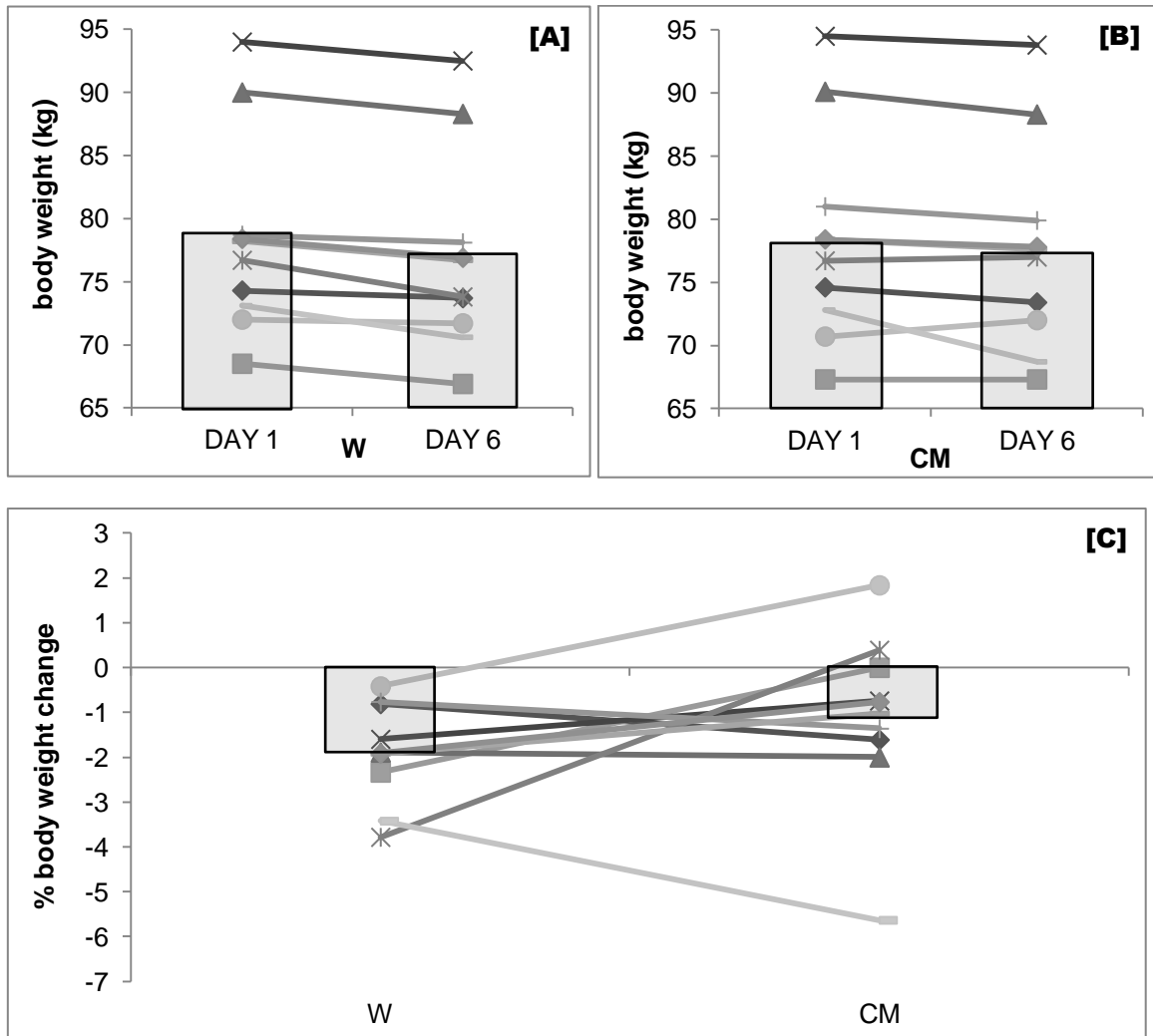


Figure 4.2. Individual data on absolute and percentage weight change of the subjects. Figures 4.2. A and B show the absolute body weight change in the W and CM conditions, respectively. Figure 4.2. C show the percentage body weight changes in the W and CM conditions for each athlete. Each data point represents an athlete; same shape data points represent data for the same athlete.

Performance tests

Countermovement horizontal jump

No significant main effect of drink or interaction ($p > 0.05$) indicated that performance in the horizontal jump did not change with the consumption of either beverage, even though a significant effect of time ($p = 0.05$) showed that mean jump performance was generally better during the CM condition. Data is shown on Table 4.2.

Timed push-ups

Significant main effects of drink ($p < 0.001$, $ES = 0.71$), time ($p < 0.001$, $ES = 0.64$) and interaction ($p < 0.001$, $ES = 0.74$) showed that number of push-ups performed in 30-s increased significantly by the end of the training week in the CM but not in the W condition; performance enhanced in all subjects by a mean of 14.6% in the CM condition (CI 63 to 136%) and in 4 out of 12 subjects by a mean of 2.2% in the W condition (CI -100 to 224%). Data is shown on Table 4.2.

Special Judo Fitness Test

Mean number of throws in the SJFT was generally higher during the CM condition ($p < 0.001$), with no significant effects of CM. Significant effects of drink ($p = 0.04$, $ES = 0.58$), time ($p = 0.04$, $ES = 0.57$) and interaction ($p = 0.05$, $ES = 0.50$) showed that SJFT performance index improved significantly after CM consumption (CI 90 to 530%) but not after W consumption (CI -67 to 265%); performance enhanced in 10 out of 12 subjects in the CM condition and in 5 out of 12 subjects in the W condition (Table 4.2).

Muscle soreness

Significant effects of drink ($p < 0.001$, $ES = 0.79$), time ($p < 0.01$, $ES = 0.70$) and interaction ($p < 0.001$, $ES = 0.77$) showed that general muscle soreness was lower throughout the week in the CM condition compared with W (CI -45 to -155%); muscle soreness rose from day 1 in both treatments but kept increasing from mid-week to the end of the week in the W (CI 46 to 153%) but not the CM condition (CI -377 to 398). Soreness was mainly located on upper body muscles ($p = 0.002$) with a similar pattern of increase to general soreness (Table 4.3).

Mood state

Significant effects of drink ($p < 0.0001$, $ES = 0.85$), time ($p = 0.007$, $ES = 0.72$) and interaction ($p < 0.001$, $ES = 0.79$) showed that total mood disturbance scores were lower during the CM condition compared with W (CI -33 to -165%). By day 5, mood disturbance increased progressively from day 1 during the W week (CI 54 to 146%), whereas no significant changes were observed during the CM week (CI -88 to 288%). Subscale of tension

($p < 0.01$) was lower during the CM compared with W, without differences in subscales of vigour, aggression, confusion, fatigue and depression between drinks ($p > 0.05$) (Table 4.3).

Table 4.2. Performance tests at the beginning (DAY 1) and end (DAY 5) of training weeks during the water (W) and chocolate milk (CM) treatment (Mean \pm SD).

Performance test		DAY 1	DAY 5
Horizontal jump (cm)	W	2.32 \pm 0.16	2.36 \pm 0.21
	CM	2.41 \pm 0.17#	2.43 \pm 0.17 #
Push-ups in 30 s (no.)	W	45 \pm 7	46 \pm 6
	CM	48 \pm 7	55 \pm 6 *#
Special Judo Fitness Test (throws)	W	25 \pm 3	25 \pm 3
	CM	27 \pm 2 #	28 \pm 2 #
Special Judo Fitness Test (index)	W	14.2 \pm 1.6	13.7 \pm 1.2
	CM	13.3 \pm 2.1	12.4 \pm 1.1*#

* indicates significantly different ($p < 0.05$) from Pre; # indicates significantly different ($p < 0.05$) than W.

Table 4.3. Changes in muscle soreness and mood disturbance during the weeks with water (W) and chocolate milk (CM) treatment (Mean \pm SD).

		DAY 1			DAY 3			DAY 5		
General muscle soreness	W	1.5	\pm	0.7	3.2	\pm	1.6 *	4.5	\pm	1.8 *§
	CM	1.6	\pm	0.8	2.4	\pm	1.0 *#	2.5	\pm	1.0 *#
Front thigh soreness	W	1.4	\pm	0.7	2.2	\pm	1.6	3.4	\pm	1.6 *
	CM	1.3	\pm	0.6	2.2	\pm	0.8	2.4	\pm	1.1 #
Upper body soreness	W	1.2	\pm	0.4	2.8	\pm	1.6 *	3.8	\pm	1.6 *§
	CM	1.5	\pm	0.8	2.2	\pm	0.8 *#	2.3	\pm	1.1 *#
Total mood disturbance	W	-6.0	\pm	5.1	1.4	\pm	7.3 *	4.8	\pm	6.1 *§
	CM	-4.3	\pm	5.2	-1.6	\pm	5.3	-3.4	\pm	6.0 #
Vigour	W	13.9	\pm	3.7	11.1	\pm	4.1	9.6	\pm	3.8
	CM	10.7	\pm	3	11.1	\pm	3.7	11.1	\pm	2.9
Tension	W	2.2	\pm	2	3.6	\pm	2.8	4.7	\pm	3.7
	CM	2.0	\pm	1.8	2.6	\pm	2.9	2.6	\pm	2.6 #
Depression	W	0.2	\pm	0.4	1.0	\pm	1.2	0.7	\pm	1.2
	CM	0.3	\pm	0.7	0.1	\pm	0.3	0.1	\pm	0.3
Aggression	W	1.6	\pm	1	2.3	\pm	2.4	2.3	\pm	1.6
	CM	2.0	\pm	1.2	1.8	\pm	2.2	1.9	\pm	1.9
Fatigue	W	3.7	\pm	2.2	5.2	\pm	1.9	6.3	\pm	3.8
	CM	4.0	\pm	3	5.1	\pm	2.1	3.8	\pm	3.2
Confusion	W	0.3	\pm	0.5	0.4	\pm	0.7	0.4	\pm	0.5
	CM	0.6	\pm	1.1	0.3	\pm	0.7	0.2	\pm	0.4

* indicates significantly different ($p < 0.05$) from day 1; § indicates significantly different ($p < 0.05$) from day 3; # indicates significantly different ($p < 0.05$) than W

Salivary hormones

Data for sC, sT and sT/C ratio is shown on Figure 4.3 A, B and C, respectively. A significant effect of drink ($p=0.02$, $ES=0.68$) and interaction ($p<0.001$, $ES=0.59$) showed that mean sC concentrations were significantly lower during the week with the CM condition (CI -18 to -182%) without significant differences across time ($p>0.05$). Concentrations of sT were similar across time and between the two treatments ($p>0.05$). Significant main effects of time ($p=0.03$, $ES=0.44$) and interaction ($p=0.02$, $ES=0.67$) showed that mean sT/C ratio increased significantly from baseline in the CM treatment (day 2: CI 5 to 195%; day 4: CI 1 to 249%) with a tendency for higher values during the CM condition compared with W ($p=0.07$, $ES=0.48$; CI -9 to 209%).

Salivary IgA

Data for SIgA absolute concentrations and secretion rate is shown in Figures 4.4 A and B, respectively. Although mean SIgA absolute concentrations increased in the morning of the competition day from the first days of the week in the W condition ($p=0.004$, $ES=0.26$), no significant effect of drink or interaction was found ($p>0.05$). A significant effect of time showed that mean SIgA secretion rate increased towards the end of the week ($p=0.02$, $ES=0.81$), in a similar manner in both conditions ($p>0.05$).

Saliva flow rate

A significant main effect of drink ($p=0.008$, $ES=0.70$) and interaction ($p<0.001$, $ES=0.72$) showed that mean saliva flow rate was significantly higher during the week of the CM condition compared with W (CI 86 to 111%), without significant changes across time ($p>0.05$). Data is shown in Figure 4.4 C.

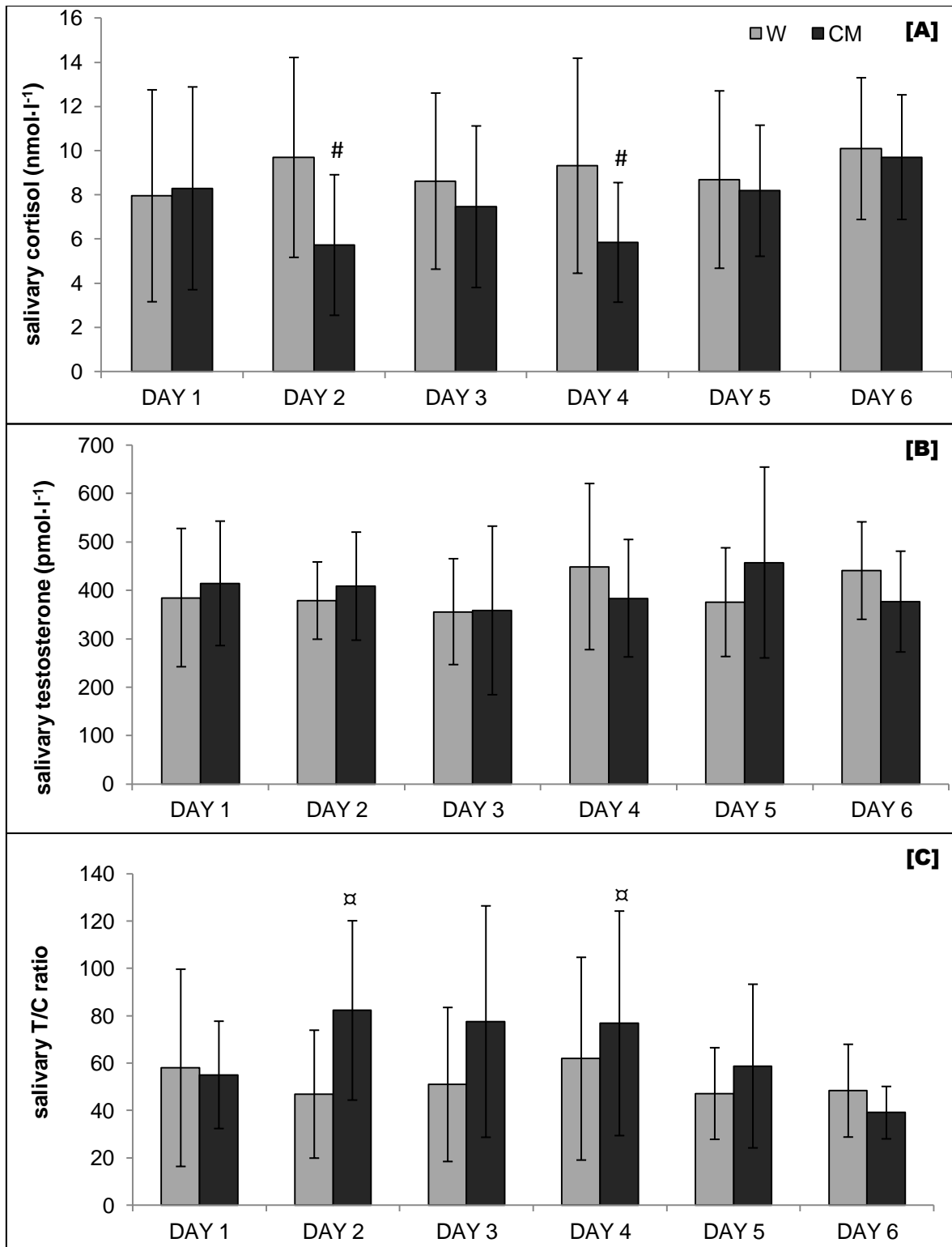


Figure 4.3. Mean (\pm SD) concentrations of [A] salivary cortisol, [B] salivary testosterone and [C] salivary T/C ratio during the weeks with water (W; grey columns) and chocolate milk (CM; black columns) conditions. α indicates significantly different ($p < 0.05$) from day 1; # indicates significantly different ($p < 0.05$) than water.

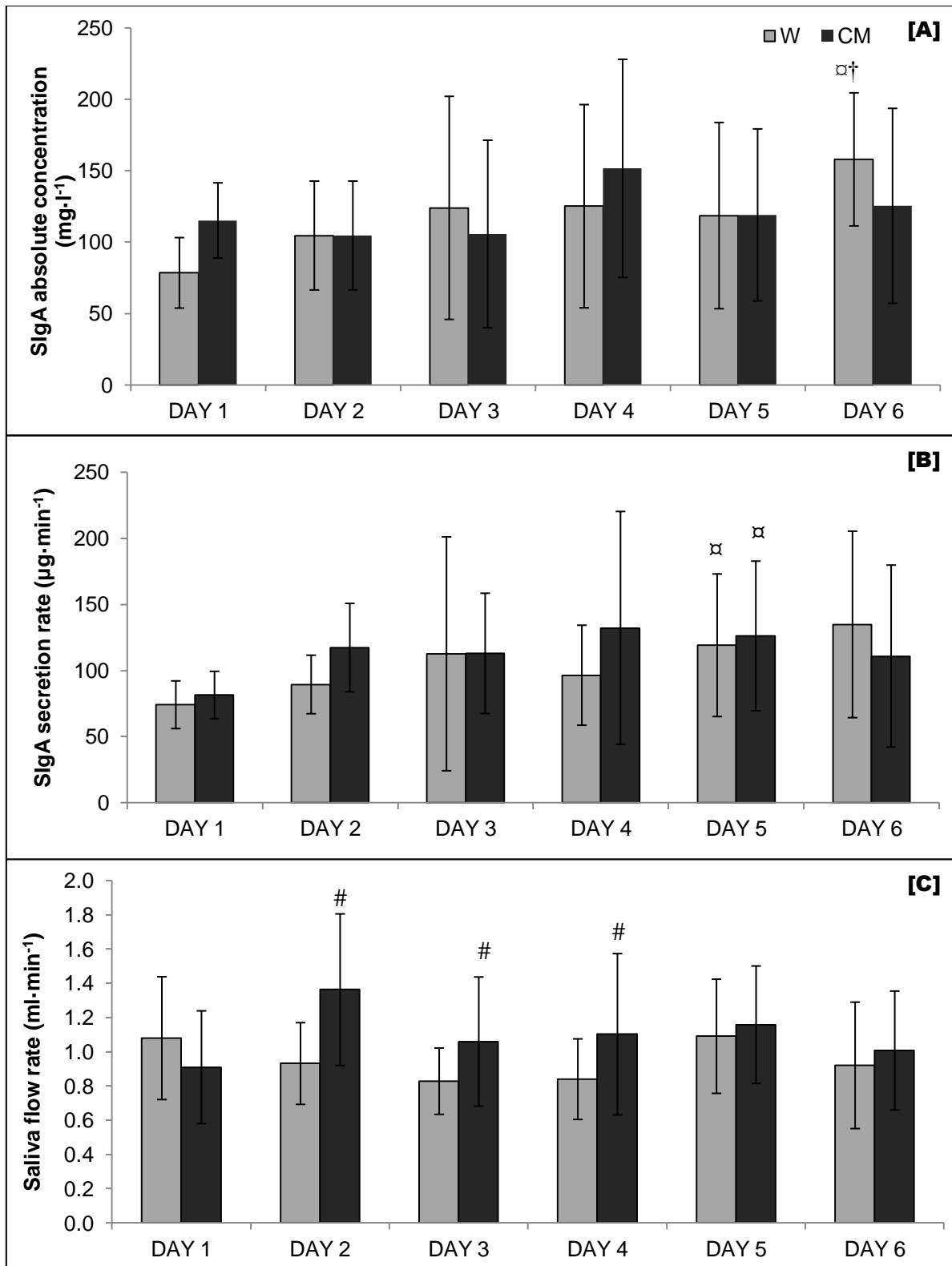


Figure 4.4. Mean (\pm SD) concentrations of [A] SIgA absolute concentrations, [B] SIgA secretion rate and [C] saliva flow rate during the weeks with water (W; grey columns) and chocolate milk (CM; black columns) conditions. α indicates significantly different ($p < 0.05$) from day 1; \dagger indicates significantly different ($p < 0.05$) to day 2; # indicates significantly different ($p < 0.05$) than water.

4.5. Discussion

This study showed that post-exercise chocolate milk consumption during 5 days of intensive judo training was favourable for enhancing several aspects of recovery from intensive judo training, without affecting intentional weight loss. Post-exercise CM consumption was associated with lower sC responses and higher saliva flow, attenuated muscle soreness ratings, ameliorated mood disturbance and enhanced judo-specific performance, whereas at the same time athletes managed to “make weight” by the end of the week.

In this study, post-exercise CM consumption improved timed push-ups and judo-specific performance by the end of the week, without changes in countermovement jump. The findings of our study agree with some (Karp et al. 2006; Cockburn et al. 2008; Thomas et al. 2009; Ferguson-Stegall et al. 2011; Lunn et al. 2012) but not all studies (Pritchett et al., 2009; Gilson et al. 2010; Spaccarotella and Andzel 2011). The majority of previous investigations assessed the effects of CM during laboratory-based standardized tests, whereas the present study assessed the effects of CM in an applied sport setting. Morning sC concentrations were lower in the week of the CM treatment compared with W, which may indicate that accumulated stress of the consecutive intense training sessions was lower when CM was consumed. Similarly, mood was not disturbed when CM was consumed after training. Deterioration of physical performance, elevated C responses and disturbance of mood state are all considered as markers of overreaching and recovery (Meeusen et al., 2013). CHO supplementation during intensified exercise/training has been shown to maintain physical performance and mood (Achten et al., 2004; Halson et al., 2004). Therefore we suggest that the higher total caloric and CHO content in the CM aided the recovery from exercise and attenuated the symptoms of overreaching during a short-term period of intense judo training, possibly due enhanced energy and CHO availability. Saliva T and SIgA responses did not present differences between treatments in this study, as expected to decrease from baseline during periods of intensive training (Meeusen et al., 2013). This could possibly indicate that 5 days of intense judo training were not enough to induce changes in these markers and that a more prolonged training period would be required to affect these markers. However, due to the short-term period of intense training in this study we can only discuss functional overreaching, yet it is possible that should

intense training continue, these athletes could reach the onset of non-functional overreaching.

Attenuation of muscle soreness ratings during the week with CM consumption was observed in this study. These results are similar with our previous study in these judo athletes (chapter 3) and confirm the findings of Cockburn et al. (2010) who reported that CM consumption after muscle-damaging exercise attenuated the increases in ratings of delayed-onset muscle soreness, enhanced muscle-related performance and attenuated the rise in CK responses. Similar investigations showed attenuated rises in CK after the consumption of CM during recovery (Wojcik et al., 2001; Cockburn et al., 2008; Pritchett et al., 2009; Gilson et al., 2010). It has been previously suggested that the protein content in the CM was associated with higher muscle amino-acid uptake and increased muscle protein synthesis (Wilkinson et al., 2007) as well as increased activation status of signalling proteins associated with protein synthesis and attenuation of markers of muscle protein degradation (Ferguson-Stegall et al., 2011; Lunn et al., 2012). In our study, the lower sensation of muscle soreness along with enhancement of functional tests could be related with a lower degree of muscle tissue disruption with the CM.

One key aspect of this study was to observe whether consuming a milk-based CHO-protein recovery beverage could affect weight loss in judo. Typically, judo athletes do not tend to consume CHO in the week preceding a competition, as it could possibly interfere with their weight loss practices. In our study, body weight decreased by the morning of the competition day by 1.9 % in the W condition and 1.1% in the CM condition. Although not reaching statistical significance, body weight was maintained throughout the CM week, whereas it was reduced progressively in the W condition; this could indicate two things: (a) that the higher energy content in the CM affected the usual weight loss practice of the judo athletes, as seen on W week (observation week), and making it more difficult to “make weight” or (b) the reduction in body weight of these subjects was actually the effect of mild dehydration. Although no urine osmolality measurements were made, saliva flow rate was higher during the CM week compared with the W week. This could indicate that CM may have been associated with enhanced hydration in these subjects, as decreased rates of saliva flow were reported in dehydrated subjects (Fortes et al., 2012). Additionally, measurements of body fat actually increased from day 1 and did not present any significant differences between beverages, indicating that weight loss was not achieved through a decrease in adipose tissue. In addition, no difference was found in the total energy intake

from food diaries data. Therefore, it appears more probable that the decrease in weight loss in these subjects was actually a result of mild dehydration. Previous studies have shown that fluid milk consumption post-exercise was more effective in restoring sweat losses compared with W after exercise-induced mild dehydration (Shirreffs et al., 2007), whereas in already exercise/heat-induced dehydrated subjects milk was effective for maintaining positive net fluid balance during recovery (Watson et al., 2008). This could explain the difference in weight loss between the two beverages, indicating that subjects had higher fluid retention during recovery and were possibly in positive net fluid balance with the CM. The findings indicate that CM consumption post-exercise probably has no meaningful effect on the subjects' weight loss practices; on the contrary the beneficial effects of the CM for enhancing recovery may be more important for effective competition performance than any possible consequence on weight loss.

Limitations of this study were the lack of a randomised, double-blind, crossover design with equicaloric placebo. Due to the nature of the beverages, it was impossible to blind the treatment to the researchers and subjects. The lack of equicaloric placebo in this study was chosen as to comply with the usual nutritional practices of judo athletes preceding competition; however, future investigations may assess the effects of CM versus a same equicaloric, flavoured and coloured beverage. The reason for not choosing a crossover design was to eliminate the bias of subjects regarding practices for weight loss. Subjects were requested to follow their usual practices for "making weight" in the first week (i.e. limiting CHO and total energy consumption, restricting fluid intake), and follow these practices during the CM week. Should CM was given to some subjects on the first week and observe that it interfered with their required weight loss it is possible that on the second week these subjects would try harder to lose weight by further reducing energy consumption. Even though the subjects were instructed to follow the same diet on both weeks and while care was taken as to try to control for all food and drink intake via food diaries, subjects had all their meals at their own space without supervision. However, it should be noted that this was a field study involving national elite athletes during "real-life" training situations; therefore the main objective of athletes and coaches was to enhance performance and perform better at the upcoming competition. Hence, a crossover design was not a safe choice for this cohort of athletes because of the risk that energy consumption would not have been the same between conditions and consequently the effects of CM on weight loss would not have been reliable.

4.6. Conclusions

This study identified that the consumption of CM compared with W during 5 days of intensive judo training was associated with lower sC responses, limited the disturbances in mood, attenuated ratings of muscle soreness and enhanced judo-related performance. Therefore, this study suggested that CM can successfully serve as a recovery beverage during periods of intensive judo training as it can have beneficial effects on several aspects of recovery, without meaningful effects on pre-competition intentional weight loss.

**CHAPTER 5: STUDY 3. Salivary hormones, IgA
and performance during intense training and
tapering in judo athletes.**

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5.1. Abstract

The aims of this study were to identify the time-course of change of sT, sC and SIgA, mood state and performance capacity during a 2-week taper in judo athletes, and to examine the diurnal variation in these salivary markers. Eleven male judo athletes completed 5 weeks of training: 1 week of normal training (NORM), 2 weeks of intensified training (INT) and 2 weeks of exponential tapering (TAPER). Once per week subjects completed anthropometric measurements, vertical and horizontal countermovement jump tests, a handgrip strength test, a SJFT, a multistage aerobic fitness test, a 3x300-m run test. Subjects also completed questionnaires to assess mood state and muscle soreness. Two daily saliva samples (at 07:00 and 19:00) were collected at the end of each week during NORM and INT and every day during TAPER. Increased morning sT, decreased evening sC, lower muscle soreness and enhanced mood state ($p < 0.05$) were evident by the early phases of TAPER. A significant 7.0% improvement in 3x300-m performance time, a 6.9% improvement in the vertical jump ($p < 0.05$) and increased morning and evening SIgA secretion rate ($p < 0.01$) were observed during the middle-late phases of TAPER. The higher values of salivary immunoendocrine variables were observed in the morning, whereas saliva flow rate was higher in the evening. This study indicates that salivary hormones display diurnal variation. Furthermore, changes in hormonal responses, mood state and muscle soreness precede enhancements in performance and mucosal immunity, suggesting that judo athletes taper for at least a week prior to competition.

Keywords: mucosal immunity, cortisol, testosterone, diurnal variation, recovery, SJFT

5.2. Introduction

Previous chapters (chapters 3 and 4) have illustrated that judo is a physically demanding combat sport consisting of short duration, dynamic high-intensity and intermittent exercise, as shown on the high units of training load and HR data and the high rates of DOMS. Therefore, to promote effective recovery and subsequently optimise performance, the need for tapering periods during judo periodisation is essential. Tapering is a gradual reduction in the training load which allows the recovery of physiological capacities that were impaired by the previous training phase; this in turn should restore the tolerance to training resulting in further training-induced adaptations along with competition performance enhancements (Mujika and Padilla, 2003).

A successful taper requires careful planning and monitoring, which aims to optimise training-induced adaptations, including performance capacity, cardiorespiratory, hormonal, haematological, biochemical, immunological and psychological markers. Performance optimization during tapering periods is not the result of additional training-induced fitness gains; rather, it results from significant reductions in the accumulated levels of fatigue (Mujika and Padilla, 2003). In general, the improvements in performance range from 0.5-6.0% (Mujika and Padilla, 2003), which can often make a substantial difference to the outcome of competition performance. Tapers usually involve an increase in anabolism and a reduction in catabolism, manifested by increases in circulating T concentrations along with decreases in C (Coutts et al., 2007a; Coutts et al., 2007b; Coutts et al., 2007c; Santhiago et al., 2011). Furthermore, tapers are often associated with reduced muscle damage, evidenced by decreased plasma CK activity (Coutts et al., 2007a; Coutts et al., 2007b).

Intense training, usually performed before tapering, is often associated with suppression of several aspects of immunity, and during this time athletes are more susceptible to infections (Gleeson, 2002). Strenuous long-term training is associated with chronic suppression of mucosal immunity lasting 7 days or more (Bishop and Gleeson, 2009), and it is during this “open window” period of depressed mucosal immunity that athletes are more susceptible to upper respiratory tract infections, which can in turn negatively affect training and performance (Pyne and Gleeson, 1998). Engaging in long-term, strenuous training has been reported to result in decreased salivary levels of SIgA in trained athletes (Gleeson et al., 1999b; Fahlman and Engels, 2005; Neville et al., 2008). These studies

examined the responses of SIgA concentrations and/or secretion rate during intensive training but very few studies have examined SIgA responses during tapering after an intensive training period. To the authors knowledge only one study has reported some non-significant recovery of SIgA concentrations to baseline after 2-weeks of reduced training load following an intensive training period (Halson et al., 2003). However, no strict control of tapering was evident in this study.

Mood state has also been observed to be negatively affected by excessive training-induced stress and fatigue (Halson and Jeukendrup, 2004), whereas during tapering the levels of mental fatigue decrease, usually manifested by enhancements in global mood state (Santhiago et al., 2011; Zehsaz et al., 2011). Therefore, tapers aim to restore immunity as well as mental and physical performance to keep the athletes illness-free and in an optimum state for successful competition performance.

It appears that physiological responses during tapering in judo have not been studied extensively. Thus, the main objective of this study was to identify the time course of change of selected salivary hormonal and immunological markers, mood state and performance capacity related to judo during a 2-week taper in judo athletes. A secondary aim was to examine diurnal variation in sC, sT and SIgA in the morning and evening during a period of normal training, more intensive training and subsequent tapering.

5.3. Methods

Subjects

Eleven male competitive judo athletes volunteered to participate in the current study. All subjects had competed in judo for at least four years and trained for a minimum of 4 times per week, were non-smokers and were not taking any form of medication. They refrained from alcohol consumption and remained illness-free for the total study duration. No overt signs of overtraining (as described in chapter 3) were evident in the subjects before commencing the study. After having the aims and procedures of the study explained to them, each subject signed an informed consent and completed a medical health questionnaire. The characteristics (mean \pm SD) of the subjects were: age 20 ± 6 years; height 172 ± 4 cm; body weight 74.9 ± 12.1 kg; $\dot{V}O_{2\max}$ 57.2 ± 7.2 ml·kg⁻¹·min⁻¹; HRmax

190 ± 5 bpm; body fat 8.1 ± 1.9 %, training experience 9 ± 5 years. The Cyprus National Bioethics Committee approved all procedures undertaken.

Experimental design

This study examined the salivary responses of C, T and SIgA, saliva flow rate, mood state, muscle soreness and performance changes of trained judo athletes during their normal training, more intensive training and subsequent tapering, as to identify the time needed to maximise hormonal responses and performance indices. Subsequently, the time-frame needed for tapering can therefore be identified by coaches to plan their periodisation and to be used by judo athletes prior to a competition. The experimental approach of this study was a repeated measures design, where all athletes engaged in five weeks of training, with modifications of training load across weeks. The study took place between the months February and March during pre-season preparations and all subjects trained together in the same dojo under the supervision of the same coach. Subjects were initially reported to the laboratory for the preliminary measurements of their $\dot{V}O_2\text{max}$, body weight, body fat and body height, as they were described in chapter 3. Following at least one week, subjects began their programmed training routine. The training for each individual was controlled and monitored for five weeks in total. During week 1, subjects trained moderately 4-5 times per week completing their normal volume and type of training (NORM). Subjects had been engaging in this level of training for at least 4 weeks beforehand. The pre-season training programs of judo athletes comprise of technical judo (techniques and strategies) and anaerobic training. The training load and training programs followed in this study were based on usual training of previous weeks. During weeks 2 and 3, subjects trained intensively 6 times per week whilst training volume doubled (INT). During weeks 4 and 5, subjects followed a fast decay exponential taper where the training volume was progressively reduced to the half of NORM (TAPER). The study design is illustrated in Figure 5.1. During the total study period, subjects performed five anthropometric measurements, five vertical and horizontal jump tests, five handgrip strength tests, five SJFT, five multistage fitness tests (MSFT) and five 3 x 300-m run tests. The tests were performed every week on the same day, same time of day and same testing area and under similar experimental conditions. All subjects were instructed to consume a high carbohydrate diet and remain euhydrated throughout the study period. Subjects have had

their last meal at least 3 h prior to testing and were instructed to avoid beverages with caffeine and high-carbohydrate content at least 3 h before testing. Saliva samples were collected frequently during the study for the determination of saliva flow rate, sC, and sT concentrations, as well as SIgA concentrations and secretion rate. Furthermore, during the study the subjects completed questionnaires for assessment of mood state and muscle soreness.

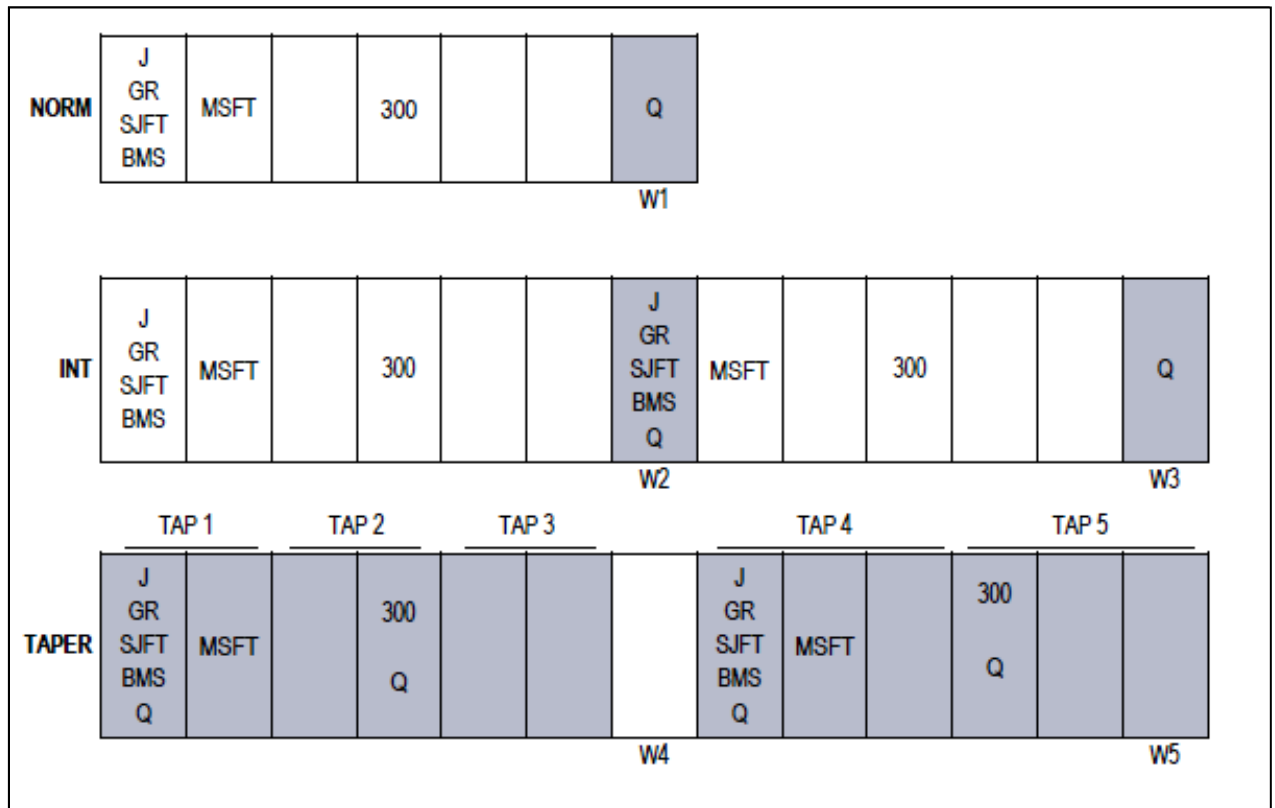


Figure 5.1. Schematic representation of experimental study design. J: Jumps, GR: Grip strength, SJFT: Special judo fitness test, MSFT: Multi stage fitness test, BMS: Body weight and skinfold measurements, 300: 3 x 300-m, Q: Questionnaires (DOMS, POMS). NORM: Normal training, INT: Intensified training, TAPER: Tapering. W1: week 1, W2: week 2, W3: week 3, W4: week 4, W5: week 5. Grey cells indicate saliva collection. Each block represents a day.

Training quantification

Judo training session durations were on average 1.5 - 2.0 h during NORM, 2.0 - 2.5 h during INT and 0.5 - 1.0 h during TAPER. On average, the subjects' usual training consisted of sets of 3 x 5 min of standing *Randori* (simulated combat) and 2 x 3 min of ground *Randori* interspersed by 5 min rest in addition to several judo-specific skills and drills and mat work. The same training volume and type of training were kept for NORM.

To double the training volume during INT, *Randoris* were increased in number of sets and duration to 5 x 8 min standing *Randori* and 3 x 5 min ground *Randori*, whereas rest time between sets was decreased to 2 min. The number of judo skills and drills and mat work increased in volume and intensity. Training volume fell exponentially by half during TAPER: during week 4 numbers of *Randori* fell to 3 x 3 min and 2 x 3 min of standing and ground *Randori* respectively, with 5 min rest intervals in addition to judo-specific skills and drills and mat training; during week 5 subjects performed only the aforementioned bouts of standing and ground *Randori* with 2 days of complete rest. A training diary was kept to record the duration of training sessions and type of exercises performed (number of *Randori* sets and intervals). Training and taper regimens were individualized based on each athlete's usual volume of training. Quantification of training intensity, calculation of training volume and calculation of training load were made as described in chapter 3.

Anthropometric measurements

Body weight and skinfold measurement were assessed once per week in the dojo at the start of the training week. Body weight was recorded before training in shorts (Seca 703, Vogel & Halke, Germany). Percentage of body fat was calculated as described previously (chapters 3 and 4) using the equation of Jackson and Pollock (1978).

Performance testing

Subjects performed a series of tests in frequent times during the study; tests were performed at the same day and time each week. Relative humidity and temperature (mean \pm SD) during the tests were 59 ± 3 % and $22 \pm 2^{\circ}\text{C}$, respectively.

Jumps

For the measurement of the horizontal jump distance, subjects used a free countermovement jump protocol, as described in chapter 4. They performed two jumps and the best of the two jumps was recorded. The assessment of the vertical jump height was assessed using a specially designed platform to calculate time of flight (MuscleLab, Ergotest Innovation, Norway); each subject performed three countermovement jumps and the best of three was recorded.

Handgrip strength

Handgrip strength of both hands was measured as described in chapter 3. Nine out of the eleven subjects were right handed. Both jump tests and grip strength were assessed indoors in the dojo at the first day of each training week.

Special Judo Fitness Test

The SJFT was conducted as described in chapter 3. Calculation of SJFT index is described in chapter 3.

Multi-Stage Fitness Test

The MSFT was performed one day following the jumps and the SJFT on an indoors parquet basketball court (Leger and Lambert, 1982). Briefly, all subjects at the same time ran continuously, back and forth in a 20-m court keeping in track of the audio signals of a recorded disk. The running speed progressively increased until subjects were volitionally fatigued or could not keep up. The total distance covered before failing to keep up with the increasing speed was recorded as the final score of the test.

3 x 300-m running test

The 3 x 300-m bouts were performed two days following the MSFT on a 400-m outdoor track. Runs were separated by 3 min of active rest. Each run was timed individually for each subject with a stopwatch and the mean of the three runs was then calculated. This test was previously used in judo athletes and has been shown to be a sensitive marker of anaerobic performance during overtraining (Callister et al., 1990). No rain or strong wind was evident during the test in either week.

Questionnaires

At the end of each training week (weeks 1-3) and twice per week (i and ii) during the taper weeks (weeks 4-5), subjects completed the POMS short form questionnaire, a VAS for general fatigue and a DOMS questionnaire (Figure 5.1). Subjects completed these questionnaires at the same time of day prior to training. Using the VAS for general fatigue subjects rated their subjective feeling of accumulated fatigue on a scale of 1 (not tired) to 10 (extremely tired). DOMS was measured for overall body soreness, soreness on front

thigh muscles and soreness of upper body muscles (arms, chest, trapezoids), as described in chapter 3. Mood state was assessed by the POMS short form questionnaire, as described in chapter 4.

Saliva collection and analysis

Resting saliva samples were collected at the end of each week during training (weeks 1-3) and almost every day during the taper (weeks 4-5). Subjects provided two saliva samples each time; one in the morning at ~07:00 within 20 min after waking up and one in the evening at ~19:00 before training. Each saliva collection was performed on the same time of day each time. The procedures for saliva collection and saliva analysis were made as described in chapter 3. High and low controls were run with every assay. The sensitivity of the kits were $0.08 \text{ nmol}\cdot\text{L}^{-1}$ for sC, $<3.46 \text{ pmol}\cdot\text{L}^{-1}$ for sT and $0.25 \text{ }\mu\text{g}\cdot\text{ml}^{-1}$ for SIgA. Mean intra-assay coefficients of variation were 2.9 %, 2.4 % and 1.5 % for sC, sT and SIgA, respectively. Estimation of saliva volume and calculation of saliva flow rate and SIgA secretion rate were made as described in chapter 3.

Statistical analysis

For statistical analysis the values of sC, sT and SIgA across the 2-week taper were divided in 5 distinct phases; days 1-2 consisted phase 1 (TAP1), days 3-4 consisted phase 2 (TAP2), days 5-6 consisted phase 3 (TAP3), days 8-10 consisted phase 4 (TAP4) and days 11-13 consisted phase 5 (TAP5) (Figure 5.1). Data was checked for normality, homogeneity of variance and sphericity before statistical analysis. If Mauchly's test indicated that assumption of sphericity was violated the degrees of freedom were corrected using Greenhouse-Geisser estimates. Reliability of the tests was analysed using intra-class correlation coefficients (r). One-way ANOVA with repeated measures with Fisher's Least Significant Differences (LSD) comparisons was used to assess any differences across time points in all measures except for saliva. Differences across time between morning and evening saliva values were tested with a two-way ANOVA for repeated measures followed by LSD comparisons. The 95% confidence intervals (CI) for relative differences and size effects (ES) from simple planned contrasts were calculated to confirm significant differences. Statistical significance was set at $p \leq 0.05$. All data are presented as mean \pm SD. Data was analysed using SPSS (SPSS v. 19.0; SPSS Inc, Chicago, IL, USA).

5.4. Results

Training load, ratings of perceived exertion, body weight and body fat

Training load doubled during INT mainly by increasing the time spent in high intensity training (Figure 5.2) and then fell below baseline during TAPER ($p < 0.01$; Table 1). RPE ratings also significantly increased during INT and fell during TAPER ($p < 0.01$; Table 5.1). Body weight did not change across weeks. However, body fat was significantly lower at week 3, compared with NORM and TAPER ($p = 0.03$; Table 5.1).

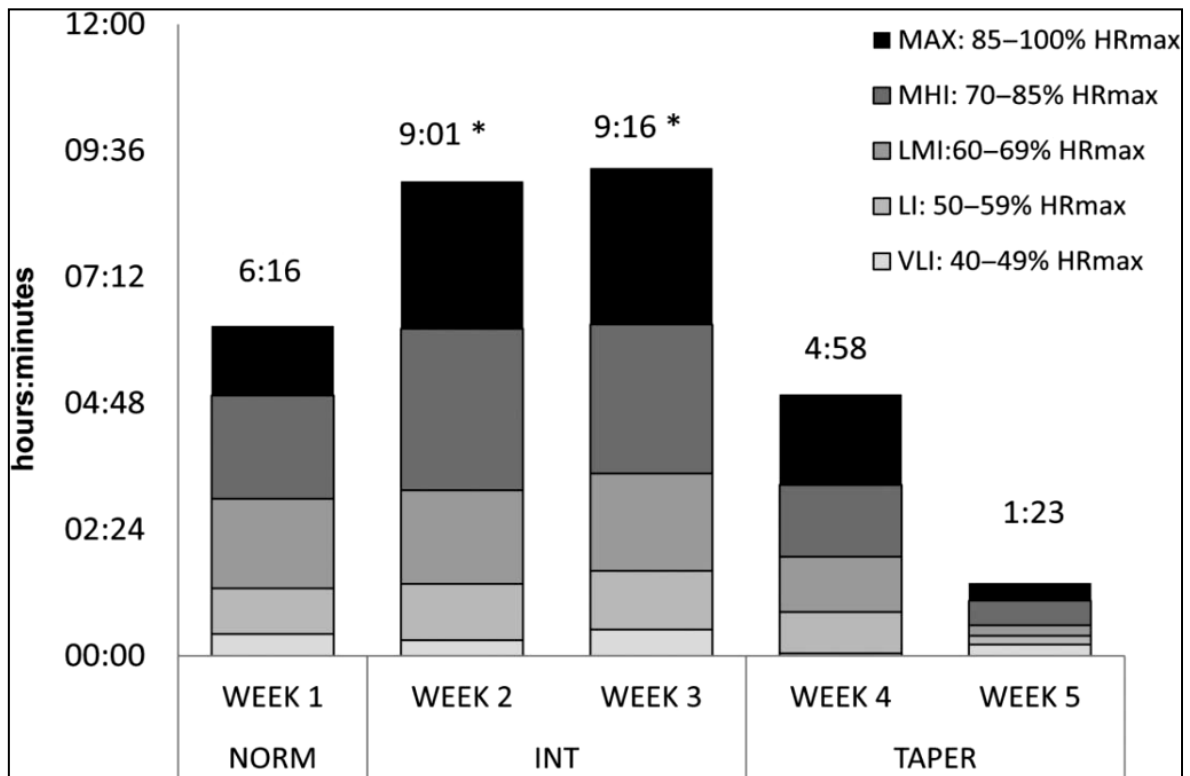


Figure 5.2. Changes in training volume as time spent in each heart rate zone during normal training (NORM), intensified training (INT) and tapering (TAPER). * MAX and MHI intensities during INT were significantly different from NORM and TAPER.

Performance tests

Jumps

Intra-class correlations were $r=0.85$ and $r=0.71$ for horizontal and vertical jump tests, respectively. Performance on the horizontal jump significantly declined by 4.3% during week 2 ($p=0.03$, $ES=0.68$, CI -25 to -173%) and returned to baseline levels during TAPER ($ES=0.85$, CI 40 to 48%). Vertical jump performance showed a non-significant decline during week 3 and was enhanced by 6.9 % at the end of TAPER ($p=0.04$, $ES=0.64$, CI 15 to 185%).

Handgrip strength

Reliability of the handgrip strength test was $r=0.85$ for the right hand and $r=0.77$ for the left hand. Handgrip strength on the right hand (R) did not change across weeks; however, the handgrip strength of the left hand (L) increased from baseline to reach the strength levels of the right hand ($p=0.03$, $ES=0.57$, CI 19 to 181%; Table 5.1).

SJFT

Intra-class correlation was $r=0.67$ for the SJFT. Performance on the SJFT index tended to improve by 5.9% on week 4 ($p=0.08$, $ES=0.52$, CI -16 to 217%) and by 7.4% on week 5 ($p=0.06$, $ES=0.55$, CI -6 to 206%), compared with NORM training values. By the end of TAPER, 6 out of 11 subjects improved their performance on the SJFT (Table 5.1).

MSFT

Intra-class correlation was $r=0.68$ for the MSFT. Performance on MSFT tended to improve by 11% by week 4 compared with week 1 ($p=0.08$, $ES=0.62$, CI -42 to 242%). By week 4, 9 out of 11 subjects increased their distance covered (Table 5.1).

3 x 300-m performance

Reliability for the 3x300-m test was high, with $r=0.71$. The mean time for the 3 x 300-m running improved during TAPER ($p<0.01$; Table 5.1). Although the 300-m performance did not significantly decline during INT, it was significantly enhanced by ~5% during week 4 ($ES=0.82$, CI 47% to 153%) and by ~7% during week 5 ($ES=0.73$, CI 28% to 172%), nearly in all subjects (Figure 5.3).

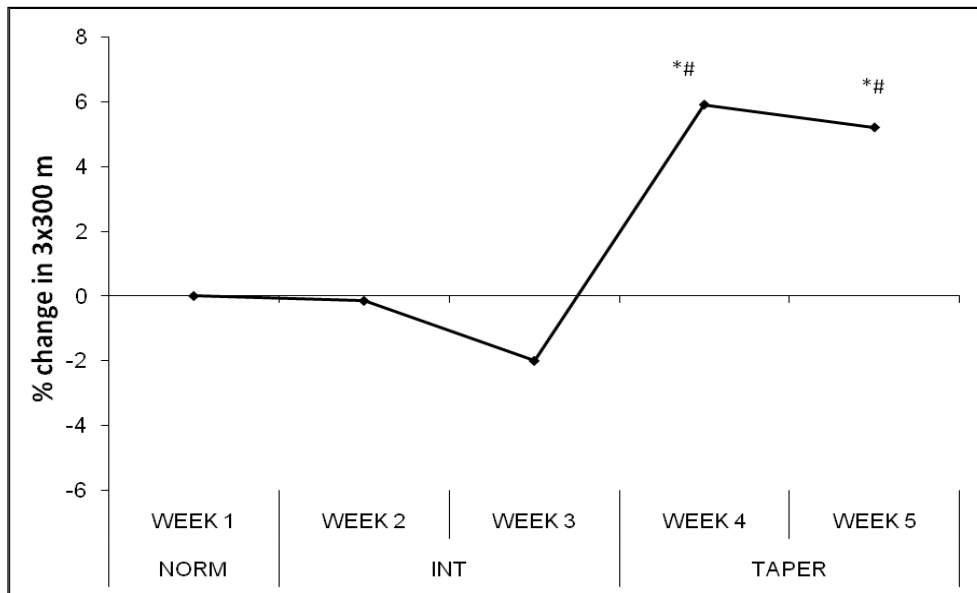


Figure 5.3. Percentage change in 3 x 300-m mean time over the course of the study period.
* significantly different from NORM; # significantly different from INT.

Questionnaires

General fatigue

Subjective ratings for accumulated fatigue increased from baseline during INT ($p < 0.01$, $ES = 0.61$, CI 55 to 202%), then fell from INT levels during TAPER at week 4 ($p < 0.01$, $ES = 0.79$, CI -41 to -141%) and remained low until week 5 ($p = 0.03$, $ES = 0.86$, CI -58 to -142%). Data is shown on Table 5.2.

Muscle soreness

Ratings for general DOMS significantly decreased during the TAPER compared with NORM ($p = 0.02$; week 4: $ES = 0.72$, CI -32 to -168%; week 5: $ES = 0.62$, CI -119 to -188%) and INT ($p < 0.05$; week 4: $ES = 0.78$, CI -44 to -156%; week 5: $ES = 0.78$, CI -18 to -182%). Muscle soreness was mainly located on the upper part of the body, while ratings of upper body soreness displayed a similar trend to general soreness ($p = 0.02$). Front thigh muscle soreness did not change (Table 5.2).

Mood state

Total mood disturbance scores significantly decreased at week 4 of the TAPER compared with NORM (ES=0.79, CI -40 to -160%) and INT (ES=0.81, CI -45 to -155%) and remained low until week 5 ($p<0.01$). From this questionnaire the subscales of tension, aggression, confusion, fatigue and depression also significantly declined during TAPER compared with both NORM and INT ($p<0.05$). Subscales of vigour remained unchanged throughout the study period (Table 5.2).

Table 5.1. Changes in training load, RPE, body weight, body fat and performance tests over the course of the study period (Mean \pm SD).

Week	NORM		INT		TAPER	
	1	2	3	4	5	
Training load (AU)	4388 \pm 341	8276 \pm 490 #	9301 \pm 485 #	3317 \pm 499 #	317 \pm 130 #	
RPE	12 \pm 1	15 \pm 1 *	16 \pm 1 *	11 \pm 1* <i>ab</i>	11 \pm 1* <i>ab</i>	
Body weight (kg)	76.0 \pm 12.3	76.1 \pm 12.5	75.7 \pm 12.2	76.3 \pm 12 <i>b</i>	76.1 \pm 11.7 <i>b</i>	
Body fat (%)	8.9 \pm 2.6	8.8 \pm 2.4	7.9 \pm 2.3 *	8.8 \pm 2.5	9.5 \pm 3.4	
Vertical jump (cm)	41.7 \pm 5.3	42.6 \pm 5.6	41.1 \pm 3.4	43.1 \pm 5.7	44.6 \pm 3.9 * <i>b</i>	
Horizontal jump (m)	2.47 \pm 0.16	2.39 \pm 0.14 *	2.44 \pm 0.15	2.46 \pm 0.16 <i>a</i>	2.44 \pm 0.15	
Grip strength (kg)	R	46.5 \pm 8.8	45.5 \pm 9.1	46.4 \pm 8.0	47.3 \pm 8.3	45.9 \pm 8.2
	L	42.0 \pm 8.8	45.8 \pm 9.3 *	45.8 \pm 8.1 *	47.1 \pm 8.6 *	46.4 \pm 5.9 *
MSFT (m)	1813 \pm 417	1907 \pm 493	1825 \pm 370	2051 \pm 458	1813 \pm 369	
3 x 300m (sec)	53.37 \pm 4.29	53.45 \pm 4.13	54.46 \pm 4.84	50.24 \pm 3.39* <i>ab</i>	50.59 \pm 3.45 * <i>ab</i>	
SJFT (index)	12.21 \pm 2.16	12.32 \pm 2.03	12.23 \pm 1.48	11.47 \pm 1.61	11.31 \pm 1.87	

Training load is presented as arbitrary units (AU). # significantly different from all ($p < 0.05$); * significantly different from NORM ($p < 0.01$); *a*: significantly different from Week 2 (INT) ($p < 0.01$); *b*: Significantly different from Week 3 (INT) ($p < 0.05$).

Table 5.2. Changes in questionnaire scores regarding general fatigue, delayed-onset muscle soreness and profile of mood states over the course of the study period (Mean \pm SD).

Week	NORM		INT		TAPER		
	1	2	3	4i	4ii	5i	5ii
General fatigue	2.6 \pm 0.7	4.0 \pm 1.1 <i>a</i>	3.7 \pm 1.1 <i>a</i>	2.7 \pm 0.7 <i>abc</i>	1.8 \pm 0.3 <i>abcd</i>	2.2 \pm 0.7 <i>bcd</i>	1.9 \pm 0.5 <i>abcd</i>
General soreness	2.8 \pm 0.9	3.4 \pm 1.4	2.9 \pm 1.1	1.9 \pm 0.9 <i>abc</i>	2.2 \pm 0.8 <i>bc</i>	1.9 \pm 0.5 <i>abc</i>	2.1 \pm 0.5 <i>bc</i>
Upper body soreness	2.3 \pm 1.0	2.5 \pm 1.5	2.2 \pm 1.6	1.3 \pm 0.4 <i>ab</i>	2.0 \pm 0.8 <i>d</i>	1.3 \pm 0.3 <i>abd</i>	1.7 \pm 0.6
Front thigh soreness	2.3 \pm 1.6	2.5 \pm 1.5	2.4 \pm 1.5	1.8 \pm 1.2	2.4 \pm 1.0	1.7 \pm 0.6	2.1 \pm 0.8
Total mood disturbance	7.2 \pm 7.3	5.4 \pm 11.3	5.7 \pm 6.9	-2.1 \pm 9.9 <i>abc</i>	-2.4 \pm 7.7 <i>bc</i>	-1.3 \pm 6.8 <i>abc</i>	-3.4 \pm 7.8 <i>bc</i>
Depression	2.1 \pm 2.3	1.8 \pm 2.0	1.1 \pm 2.1	0.6 \pm 1.6	1.1 \pm 1.3 <i>a</i>	0.7 \pm 1.1 <i>abd</i>	0.1 \pm 0.4
Aggression	5.1 \pm 4.0	4.5 \pm 3.9	5.0 \pm 3.8	3.1 \pm 4.0 <i>c</i>	2.6 \pm 4.0 <i>abc</i>	0.7 \pm 0.8 <i>abc</i>	2.0 \pm 2.0 <i>acf</i>
Confusion	1.4 \pm 2.0	1.2 \pm 1.5	1.6 \pm 1.8	0.6 \pm 1.3	0.7 \pm 1.1	0.7 \pm 0.8	0.1 \pm 0.4 <i>abcef</i>
Fatigue	4.0 \pm 2.7	6.5 \pm 3.2 <i>a</i>	6.2 \pm 3.4 <i>a</i>	2.2 \pm 2.2 <i>bc</i>	4.1 \pm 3.6	3.2 \pm 2.2 <i>bc</i>	2.3 \pm 3.5 <i>bc</i>
Tension	4.6 \pm 2.5	3.2 \pm 2.7	2.3 \pm 1.8 <i>a</i>	1.1 \pm 1.9 <i>ab</i>	1.4 \pm 2.1 <i>ab</i>	2.0 \pm 2.1 <i>a</i>	2.0 \pm 2.0 <i>a</i>
Vigor	9.2 \pm 4.0	11.8 \pm 2.3	10.4 \pm 2.0	9.7 \pm 6.0	12.4 \pm 1.6	11.2 \pm 2.8	10.8 \pm 4.0

a: significantly different from Week 1 ($p < 0.01$); *b*: significantly different from Week 2 ($p < 0.05$); *c*: significantly different from Week 3 ($p < 0.05$); *d*: significantly different from Week 4i ($p < 0.05$); *e*: significantly different from Week 4ii ($p < 0.05$); *f*: significantly different from Week 5i ($p < 0.01$).

Salivary hormones

Mean sC concentrations were higher in the morning than in the evening ($p < 0.01$). Evening sC fell below baseline during TAP1-3 ($p < 0.01$, $ES = 0.67$, $CI -39$ to -161%), where it returned to baseline levels by the end of the taper ($p < 0.05$; Figure 5.4 A). Mean sT concentrations were significantly higher in the morning than in the evening ($p < 0.0001$). Morning sT concentrations exhibited a biphasic increase during tapering. The first peak was observed at the beginning of the taper compared with INT values ($p = 0.03$, $ES = 0.58$, $CI 31$ to 169%), followed by a progressive increase until the end of tapering (all $p < 0.01$) compared with all previous time points (NORM: $ES = 0.78$, $CI 60$ to 140% ; INT $ES = 0.89$, $CI 69$ to 116% ; TAP1: $ES = 0.65$, $CI 42$ to 158% ; TAP3: $ES = 0.66$, $CI 43$ to 157%). No differences were found in the evening sT concentrations across time (Figure 5.4 B). Higher mean sT/C ratio was observed in the evening than in the morning ($p < 0.01$). The evening sT/C ratio increased significantly from baseline during week 2 ($p < 0.05$, $ES = 0.49$, $CI 13$ to 187%), remained high during TAP1-4 ($p < 0.01$, $ES = 0.59$, $CI 32$ to 168%) until it returned to baseline levels in TAP5 (Figure 5.4 C).

Salivary IgA

Higher values were observed in both mean SIgA absolute concentrations and SIgA secretion rates in the morning (both $p < 0.0001$). SIgA absolute concentrations fluctuated in the morning samples with elevations during INT ($p < 0.01$, $ES = 0.86$, $CI 61$ to 139%), TAP3 ($p < 0.01$, $ES = 0.79$, $CI 48$ to 152%) and TAP5 ($p < 0.01$, $ES = 0.79$, $CI 49$ to 151%), compared with baseline. The evening concentrations of SIgA concentrations remained unchanged until a small increase during the last phase of TAPER compared with all previous time-points ($p < 0.01$; Figure 5.5 A). Secretion rate of SIgA was found to increase during TAPER in a similar manner in both morning and evening samples. Morning SIgA secretion rate increased (all $p < 0.01$) at TAP3 compared with baseline ($ES = 0.94$, $CI 83$ to 117%), intensive training ($ES = 0.69$, $CI 51$ to 149%) and the early phase of tapering ($ES = 0.69$, $CI 52$ to 148%). Morning rates of SIgA secretion remained elevated until TAP5 compared with baseline ($ES = 0.75$, $CI 34$ to 166%), intensive training ($ES = 0.75$, $CI 32$ to 168%) and early-tapering ($ES = 0.69$, $CI 20$ to 180%). SIgA secretion rates in the evening increased in a similar manner, with elevations at TAP3 compared with baseline ($ES = 0.94$, $CI 83$ to 117%), intensive training ($ES = 0.69$, $CI 51$ to 149%) and the early phase of

tapering (ES=0.69, CI 52 to 148%). SIgA secretion rate remained elevated until TAP5 compared to all previous time-points (NORM: ES=0.93, CI 82 to 118%; INT: ES=0.86, CI 73 to 127%; TAP1: ES=0.90, CI 77 to 123%; TAP3: ES=0.71, CI 54 to 146%) (Figure 5.5 B).

Saliva flow rate

Mean rates of saliva flow were higher in the evening than in the morning ($p<0.01$). The morning saliva flow rate was similar across time. The evening saliva flow rate increased during TAPER (all $p<0.01$) with the highest rates of saliva flow at TAP4 compared with baseline (ES=0.85, CI 74% to 126%), intensive training (ES=0.77, CI 73% to 157%) and early-tapering (ES=0.74, CI 62% to 138%) (Figure 5.5 C).

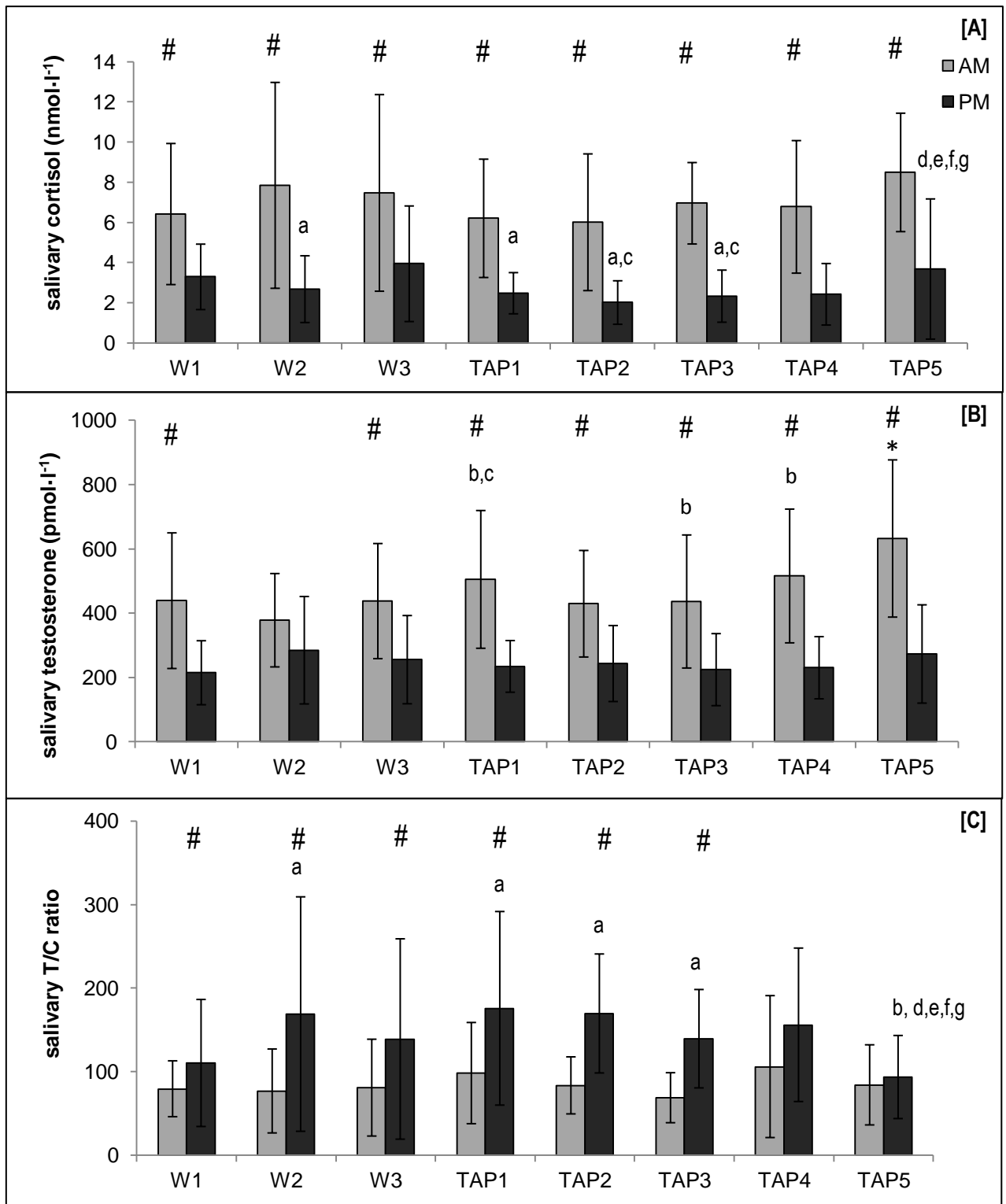


Figure 5.4. Mean (\pm SD) responses of salivary cortisol (A), testosterone (B) and T/C ratio (C) over the course of the study period. Grey columns present morning responses (AM), black columns present evening responses (PM). W1 indicates normal training week, W2 and W3 indicate week 2 and week 3 respectively of intensive training (INT), tapering days 1-2 indicate TAP1, tapering days 3-4 indicate TAP2, tapering days 5-6 indicate TAP3, tapering days 8-10 indicate TAP4 and tapering days 11-13 indicate TAP5; a: indicates significantly different from W1, b: indicates significantly different from INT (W2), c: indicates significantly different from INT (W3), d: indicates significantly different from TAP1, e: indicates significantly different from TAP2, f: indicates significantly different from TAP3, g: indicates significantly different from TAP4, * indicates significantly different from all, # indicates significant difference morning to evening.

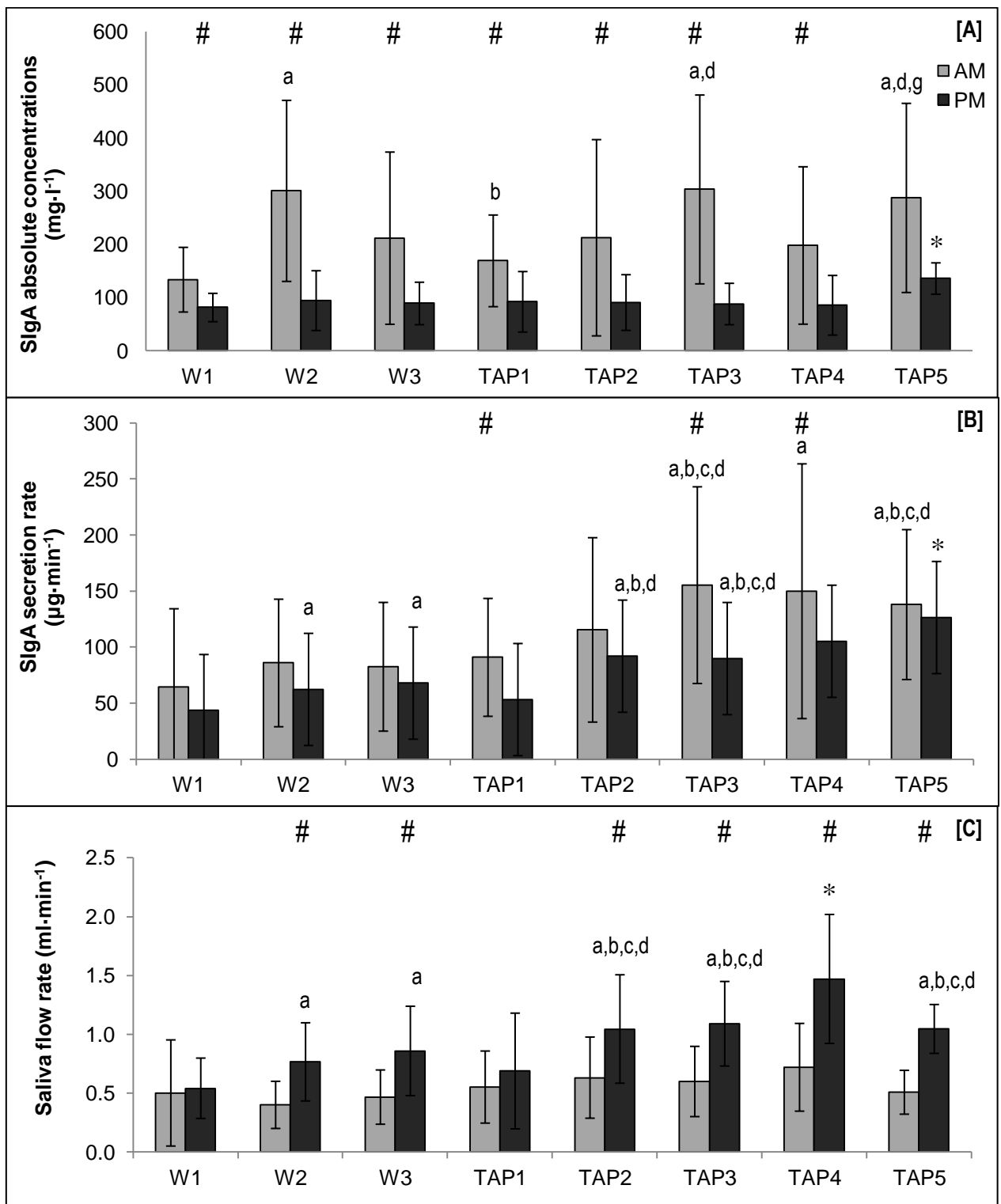


Figure 5.5. Mean (\pm SD) responses of salivary IgA absolute concentrations (A), salivary IgA secretion rate (B) and saliva flow rate (C) over the course of the study period. Grey columns present morning responses (AM), black columns present evening responses (PM). W1 indicates normal training week, W2 and W3 indicate week 2 and week 3 respectively of intensive training (INT), tapering days 1-2 indicate TAP1, tapering days 3-4 indicate TAP2, tapering days 5-6 indicate TAP3, tapering days 8-10 indicate TAP4 and tapering days 11-13 indicate TAP5; a: indicate significantly different from W1, b: indicate significantly different from INT (W2), c: indicate significantly different from INT (W3), d: indicate significantly different from TAP1, g: indicate significantly different from TAP4, * indicate significantly different from all, # indicate significant difference morning to evening.

5.6. Discussion

This study has illustrated that a 2-week taper after 2 weeks of intensified training resulted in significant performance enhancements in the 3 x 300-m run test and countermovement jump without significant changes in the SJFT and MSFT in male judo athletes. The improvements in performance were accompanied by increased sT/C ratio, morning and evening SIgA secretion rate, lower muscle soreness and enhanced mood state. The time-course of change for the abovementioned variables was not consistent in this study, whereas changes in sT, sC, muscle soreness and mood states precede performance and mucosal immunity enhancements. Furthermore, it was shown that salivary hormones and both SIgA concentrations and secretion rate were higher in the morning than in the evening.

The main goal of the taper is to enhance pre-competition performance. In this group of judoists, performance was significantly enhanced in the multiple 300-m run test which indicates an improvement in anaerobic capacity. Callister and colleagues (1990) aimed to induce deliberate overreaching in trained male judoists by increasing the load of high-intensity training and training volume; running performance of 3 x 300-m declined during a period of heavy training, whilst vertical jump and 5 x 50-m performance did not change. Thus, these authors concluded that selection of specific performance variables for monitoring overreaching (and possibly subsequent recovery) should be utilised, as some variables may be more sensitive to the type of sport than others; thus these authors suggested that 3x300 m performance was a sensitive marker of anaerobic capacity during overtraining, whereby vertical jump performance may not be a sensitive-enough marker for overreaching and recovery in judo. In our study, 3x300-m performance did not decrease during INT, but improved significantly during tapering, which may be attributed to the large quantity of high intensity training. Significant enhancements were also observed in the vertical jump by the second taper week, which is in disagreement with the work of Callister et al. (1990) that vertical jump performance may not be a sensitive-enough marker for overreaching and recovery in judo. A study by Izquierdo and colleagues (2007) showed that tapering can result in further improvements in muscle strength but not maximal power in strength-trained athletes. This contradicts the findings of the present study, where significant improvements were found in the power of lower extremities during tapering. Furthermore, a study by Kraemer et al. (2002) indicates that muscle power is very sensitive

to detraining and that a minimal maintenance strength training program is recommended to avoid losses in muscle power. Consequently, the significant improvement in the countermovement vertical jump in the present study indicates that the intensive training followed by a 2-week exponential tapering not only maintained but improved power and strength capacity of the lower limbs.

Performance in the SJFT and the MSFT presented a tendency to improve; however, this was not statistically significant and improvements were not observed in all subjects. The non-significant change in the MSFT cannot fully support previous findings in rugby league players (Coutts et al., 2007a; Coutts et al., 2007b) showing significant 5% enhancements in the MSFT during tapering. This discrepancy could be explained by differences in the type of sport or variations in the training load during the intensive training period. The SJFT improved non-significantly by the end of the taper. This is the first study to examine the performance in the SJFT during a period of intense training and tapering. However, half of the athletes presented improvements in that test, which could indicate that athletes with lower technical skills may be more responsive to improvements in the SJFT than athletes with a high technical level. Therefore, it appears that the intense training and the subsequent 2-week taper enhanced anaerobic capacity and power of lower extremities. However, this was not translated into judo-specific test and aerobic capacity improvements.

TAPER also resulted in increases in morning sT and declines in evening sC, which were evident at the beginning of the taper. Furthermore, an increase in the evening sT/C ratio was also observed at the same time. Our results show the changes in hormones precede performance enhancements during tapering in these judo athletes. The results agree with Zehsaz et al. (2011) who reported increased plasma total T concentrations and T/C ratio and reductions in C at rest, which coincided with improvements in performance capacity following a 1- and 3-week taper in cyclists. Similarly, our findings are comparable with the results of Izquierdo et al. (2007) reporting increased anabolic activity during tapering. This study supports the use of T/C ratio to assess training stress and recovery and is in contrast with studies reporting unchanged T/C ratio levels in response to tapering (Mujika et al., 2000; Izquierdo et al., 2007)

SIgA concentrations and secretion rate increased during tapering in this study, which disagrees with the findings of Moreira et al. (2012b) reporting no changes in SIgA

concentrations during a reduced training period in basketball athletes. Absolute concentrations and secretion rate of SIgA were higher in the morning than in the evening, which is in agreement with previous studies (Gleeson et al., 1999b; Dimitriou et al., 2002). The responses of absolute SIgA concentration to training and tapering were not consistent between morning and evening, as no changes were evident in the evening values. It could be argued that morning assessments of SIgA concentrations may be more sensitive to training stress than evening responses. However, a large variability existed in the morning values, hence monitoring SIgA absolute concentrations in the morning should be assessed individually and with caution. On the other hand, SIgA secretion rate responses to training and tapering appear fairly similar in the morning and evening despite the larger variability in the morning values, showing that the levels of available SIgA for defence in the mucosal surfaces increased in a similar manner in the morning and evening during TAPER.

In this study, saliva flow rate was significantly lower in the morning than in the evening, which was possibly attributable to the effect of mild dehydration following a night's sleep. Therefore, the similar increase in SIgA secretion rates in morning and evening could be explained by two reasons. The increase in SIgA concentrations in the morning may have occurred to compensate the lower flow of morning saliva and the higher rate of saliva flow in the evening may have compensated for the lower SIgA concentrations at that time; thus the evening SIgA secretion rate responses may have just reflected the responses of saliva flow rate.

Judo is a sport that incorporates a variety of movements, such as eccentric muscle contractions and high impact forces, thus inducing a high degree of muscle damage. In this study muscle soreness significantly decreased during tapering, indicating that muscle damage, manifested by the perception of aching muscles, decreased with reduced training. Similar results were found in cyclists (Halson et al., 2003) and rugby league players (Coutts et al., 2007b) with reductions in muscle damage during tapers, manifested by decreases in plasma CK activity. Therefore, assessing muscle soreness and responses to training and tapering in such sports can be a useful means for assessing muscle-related fatigue. Furthermore, the decrease in perception of muscle soreness was similar to the decrease in the perception of general fatigue in this study, indicating that the general perception of fatigue is comparable with the feelings of muscle soreness for this group of athletes.

The positive psychological effects associated with taper include enhancements in mood state and reduced perception of fatigue (Mujika et al., 2004). The results of the present study are in line with Zehsaz et al. (2011) reporting enhanced global mood scores during 1- and 3-week tapers in cyclists. Interestingly, vigour scores did not show differences across the study period, probably because the training load during INT was not monotonous enough to negatively affect drive in these judo athletes. Previous studies have recommended a period of tapering during periodisation, as to avoid overreaching that subsequently leads to excessive mental fatigue and injury (Vetter and Symonds, 2010). Performance in judo depends highly on the mental state of the athletes; therefore from these results it is evident that tapering can enhance mood state of judo athletes which may subsequently be related to better competition performance.

In conclusion, the time course of change showed that increases in sT/C ratio, enhancements in mood state and lower muscle soreness precede improvements in performance and mucosal immunity. In this study the changes in salivary hormones, lower muscle soreness and enhanced mood state were observed within the first days of TAPER, followed by improvements in performance and enhanced mucosal immunity. Regarding mucosal immune status, enhancements were evident after the middle of tapering, which may suggest that training stress needs to be low for mucosal immunity enhancements. Thus, it can be estimated that in these judo athletes the optimal training-induced adaptations are likely to occur within 7-12 days of tapering.

5.7. Conclusions

This study has identified that 2 weeks of intensive judo training followed by a 2-week exponential taper enhanced anaerobic performance and power of lower extremities in trained judo athletes, within the first 7 days of tapering. Enhancements were concomitant with enhanced mucosal immunity, increased morning sT responses and evening sT/C ratio, decreased evening sC responses, decreased muscle soreness and enhancements in mood state. The time-course of change for the abovementioned variables was not consistent in this study, whereas changes in sT, sC, muscle soreness and mood states precede performance and mucosal immunity enhancements. The enhancements in salivary hormonal responses as well as mood state and muscle soreness were evident during the early phases of tapering and it seems that these markers can be used to predict performance

improvements in judo athletes. Performance improvements needed longer to emerge during tapering; therefore coaches should plan their training programs accordingly that the athletes taper for at least a week prior to a judo competition, so that all aspects of conditioning (i.e. hormones, mood state, muscle soreness and mucosal immunity) are optimised. Finally, this study showed that responses of sT, sC and SIgA absolute concentrations and secretion rate display a diurnal variation with higher values in the morning than in the evening. Therefore, taking this into account, saliva monitoring should be made at the same times to control for diurnal variation.

**CHAPTER 6: STUDY 4. Salivary cortisol, salivary
testosterone, SIgA responses and
psychophysiological anxiety during a judo
competition**

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6.1. Abstract

The purpose of this study was to investigate the responses of sC, sT, sT/C ratio, SIgA, saliva flow rate and psychophysiological anxiety during an international judo competition. Twenty-three trained, male, national level judo athletes (age 20 ± 4 years; $\dot{V}O_{2\max}$ 52.8 ± 5.4 ml·min⁻¹·kg⁻¹; training experience 8 ± 4 years) provided three saliva samples during a competition day: morning, in anticipation of competition after an overnight fast (08:00 – 08:30), mid-competition (10:30 – 11:30), and post-competition within 15 min post-fight (14:00 – 14:30) for determination of salivary hormones, SIgA absolute concentrations, SIgA secretion rate and saliva flow rate. The competitive state anxiety inventory questionnaire was completed by the athletes (n=12) after the first saliva collection for determination of somatic anxiety, cognitive anxiety and self-confidence. Winners were considered 1-3 ranking place and losers below 3rd place in each weight category. Pooled data of all athletes showed that sT was higher in the morning compared with post-fight (p=0.01), anticipatory sT/C ratio was lower mid-competition compared with other time-points (p=0.003) and saliva flow rate was higher in the morning compared with other time-points (p=0.008). Concentrations of sC and SIgA and SIgA secretion rate did not change significantly across time. When data was divided into winners (n=12) and losers (n=11) higher anticipatory sC concentrations (p=0.03) and a lower mid-competition sT/C ratio (p=0.003) were observed in the winners with no differences for sT. Winners tended to have higher SIgA secretion rates (p=0.07) and significantly higher saliva flow rates (p=0.009) at mid-competition. Higher levels of cognitive anxiety (p=0.02) were observed in the winners, without differences according to the outcome in somatic anxiety and self-confidence. The results indicate that winners experienced higher levels of physiological arousal and better psychological preparedness. Therefore, elevated C levels in anticipation of a judo competition and higher levels of arousal could have some predictive value for winning performance in judo.

Keywords: winning performance, competition outcome, salivary hormones, mucosal immunity, arousal

6.2. Introduction

Judo competition performance depends greatly on the whole periodisation schedule, including proper recovery after exercise (chapter 3 and 4) as well as effective tapering before the competition (chapter 5). However, judo performance may be affected by several other stimuli on the competition day, manifested on the endocrine responses and psychological measures. Anticipating upon a judo competition can lead to high psychophysiological strain on the athletes manifested by elevated cognitive and somatic anxiety, low self-confidence and high sC and sT levels (Filaire et al., 2001a,b). Acute elevations in sC concentrations were reported after a weightlifting competition (Le Panse et al., 2010), after a basketball match (Gonzalez-Bono et al., 1999), after simulated and actual karate fights (Parmigiani et al., 2009), after a judo competition (Suay et al., 1999) and following a youth taekwondo competition (Chiodo et al., 2011). Studies have reported elevations in salivary concentrations of C and T in anticipation of a tennis tournament (Filaire et al., 2009) and a powerlifting competition (Le Panse et al., 2010). Elevations in anticipatory C were also observed during martial arts tournaments, as C concentrations were observed to rise before a judo competition (Suay et al., 1999; Salvador et al., 2003) and before simulated and actual karate fights (Parmigiani et al., 2009). Responses of T to competition are less consistent; serum T was reported to rise in anticipation of a competitive match in wrestlers (Fry et al., 2011), but not in judo athletes (Filaire et al., 2001b).

SIgA responses to acute exercise are not consistent, with some studies reporting increases and some decreases of SIgA after acute exercise bouts (Bishop and Gleeson, 2009). The overall intensity of the exercise bout appears to influence the post-exercise SIgA response, with short duration, high-intensity exercise reported to induce increases in SIgA secretion rate (Allgrove et al., 2008). In general, increases are seen in response to short bouts (<30 min) of high intensity exercise (>80% $\dot{V}O_2\text{max}$), whereas no change or falls are seen with very prolonged exercise (>2 h) (Bishop and Gleeson, 2009). However, studies examining SIgA responses to competitive situations are limited (Moreira et al., 2012a; Moreira et al., 2013a), with no studies on SIgA responses on the sport of judo.

Increased plasma C levels are associated with anxiety and physical exertion (Viru and Viru, 2004), whereas acute elevations of this glucocorticoid can be euphorogenic and neurostimulatory (Duclos, 2010a). Suay et al. (1999) observed that winners of a judo

competition had higher serum C levels throughout the competition, despite no differences in T and prolactin and similar physical effort of the athletes. Similarly, Balthazar et al. (2012) observed that higher early-morning anticipatory sC levels were associated with winning a triathlon competition. However, no differences in anticipatory sC levels between winners and losers were observed in relation to judo fights (Salvador et al., 2003). The biosocial model of status (Mazur, 1985) suggests that elevated T levels during competitive situations are associated with dominance, fearlessness of the opponent, confidence and situation-specific aggression. Concentrations of sT in males were reported to be associated with situation-specific aggression and willingness to engage in competitive task (Carre and McCormick, 2008), traits that could positively influence judo competition-performance. Serum T was reported to rise in anticipation of a competitive match, with larger increases during the pre-fight anticipatory values in those who win a wrestling (Fry et al., 2011) and a weight-lifting competition (Passelergue et al., 1995). Winning can also lead to subsequent elevations in T, which stimulate competitiveness described as the “winners’ effect” (Booth et al., 1989). Higher levels of post-competition T were observed in the winners of a badminton competition (Jimenez et al., 2012), a wrestling competition (Fry et al., 2011) and a judo competition (Filaire et al., 2001b). The evidence suggests that responses of C and T during competition could be related to the outcome; however, findings reported for elite athletes are limited.

The association between arousal and performance has been demonstrated in an inverted U-shaped relationship, illustrating that optimal performance is accomplished at a moderate level of arousal; thus poor performance is related to very low levels of arousal, progressively enhances at moderate levels of arousal until it deteriorates at very high arousal levels (Hardy and Parfitt, 1991). Filaire et al., (2001a) observed that interregional judo competitions elicited high levels of somatic and cognitive anxiety and lower self-confidence along with increases in sC levels, suggesting that neuroendocrine response and anxiety are related in judo athletes. Arousal is closely interrelated to anxiety, whereas in athletic population it could be interpreted as the perception of the athletes’ physiological/somatic response and/or psychological/cognitive response to a stressor, which is usually the subsequent competition. The revised competitive anxiety inventory 2 questionnaire (CSAI-2R) is a commonly used, validated multidimensional construct for assessing scales of somatic anxiety, cognitive anxiety and self-confidence and one of the most used measures in sport psychology (Cox et al., 2003). Judo is a combat sport with

high body contact where the athlete should “read” the moves of the opponent; thus the mental/psychological capacity and arousal of the athletes is especially important to the combat outcome. However, evidence are lacking to whether anxiety measures and self-confidence could influence the outcome of a judo competition.

Therefore, the aims of this study were (a) to investigate the responses of sC, sT and SIgA during an international judo competition and (b) to identify whether these salivary immunoendocrine responses and anxiety measures could differentiate winners and losers of the competition.

6.3. Methods

Subjects

Twenty-three trained, male, national competitive level judo athletes volunteered to participate in the current investigation (age 22 ± 4 years; height 178 ± 7 cm; body weight 78.6 ± 13.2 kg; body fat $11.3 \pm 5.6\%$; $\dot{V}O_2\text{max}$ 52.8 ± 5.4 ml·min⁻¹·kg⁻¹; training experience 8 ± 4 years). Subjects' age range was 19 - 35 years and all subjects have competed in judo for at least five years and trained minimum 3 times per week. Subjects were officially registered under the National Judo Federation. Subjects were non smokers, not taking any form of medication, refrained from alcohol consumption and were free from illness during the study. The subjects did not exercise or train on the previous day. Prior to the study, all subjects completed an informed consent and a health screening questionnaire. Ethical approval for this study was obtained by the Cyprus Bioethics Committee.

Experimental design

The study took place during an international judo competition in November 2012. Competition began at 9:30 and ended at 15:00. The competition day began with registrations and weigh-ins of the subjects in the morning after an overnight fast (08:00-08:30), around 1.0 - 1.5 h before their first scheduled fight. Saliva samples were collected three times in total, before, during and after the competition. Immediately after the first saliva collection, half of the subjects (n=12) completed the revised competitive anxiety

inventory-2 questionnaire (CSAI-2R). Then the subjects were divided into their weight categories and draws determined the opposing couples within each category. When the athlete lost the fight, he was disqualified from the tournament except when he competed in a repechage round to determine the third place. During this judo competition, athletes had no limitations or control in regards of fluid or food consumption, and they were asked to keep their regular habits; however, no food or drink was consumed before weigh-ins and the first sample collection. At end of judo competition according to the final rankings, subjects were divided into winners (first, second and third place and losers (fourth place and below), at each weight category for the subsequent statistical analysis. Personal interviews revealed that in the week preceding the competition 80% of the subjects underwent a weight reduction of 2-5% of body weight, without differences between the groups of winners and losers. Assessments of $\dot{V}O_2\text{max}$ in these judo athletes were made as routine monitoring during sporting seasons. At least 3 weeks prior to the beginning of the study, preliminary anthropometric measurements and $\dot{V}O_2\text{max}$ assessments were made as described in chapter 3.

CSAI-2R

Pre-competition anxiety was assessed in the morning using the CSAI-2R as suggested by Cox et al. (2003); subjects rated their anxiety symptoms on a scale of 1 (not at all) to 4 (very much so) and subscales of somatic anxiety, cognitive anxiety and self-confidence were then calculated for each athlete on a scale of 10 to 40.

Saliva collection and analysis

Saliva samples were collected 3 times in total from each athlete during the duration of the competition to determine the concentrations of sC, sT and SIgA. Saliva samples were collected in the morning after an overnight fast and before warm-up (08:00 – 08:30), mid-competition 10 min before a fight (10:30 – 11:30), and post-fight within 15 min after their final fight (14:00 – 14:30). . The procedures for saliva collection and saliva analysis were made as described in chapter 3. Mean intra-assay coefficients of variation were 3.6 %, 2.5

% and 2.6 % for sC, sT and SIgA, respectively. Estimation of saliva volume and calculation of saliva flow rate and SIgA secretion rate were made as described in chapter 3.

Statistical analysis

Data was checked for normality, homogeneity of variance and sphericity before statistical analysis. If Mauchly's test indicated that assumption of sphericity was violated the degrees of freedom were corrected using Greenhouse-Geisser estimates. According to the outcome the athletes were divided into groups of winners (n=12) and losers (n=11). The values of sC, sT, sT/C ratio and SIgA concentrations and secretion rates between winners and losers were analysed across time using a two-way analysis of variance (ANOVA) for repeated measures (time x group) with Bonferroni adjustments. CSAI-2R responses between winners and losers were analysed using a one-way between measures ANOVA. From the subscale of cognitive anxiety, two outliers (>2 SD from the mean) were removed from the data set. Statistical significance was set at $p \leq 0.05$. To confirm statistical significance size effects (ES) from simple planned contrasts and 95% CI for relative differences were calculated. All data are presented as mean \pm SD. Data was analysed using SPSS (SPSS v. 22.0; SPSS Inc, Chicago, IL, USA).

6.4. Results

Salivary hormones

Individual subjects' data for sC, sT and sT/C ratio is presented in Figure 6.1 A, B and C, respectively. A significant effect of group showed that winners presented higher concentrations of sC compared with losers in the morning ($p=0.03$, ES=0.58, CI 36 to 165%). No significant effects of time and interaction ($p>0.05$) showed that mean sC responses were similar across the competition. Mean sT concentrations were higher in the morning compared with post-fight values ($p=0.01$, ES=0.52, CI 10 to 190%); however no significant effects of group and interaction showed no differences in sT between winners and losers of the competition ($p>0.05$). Significant effects of time ($p=0.02$; ES=0.60) and group ($p=0.03$, ES=0.53) but not interaction ($p>0.05$) showed that mean sT/C ratio fell mid-competition compared with morning values (CI -27 to -173%) and winners presented

lower sT/C ratio in the morning (CI -43 to -156%) and mid-competition (CI -28 to -171%) compared with losers.

Salivary IgA

Individual subjects' data for SIgA absolute concentrations and secretion rate is shown in Figure 6.2 A and B, respectively. No significant effects of time, group and interaction were found SIgA absolute concentrations and secretion rate ($p>0.05$); however winners tended to have higher SIgA secretion rates at mid-competition ($p=0.07$, $ES=0.35$, CI -12 to 212%).

Saliva flow rate

Individual subjects' data for saliva flow rate responses is shown in Figure 6.2 C. A significant effect of group ($p=0.009$, $ES=0.51$) showed higher saliva flow rates in the winners at the mid-competition time-point (CI 23 to 173%). Significant effects of time ($p=0.02$, $ES=0.46$) and interaction ($p=0.007$, $ES=0.53$) showed that saliva flow rate was lower in the morning compared with mid-competition (CI -5 to -204%) and post-fight (CI -3 to -368%).

Somatic anxiety, cognitive anxiety and self-confidence

Individual subjects' data for CSAI-2R ratings is shown in Figure 6.3. Levels of cognitive anxiety were significantly higher for the winners compared with losers ($p=0.02$, $ES=0.72$, CI 23 to 177%). No significant differences between winners and losers were found on somatic anxiety and self-confidence ($p>0.05$).

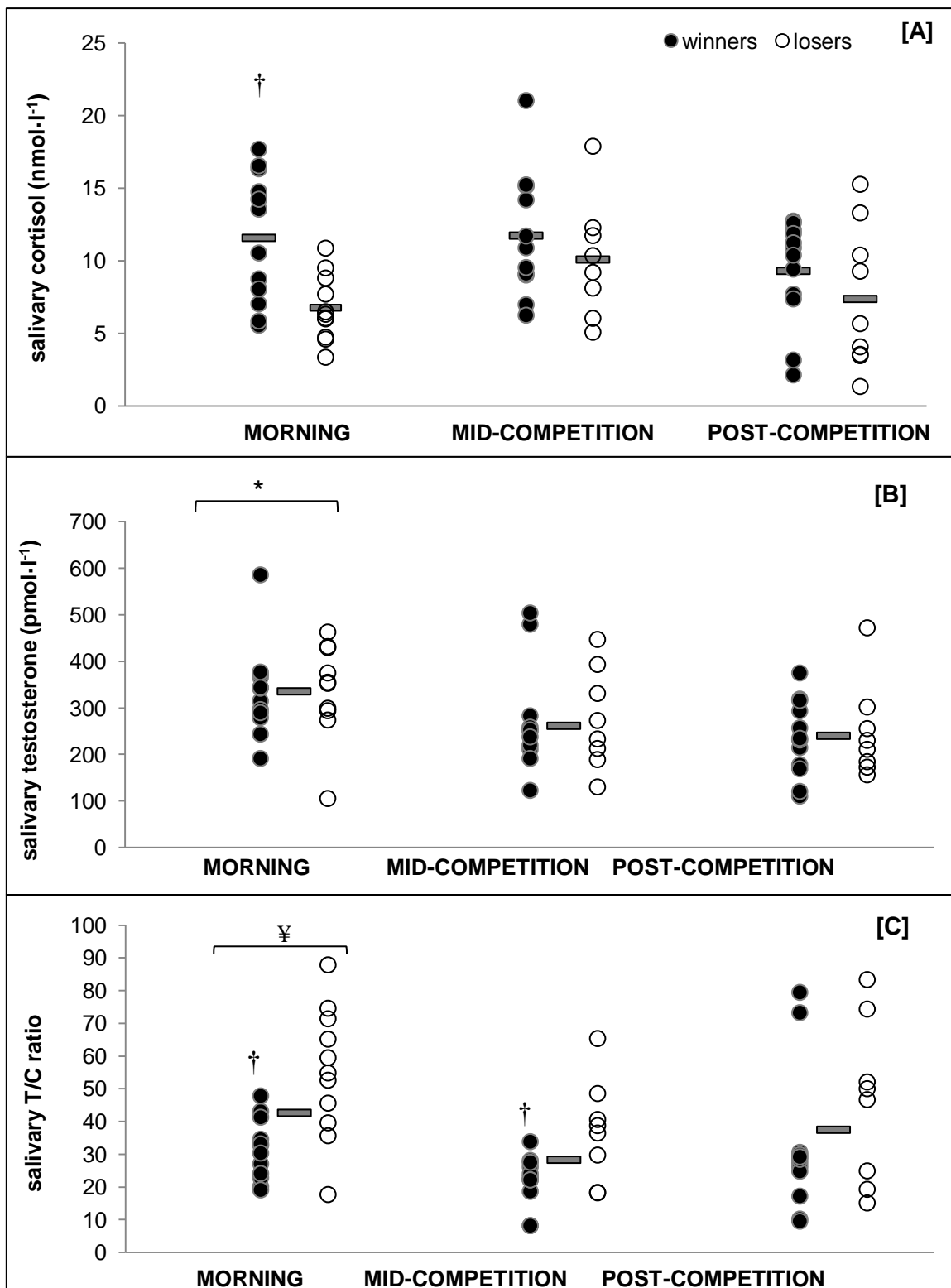


Figure 6.1. Individual responses of [A] salivary cortisol, [B] salivary testosterone and [C] salivary T/C ratio across time in winners and losers. Filled dots indicate the winners, empty dots indicate the losers and horizontal lines indicate the mean for all subjects. *indicates significantly different ($p < 0.05$) mean to post-competition; ¥ indicates significantly different ($p < 0.05$) mean to mid-competition; † indicates significantly different ($p < 0.05$) to losers.

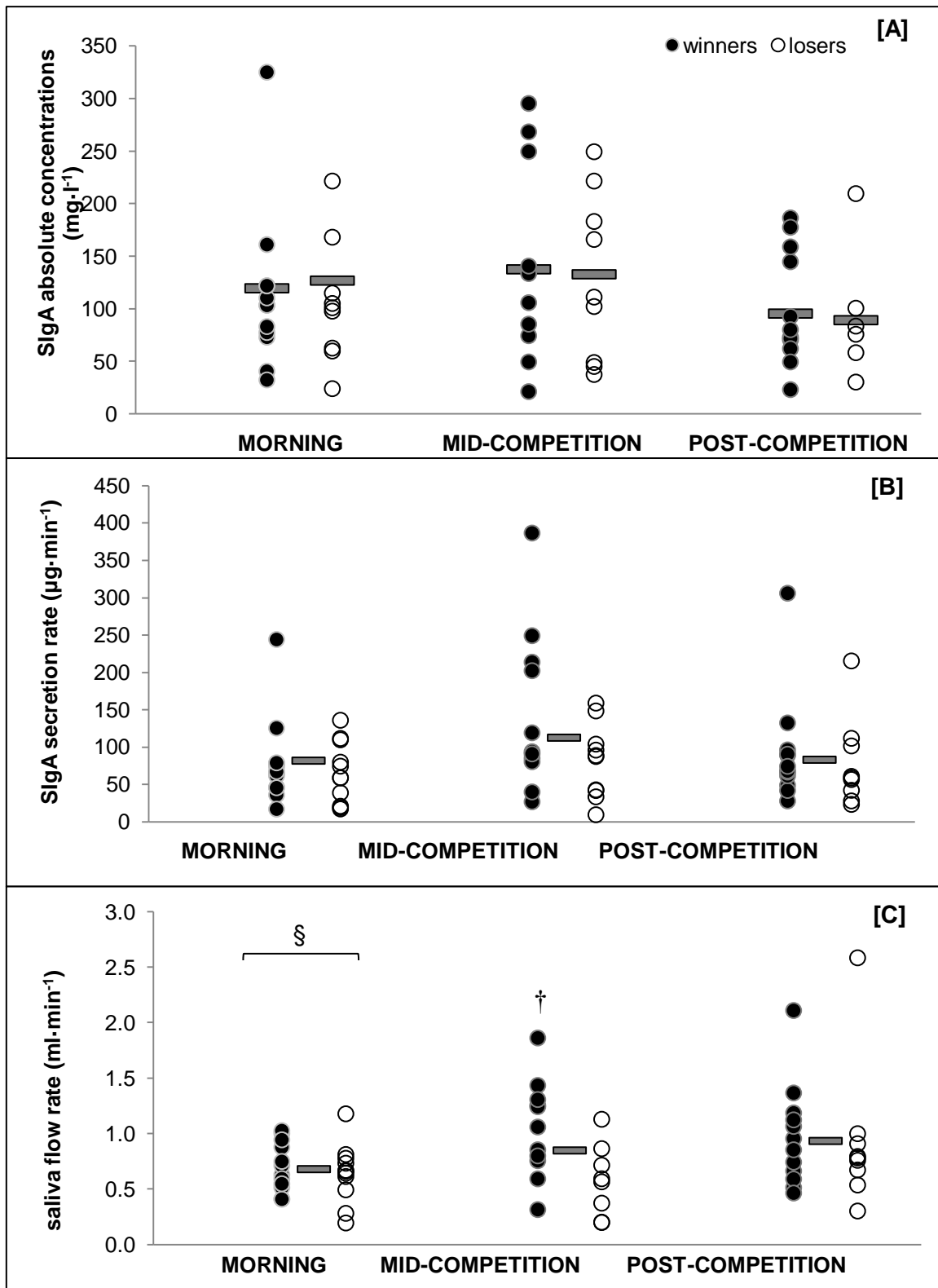


Figure 6.2. Individual responses of [A] SIgA absolute concentrations, [B] SIgA secretion rate and [C] saliva flow rate across time in winners and losers. Filled dots indicate the winners, empty dots indicate the losers and horizontal lines indicate the mean for all subjects. § indicates significantly different ($p < 0.05$) mean to all other time-points; † indicates significantly different ($p < 0.05$) to losers.

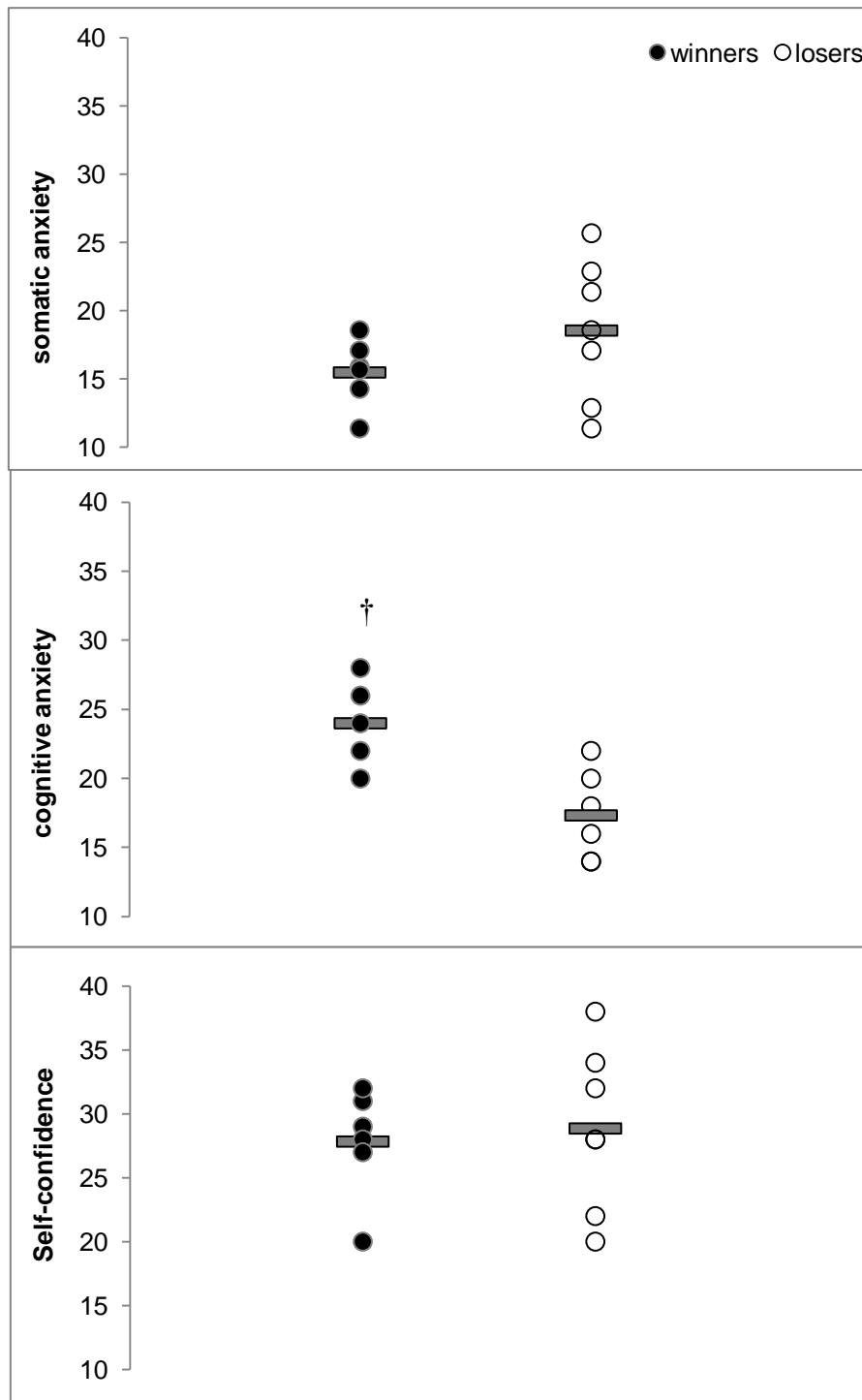


Figure 6.3. Individual responses of CSAI-2R ratings of somatic anxiety, cognitive anxiety and self-confidence in winners and losers. Filled dots indicate the winners, empty dots indicate the losers and horizontal lines indicate the mean for each group. † indicates significantly different ($p < 0.05$) to losers.

6.5. Discussion

This study showed that winners had higher sC concentrations in anticipation of the competition and higher saliva flow rate and a tendency for higher rates of SIgA secretion mid-competition compared with losers. In addition, winners had higher levels of cognitive anxiety compared with losers; no differences were found in levels of somatic anxiety and self-confidence according to the outcome. Therefore, this study suggested that higher levels of psychophysiological arousal in the morning of a judo competition may be related with enhanced performance.

In the present study, the physical stress of the competition did not increase sC, sT or SIgA. No significant differences from pre-competition were found across the competition day for sC, whilst sT concentrations decreased from morning values compared with post-competition levels and sT/C ratio decreased at mid-competition. Similarly, SIgA concentrations and secretion rate did not present significant differences across the competition day and are in agreement with studies reporting no change of SIgA concentrations and secretion rate following a kickboxing competition (Moreira et al., 2010), a basketball match (Moreira et al., 2013a) and Brazilian jiu-jitsu matches (Moreira et al., 2012a). Mean responses of sC and SIgA concentrations and SIgA secretion rate remained relatively steady across the competition day; these findings may indicate a disturbed circadian rhythm that was induced by the psychophysiological stress in response to the competition. The first samples were collected in the morning (~08:00) where salivary sC and SIgA were expected to be elevated due to the effects of diurnal variation, as shown in our previous study with the majority of these participating athletes (chapter 5). However, an additional sample collection on a resting day could provide reference values for these hormones and confirm this suggestion. Conversely, sT concentrations decreased from morning values to post-competition levels, whereas this could merely illustrate the effect of circadian rhythm of T concentrations. This could indicate that sT responses were not sensitive enough to the acute psychophysiological stress of this judo competition.

This study presented higher morning anticipatory sC concentrations in the winners of the judo competition; thus, morning sC concentrations ranged 5-17 nmol·l⁻¹ in the winners and 4-10 nmol·l⁻¹ in the losers. Similar findings in judo athletes were observed by Suay et al. (1999), presenting higher anticipatory, pre-competition serum C but not T concentrations in the winners of judo competition. Comparable findings were presented in triathletes, with

higher morning sC concentrations in those who performed better, thus presenting a positive relationship between early-morning C levels and ranking place during a triathlon competition (Balthazar et al., 2012). From a physiological perspective there is evidence to suggest that acute rises in C can have ergogenic effects via its neurostimulatory, anti-inflammatory/analgesic and metabolic functions (Duclos, 2010); whereas moderate elevations in C are considered to be advantageous for increasing arousal. Possibly in our study, the higher morning sC levels in the winners could reflect the activation of the sympathetic nervous system which was associated with the “fight or flight” stress response; consequently this finding could be related to the higher levels of physiological (and mental) alertness in the winning athletes, which in turn could have prepared the body (and mind) for action at the onset of the competition.

Concentrations of sT presented no differences between winners and losers; our findings contradict the biosocial model of status (Mazur, 1985) and disagree with the findings of studies reporting higher anticipatory T concentrations in the winners of a weight-lifting competition (Passelergue et al., 1995) and higher post-competition T in the winners of a badminton (Jimenez et al., 2012), a wrestling (Filaire et al., 2001b; Fry et al., 2011) and a judo competition (Filaire et al., 2001b). A lower sT/C was observed in the winners in anticipation and at mid-competition; however it is probably of low physiological value as it has reflected sC concentrations.

The discrepancy in our findings regarding anticipatory endocrine responses could be explained by the dual-hormone hypothesis, as proposed by Mehta and Josephs (2010). These authors suggested that C and T concentrations during acute stress situations jointly interact and compensate for each other to modify dominance; thus only when C is low should higher T promote higher status and reversely when C is high, higher T may actually decrease dominance and sequentially motivate lower status. No changes in sT in our study could be related and actually explain the higher sC levels in those who won the judo competition. However, additional saliva collection on a resting day could provide further evidence for this suggestion.

Winners also presented higher levels of cognitive anxiety, without any significant differences in ratings of somatic anxiety and self-confidence between winners and losers. Our findings disagree with the findings of Filaire et al. (2001a) that winners of a judo competition present lower levels of cognitive anxiety. However, our findings are in line

with the catastrophe theory, whereas an intermediate level of arousal could mediate enhanced performance (Hardy & Parfitt, 1991). Another study in judo athletes (Filaire et al., 2001b) showed that C and cognitive anxiety were related pre- and post-competition, thus these authors suggested that elite athletes may actually utilise the high levels of cognitive anxiety to enhance performance. Hence, these authors suggested that winning judo performance is actually dependent on the ability of each athlete to control the physiological arousal that accompanies the increased cognitive anxiety (Filaire et al., 2001b). Judo is a sport where high mental alertness is required in order to face the opponent during combat, whereas the participating judokas in our study were national, experienced, elite level athletes, with possibly good control over competition stress situations. Therefore, the higher levels of cognitive anxiety along with higher C concentrations in the winners of our study could indicate better psychophysiological arousal which has possibly been a factor for promoting winning performance.

SIgA secretion rate tended to be higher in the winners, whereas this was accompanied by significantly higher rates of saliva flow at mid-competition. Salivary responses can illustrate the activity of autonomic nervous system, since saliva is regulated by both sympathetic and parasympathetic nervous system activity; saliva elicited by sympathetic stimulation reduces saliva flow rate due to vasoconstriction of the blood vessels supplying the salivary glands, whereas parasympathetic nerve activation nerve stimulation results in a higher volume of watery saliva (Chicharro et al., 1998). However, it is well known that sympathetic and parasympathetic nervous systems, work in cooperation rather than in opposition. The function of the parasympathetic nervous system is to actually work along with the sympathetic nervous system for calming the body after the arousal. Therefore, the higher saliva flow rate mid-competition in the winners could suggest increased participation (or less inhibition) of the parasympathetic nervous system, which in that case, aided to control the sympathetic nervous system activation; thus practically, the winning athletes were the ones that were able to control their stress response better during competition. Mean SIgA concentrations and secretion rate did not change from pre to post-competition, agreeing with the findings of Moreira et al. (2010) and Moreira et al. (2012) that competition may have a minimal effect on this marker of mucosal immunity.

Limitations of this study were the measurement of hormonal responses and anxiety during only one competition day; therefore, it is possible that many other factors have also influenced performance in these judo athletes. Further studies could focus on multiple

measurements of salivary hormones during competition and rest and additional measures of sympathetic nervous system activity (such as blood adrenaline levels and salivary alpha-amylase) and external influences of stress. The athletes have completed a different number of fights on the competition day, whereas this was not possible to control, especially on the post-competition samples. Therefore, this could have affected the responses of the post-competition salivary variables. In addition, the fact that T concentrations were not associated with the competition outcome, as was expected due to its physiological role in performance, should be better explored.

This study suggested that winning competition performance in judo may be influenced by the levels of psychophysiological arousal, as evidenced by the higher sC concentrations and higher self-ratings of cognitive anxiety in the morning of the competition in the winners; subsequently, as the competition progressed, the winners were the ones that managed to control their stress response better, as evidenced by higher saliva flow rate at mid-competition. Practical application of this study could suggest increasing the levels of arousal in the athletes, before competition. A study in rugby union players suggested pre-game presentation of motivational strategies to athletes involving specific video footage and coach feedback can provide effective mental arousal strategies for enhancing match performance (Cook & Crewther, 2012). Judo athletes could introduce similar mental strategies to increase pre-fight arousal levels such as watching previous fights of the opponents and coach motivation. Further studies could focus on specific strategies for increasing arousal levels before competition in judo.

6.6. Conclusions

This study highlights that winning a judo competition can be influenced by the levels of psychophysiological arousal in the participating athletes, as evidenced by higher sC concentrations in anticipation of the competition, increased anticipatory self-ratings of cognitive anxiety and higher saliva flow rates and tendency for higher SIgA secretion rate mid-competition. The results indicate that winners experienced higher levels of physiological arousal and better psychological preparedness. Therefore, elevated C levels in anticipation of a judo competition and higher levels of arousal could have some predictive value for winning performance in judo.

CHAPTER 7: GENERAL DISCUSSION

Judo is a demanding sport that induces high physiological strain on the athletes, as the combined effects of strenuous training and nutritional practices for “making weight” may often negatively affect athletes’ capacity for optimal training and performance. Although during the past decades the science behind training and recovery has rapidly evolved (Mujika and Padilla, 2003; Meeusen et al., 2013), evidence on the sport of judo is lacking. This thesis used field-based research, with all studies performed in the training field, under “real-life” sporting situations using elite national judo athletes. The aim of this chapter is to incorporate the findings from all studies completed in this doctoral thesis to provide practical recommendations for the athletes and coaches for effective judo competition performance. The main findings of the studies are illustrated as an easy reference in Table 7.1.

Laboratory-based testing is considered to operate in an accurate and reliable measurement environment as it utilises standardized exercise tests at fixed intensities and provides measurements in a controlled environment. However, laboratory testing may not always be sport-specific and laboratory-based studies most often use recreationally active individuals; therefore, the conclusions drawn are not always directly applicable to the requirements of sports training (i.e. sport equipment and external influences of training i.e. wind, heat etc.) and elite athletes. On the other hand, although field-based research lacks strict control of several lifestyle variables and external influences that may affect the research design and results, it fits in with the demands of athletes and coaches during real-life training. Field testing is often more time and cost effective for athletes (and coaches) as it can be conducted in convenient locations and during normal training hours. Therefore, the main conclusions of the studies of this doctoral thesis were drawn under an ecologically valid scenario and applicable to the elite judo athlete according to the demands of training and competition.

7.1. Judo training and nutritional recovery strategies

Key aspects of recovery are proper nutrition and effective rehydration; consumption of CHO during intense training periods has been suggested to attenuate and/or delay symptoms of overreaching (Meeusen et al., 2013), whereas restoring sweat losses is crucial for preventing dehydration and maintaining optimal performance (Shirreffs et al., 2004). However, in judo these practices are rarely followed, since undergoing several “weight making” cycles within a sporting season is a common procedure for judo athletes. A

number of previous studies support the use of CM as a recovery nutritional aid to maintain or enhance subsequent exercise performance, as it can provide the required nutrients (CHO, protein) as well as fluids and electrolytes for refuelling (Wilkinson et al., 2007; Ferguson-Stegall et al., 2011; Lunn et al., 2012) and rehydration (Shirreffs et al., 2007; Watson et al., 2008) during post-exercise recovery. Studies 1 (chapter 3) and 2 (chapter 4) of this thesis assessed the possible beneficial effects of CM as a post-exercise recovery beverage in the sport of judo.

In chapter 3, post-exercise CM ingestion did not enhance recovery as assessed by selected immunoendocrine markers, mood state and judo-related performance. However, a lower perception of soreness and a trend for better push-up performance were found, which raised the question whether a single training session was not stressful enough to observe any changes in the aforementioned variables. Therefore, in chapter 4 the effects of post-exercise CM ingestion were examined during 5 days of intensive judo training wherein subjects were instructed to follow their usual weight loss techniques, in preparation for a simulated competition at the end of the training week. In this study, (chapter 4), consumption of CM post-exercise was found to enhance physical performance, attenuate the perception of muscle soreness, lower the morning salivary C responses and prevent mood disturbance by the end of the intensive training week. CHO consumption during and after intense exercise (Halson et al., 2004) and during a period of intensified training (Achten et al., 2004) in endurance athletes has been previously shown to maintain performance and mood state. Therefore, it is possible that the higher CHO content in the CM have attenuated the levels of accumulated fatigue during the short-term intensified judo training. Other immunoendocrine responses (sT, SIgA) were not significantly affected by the consumption of CM, whereby it is likely that 5 days of intense judo training was a short time-frame to observe several symptoms of non-functional overreaching and identify the effects of CM in other immunoendocrine markers. Other studies examining the effects of CM during longer periods of intensive training (and tapering) could provide more insight in this regard. Therefore, it can be concluded that post-exercise consumption of CM is an effective nutritional strategy for aiding aspects of recovery during periods of intensified judo training.

A consequence of intense, strenuous training is muscle damage induced by tissue disruption and subsequent exercise-induced inflammation. Exercise-induced muscle damage is manifested by the “leakage” of myogenic enzymes into the circulation and the

sensation of soreness in the muscles, limiting range of motion and production of maximal force; this could negatively affect the athlete's capacity for subsequent effective training/competition performance. Although previous investigations have shown lower plasma CK responses after CM consumption, not all studies have reported enhancements in functional tests and attenuation of DOMS (Cockburn et al., 2008; Pritchett et al., 2009; Cockburn et al., 2010; Gilson et al., 2010). Studies 1 (chapter 3) and 2 (chapter 4) of this thesis demonstrated lower sensation of muscle soreness after CM consumption, with study 2 (chapter 4) providing evidence of muscle function enhancements. These findings could be compared with those of Cockburn and colleagues (2010), who showed that consumption of 1000 ml of CM vs. an equivalent volume of W after muscle-damaging exercise was associated with lower plasma CK responses, improvements in functional tests and lower sensation of DOMS.

Milk-derived proteins have been suggested to induce high rates of protein turnover into the exercising muscle and the high leucine content in milk proteins may serve as a "trigger" for increased muscle protein synthesis (Phillips, 2014). Evidence suggests that CM consumption post-exercise can have beneficial effects upon muscle protein synthesis, attenuating the degree of exercise-induced muscle disruption and/or speeding the repair process. Ferguson-Stegall et al. (2011) examined the effects of CM on muscle protein turnover after a glycogen depleting exercise bout and observed that the CM consumption increased the activation status of signalling proteins associated with increased mRNA translation and protein synthesis compared with an isocaloric CHO-protein beverage and placebo; these authors concluded that dairy proteins in the CM were related with attenuation of muscle protein degradation and faster tissue repair after a bout of strenuous exercise. Similarly, Lunn et al. (2012) showed that CM consumption after an acute bout of moderate intensity running increased kinetic measures of muscle protein synthesis and attenuated markers of whole body proteolysis. Therefore, in chapters 3 and 4, it is probable that the higher protein content in the CM attenuated exercise-induced muscle disruption, manifested by lower ratings of muscle soreness; therefore, post-exercise CM ingestion could have been related with enhanced muscle-related recovery post-exercise. Nonetheless, in neither of the studies in this doctoral thesis was plasma CK measured; possibly, measurement of CK activity in addition to measurements of range of motion and exercise-induced markers of inflammation could better illustrate the effects of CM on exercise-induced inflammation and muscle damage.

One could argue that the lower muscle soreness ratings in chapter 3 and 4 were associated with a placebo-effect rather than actual attenuation of muscle damage, since it was impossible to disguise the flavour of the two beverages. However, the beneficial effects of CM consumption on muscle-related recovery in chapter 4 were also illustrated by the better performance in functional and sport-specific tests. Judo is a sport that involves high-intensity training with high rate of body contact; therefore, in “real life” enhanced recovery is actually translated into training quality, thus the ability of the athlete to train at optimal capacity during the next training session. Therefore, the lower perception of muscle soreness along with enhancements in muscle-function tests suggest that post-exercise CM ingestion can have beneficial effects on the athletes’ recovery by promoting muscle-related recovery during a short-term period of intense judo training.

Judo is a sport classed by weight; therefore, judo athletes are very conscious regarding any changes in their body weight, especially in the days/weeks preceding a competition. During weight loss periods, the athletes’ usual nutritional practices for “making weight” mainly include elimination of high-caloric foods and CHO, increased exercising, restriction of fluid consumption, and in some cases, positively promoting sweat losses; these practices could be detrimental to subsequent performance and general health (Franchini et al., 2012). The experimental design of studies 1 (chapter 3) and 2 (chapter 4) aimed to adapt to the “culture” and sporting lifestyle of judo athletes and be as close as possible to “real-life” sporting situations; therefore, CM was compared with W instead of a CHO-sports drink, in contrast to previous investigations (Wojcik et al., 2001; Karp et al., 2006; Cockburn et al., 2008; Pritchett et al., 2009; Thomas et al., 2009; Gilson et al., 2010; Ferguson-Stegall et al., 2011; Spaccarotella and Andzel, 2011; Lunn et al., 2012). Additionally, study 2 (chapter 4) examined the effects of CM during a short-term intensified training period with concomitant rapid weight loss and a simulated competition was organised at the last day of each training week to motivate weight loss.

Subjects’ weight loss reached 1.9% in the W condition and 1.1% in the CM condition, with a trend for significant difference ($p=0.08$) between weeks. However, it is a fact that weight reductions in such small time-frame (5 days) are mostly attributed to fluid loss. Additionally, the higher saliva flow rate in CM condition and similar changes in body fat between drinks led us to the conclusion that the weight loss achieved in these subjects was mostly induced by dehydration. Additional measurements of urine and saliva osmolality in study 2 (chapter 4) before and after the drink consumption could have been used to

confirm the hydration status of the subjects. Nevertheless, it appears that the CM may better maintain fluid balance after training, since body weight was maintained until the morning of the competition day in the CM condition, whereas it was progressively reduced during the W condition. Previous studies suggested that milk can effectively restore sweat losses (Shirreffs et al., 2007) and maintain positive net fluid balance during recovery (Watson et al., 2008) compared with water after exercise-induced mild dehydration. Therefore, post-exercise consumption of CM may not have a meaningful effect on the process of “making weight”, whereby it is important to note that the beneficial effects for enhancing recovery may be more significant for attenuating overreaching symptoms and effective competition performance than any possible consequence on weight loss.

A limitation in chapter 4 was the lack of a counterbalanced crossover design in the consumption of beverages. In field-based studies, research has to be designed according to the athletes’ training schedule, requirements and habits. Therefore, taking into consideration this cohort of subjects and the aims of study 2, we concluded that a crossover design was not the best option for this group of subjects. Although the reasons for the lack of crossover design are explained in more detail in chapter 4, the main rationale was to eliminate the bias in the subjects’ weight loss practices and to make them maintain a similar energy intake between the two conditions. One could argue that the enhanced recovery aspects during the CM condition were simply due to a lower training volume. However, the measurements indicated that the training loads of the two weeks were similar, and furthermore, the mean RPE during each of the weeks was the same. Therefore, the lack of crossover design has probably not affected the research findings as they mainly validate the findings of previous studies.

7.2. Training periodisation and tapering for performance

Effective training periodisation is achieved through complex physiological processes involving careful planning and monitoring of overload training and tapering periods (Mujika and Padilla, 2003). Prolonged, intensive training periods with insufficient recovery can lead to overreaching and subsequent overtraining accompanied by several physiological, biochemical psychological disturbances and performance decrements (Meeusen et al., 2013). Effective tapering after strenuous periods of training involves achieving the right adjustments in training volume, intensity and/or frequency in a planned mode; these adjustments will allow the athlete to reach the super-compensatory phase

where the optimal enhancements in performance capacity occur (Bosquet et al., 2007). Judo athletes undergo intensive training periods with multi-directional training sessions (prolonged running for aerobic capacity, interval/intermittent running for anaerobic capacity, resistance exercise for muscle strength, judo-specific training using techniques and tactics) which could lead to overreached athletes; subsequently, without proper recovery, athletes may reach the onset of non-functional overreaching (Meeusen et al., 2013). Many studies exist that have examined the effects of intensive training and tapering in several sports (Mujika and Padilla, 2003; Mujika et al., 2004); however, studies to date to show that tapering after intensive training can enhance performance and aspects of training and recovery were lacking in elite judo athletes.

Another aspect of recovery that has been examined in this thesis is training periodisation through modification of training load. Study 3 (chapter 5) observed a training microcycle (2 weeks) in elite national judo athletes that involved intensive training sessions and examined the possible efficacy of a subsequent exponential taper (2 weeks) on the time-frame recovery of selected markers. Although no significant deterioration in performance capacity (or in other markers measured) was observed during the intensified training weeks, tapering enhanced almost all aspects of training and recovery. Should the intensive training continued for further weeks without proper recovery periods these judo athletes could possibly reach the onset of non-functional overreaching with a real risk of developing the overtraining syndrome. The subsequent taper in an exponential manner enhanced aspects of recovery and optimised judo-related exercise performance in these athletes within a period of 12 days. Tapering was associated with lower exercise-induced stress (decreased sC, increased sT and salivary T/C ratio), enhanced mucosal immune markers (SIgA absolute concentration and secretion rate), enhanced mood state and lower levels of muscle soreness. The findings of study 3 agree with studies in other sports involving intensive training and subsequent tapering (Mujika et al., 2004).

In this study the enhancements in salivary hormones, muscle soreness and mood state were observed within the first days of tapering (<7 days) and preceded the improvements in performance and mucosal immunity (7-12 days). Therefore, as described in chapter 5, tapering after intensive training periods may be an effective recovery strategy that can enhance training-induced adaptations and optimise judo competition performance. It is recommended to coaches that a similar tapering period is implemented for enhancing

performance and that athletes should taper at least a week prior to competitions in order for all training-induced adaptations to be optimised.

7.3. Endocrine responses, arousal and competition performance

The aim of every competitive athlete is to perform at his/her best capacity during competition. Chapter 6 did not directly assess recovery from exercise, but examined another crucial aspect of athletic life, which is effective competition performance. Therefore, study 4 (chapter 6) was designed again in a real-life sporting scenario, during an official judo competition. Due to the constraints on the athletes and coaches no intervention was possible in study 4. Therefore, the main aim was to observe the psychophysiological responses of national level judo athletes during a competition day, through assessing salivary immunoendocrine responses and self-measured anxiety, in order to identify any possible differences between those who win or lose the competition.

Interestingly, this study revealed that winners presented significantly higher resting sC concentrations in the morning, in anticipation of the competition, without differences in sT concentrations. Two studies in the literature support these findings showing higher anticipatory C in the winners of a judo and a triathlon competition; Suay et al. (1999) observed higher anticipatory serum C concentrations in the winners of a judo competition, and Balthazar and colleagues (2012) observed that anticipatory sC concentrations were positively related to race performance in professional triathletes; thus, those who won or who had the higher rank order in competition were the ones with the higher sC concentrations. Therefore, it can be suggested that morning sC measurements in anticipation of the competition could have some predictive value about the chances of winning.

Study 4 (chapter 6) has also found self-reported ratings of higher cognitive anxiety among the winners indicating that those who won experienced higher psychological alertness and/or better state of mental preparedness. Additionally, it was observed that winners presented higher saliva flow rate and a tendency for higher SIgA secretion rate mid-competition ($p=0.07$), which could suggest increased sympathetic activity, presumably induced by levels of higher arousal. Taking all the findings into account, it appears that winners were more alert before and during the competition and this could have had a positive influence on their competition performance.

The findings of study 4 (chapter 6) contradict the biosocial model of status (Mazur, 1985; Booth et al., 1989), that T levels are associated with dominance and aggressive behaviour, since no differences were observed in sT levels between winners and losers at either time point. However, the higher sC concentrations in the winners along with no differences in sT levels could be explained by the dual-hormone hypothesis, as proposed by Mehta and Josephs (2010). These authors suggested that the hypothalamic-pituitary-adrenal axis (cortisol) and the hypothalamic pituitary-gonadal axis (testosterone) jointly interact and compensate with each other to modify dominance; hence, only when C is low should higher T promote higher status and reversely when C is high, higher T may actually decrease dominance and sequentially motivate lower status (Mehta and Josephs, 2010). Observing the lower sT/C ratio in study 4 (chapter 6) in the winners could partly explain this suggestion. However, although it was suggested that sC measurements in anticipation of the competition could have some predictive value about the chances of winning, whether this was related or not to the levels of sT cannot be confirmed. A saliva collection in these subjects on a resting day could provide more details in this regard. These findings may stimulate further research in this area to more clearly establish how endocrine responses may affect or predict competition performance.

Although the findings show higher morning sC levels in the winners, one could argue that this was actually due to diurnal variation instead of an effect of psychophysiological arousal. Although from individual subjects' data it appears that winners had higher sC concentrations compared with losers, it is unclear if this was higher than their own levels on a typical rest day and an additional saliva sample on a resting day could provide insight in this regard. Furthermore, additional measurements of plasma adrenaline could confirm the levels of arousal in the athletes.

One could argue that the higher C concentrations in the winners could be attributed to exogenous use of stimulants. However, we can say with confidence that C concentrations at this timepoint were not affected by previous food or drink (i.e. coffee or ergogenic substances) intake or previous exercise; saliva was collected just before weigh-ins (competition took place before the change in IJF rules) and warm-up, when subjects did not consume anything (not even water) in order to maintain their body weight. It is important to note that doping control was present at the day of the competition. Furthermore, values of sC in the winners were within the normal range (although higher)

and not unusually higher than those of the losers. Therefore, it seems unlikely that there was any previous ergogenic substance use by the athletes.

7.4. Other important observations on salivary components

From all chapters of this thesis it is important to note some other key observations that could enrich the scientific knowledge on salivary immunoendocrine components. The findings of this thesis in chapter 5 provide further evidence that salivary concentrations of C, T and SIgA display a diurnal variation. The higher values of sC, sT and SIgA absolute concentrations were observed early in the morning (~07:00) and conversely, saliva flow rate was higher in the evening (~19:00). This can be taken into consideration in future studies, where saliva collection should be made accordingly to control for the effects of circadian rhythm in these immunoendocrine markers. In addition, from all chapters of this thesis, it appears that sC is quite sensitive to acute stress, whereas conversely, sT may require more chronic stress situations to present any differences. As observed in chapters 3, 4 and 5, of this thesis, the changes in sC were evident in situations of acute stress, whereas sT only showed changes in study 3 (chapter 5), which included a more prolonged physiologic stress stimulus (2 weeks of intensive training and a subsequent 2-week taper). Future studies may take these issues into consideration, especially when examining stress/endocrine responses to exercise and training.

Table 7.1. Summary of the aims and main findings of current thesis according to each study.

STUDY	AIMS	Comparisons and time points of measurements	MAIN FINDINGS				
			Performance	Salivary immunoendocrine responses	DOMS	Mood disturbance	Other observations
#1: Chapter 3 Acute effects of CM and W during recovery from a single judo training session.	Examine whether post-exercise CM consumption after a single intensive judo training session can enhance aspects of recovery and enhance subsequent performance compared to W	CM vs. W (at 24 h)	Handgrip strength: = Judo-specific test: = Timed push-ups: = (↑ p=0.09)	sC = sT = sT/C ratio = SIgA abs = SIgA secr = Saliva flow rate =	↓	Not measured	sleep disturbance: = (4.1% in CM) (6.3% in W)
#2: Chapter 4 Effects of CM and W on recovery during 5 days of judo training with concomitant weight loss.	Examine whether post-exercise CM consumption during 5 days of intensive judo training session can enhance aspects of recovery and enhance subsequent performance compared to W, without affecting intentional weight loss	CM vs. W (at day 5)	Horizontal jump: = Judo-specific test: ↑ Timed push-ups: ↑	sC ↓ sT = sT/C ratio = (↑p=0.07) SIgA abs = SIgA secr = Saliva flow rate ↑	↓	↓	weight loss: = (1.1% in CM) (1.9% in W)
#3: Chapter 5 Effects of a 2-week tapering period after 2 weeks of intensive judo training.	Examine the changes in markers of training and recovery during a 2-week taper following intensive training.	Tapering vs. normal and/or intensive training	Horizontal jump: = Vertical jump: ↑ Handgrip strength: ↑ Judo-specific test: = MSFT: = 3x300m: ↑	sC ↓ sT ↑ sT/C ratio ↑ SIgA abs = SIgA secr ↑ Saliva flow rate ↑	↓	↓	<i>Diurnal variation:</i> ↑ sC, sT, SIgA in the morning ↑ saliva flow rate in the evening
#4: Chapter 6 Salivary immunoendocrine responses and anxiety in winners and losers of a judo competition.	<ul style="list-style-type: none"> Examine the salivary immunoendocrine responses before, during and after an international national judo competition. Determine possible differences in salivary immunoendocrine markers and anxiety between winners and losers. 	<ul style="list-style-type: none"> Pre- vs. mid- and/or post-competition Winners (ranking 1-3) vs. losers (ranking ≥ 4) 	Not measured Classified according to ranking place at the competition	<i>Across time</i> sC = sT ↑ sT/C ratio ↑ SIgA abs = SIgA secr = Saliva flow rate ↓	<i>Winners had...</i> sC ↑ (pre-competition) sT = sT/C ratio ↓ (pre- and mid-competition) SIgA abs = SIgA secr = (↑p=0.07 mid-competition) Saliva flow rate ↑ (mid-competition)	↑ cognitive anxiety in the winners pre-competition	

↑ and ↓ indicates significant (p<0.05) increase and decrease, respectively; = indicates no significant change (p>0.05); DOMS indicates delayed onset muscle soreness; CM indicates chocolate milk; W indicates water; SIgA abs indicates SIgA absolute concentrations; SIgA indicates SIgA secretion rate.

7.5. Conclusions

- Post-exercise consumption of CM is an effective recovery beverage during short-term periods (≥ 5 days) of intensified judo training that can reduce symptoms of overreaching and enhance muscle-related recovery.
- Post-exercise consumption of CM is beneficial for reducing accumulated stress, enhancing mood and attenuating the sensation of muscle soreness during periods of intensified judo training.
- Following an exponential taper for 7-12 days in judo can lower the risk of overreaching and aid the achievement of optimal performance.
- A tapering period following intensive judo training can reduce the levels of accumulated stress, enhance markers of mucosal immunity and mood state, attenuate the sensation of muscle soreness and enhance judo-related performance.
- Elevated cortisol levels and high cognitive anxiety in anticipation of a judo competition could have some predictive value for winning performance.
- Salivary concentrations of cortisol, testosterone, and SIgA and saliva flow rate display diurnal variation; Concentrations of sC, sT and SIgA are highest levels in the morning and saliva flow rate is highest in the evening.

7.6. Practical suggestions

- Post-exercise CM consumption during periods of intensive judo training can have beneficial effects on the recovery of athletes.
- Post-exercise CM consumption does not significantly affect pre-competition weight loss; therefore, CM can be also used in the weeks of “making weight” prior to judo competitions.
- Tapering for 7-12 days following intensive training by exponentially decreasing training volume and maintaining training intensity can enhance performance and lower accumulated fatigue and therefore should be implemented prior to competitions.
- The enhancements in salivary hormonal responses, mood state and muscle soreness precede the enhancements in mucosal immunity and performance; therefore, it is recommended that athletes taper for at least one week prior to a judo competition, so that all aspects of conditioning are optimised.
- Increasing the levels of arousal before competition may help athletes perform better.

7.7. Future directions

According to the findings of this thesis, measurement of additional immune and endocrine markers in blood and saliva as well as hydration can be used in future studies; these measurements could provide more information on the responses of intense training and recovery in judo athletes. These markers can measure levels of muscle damage/inflammation and immune response in blood (i.e. circulating CK, lactate dehydrogenase, neutrophil phagocytic activity and oxidative burst activity) and saliva (salivary alpha-amylase) as well as levels of hydration (such as urine and saliva osmolality). Taking in account the research design and findings of studies 1 (chapter 3) and 2 (chapter 4), future research could focus on comparing CM with an equicaloric, same-flavoured and coloured placebo using a randomised, double-blind, crossover design. The aims of the studies 1 (chapter 3) and 2 (chapter 4) could be further examined in a more controlled environment, thus standardising training using laboratory measurements. Future studies could also focus on the effects of CM on post-exercise recovery and rehydration during periods with a larger amount of weight loss (more than 2% body weight). The effects of CM on recovery could subsequently be tested or applied in other sports, with a similar nature to judo (e.g. wrestling, boxing, karate, taekwondo), to confirm the beneficial effects of CM on recovery. Judo athletes are also prone to micronutrient deficiencies during weight loss periods (as discussed in detail in chapter 2); therefore, future studies could examine immune and endocrine responses during intense judo training and weight loss with supplementation with antioxidants, which may have the potential to enhance the recovery process. According to the findings of chapter 5, future studies could examine the effects of tapering after longer intensive training periods and the effects of tapering on actual judo competition performance. A tapering period of 7-12 days could be implemented in the training schedule of judo athletes before an actual competition in order to confirm whether this is a suitable strategy that can optimise competition performance. Additional measurements during a judo competition (hydration status, control of nutrient intake, performance tests) and possibly an intervention with high-glycaemic index CHO drink during the competition day could suggest future directions of research regarding the prediction of performance during judo competitions. According to the findings in study 4 (chapter 6), it may be of practical interest to introduce motivational strategies (such as video footage, music or coach motivation) for judo athletes before the competition; levels of psychophysiological arousal (such as measurement of blood adrenaline, sC, salivary

alpha-amylase, anxiety) and before and after these strategies in addition to competition performance could provide more information whether stimulating higher levels of psychophysiological arousal can be a significant contributing factor to judo performance. This study could then be replicated in several competitions and examine whether these responses are consistent. Lastly, a future direction could summarise all the strategies that contribute to recovery and subsequent competition performance and examine which are the most effective strategies using statistical significance; regression equations may be used for this regard, firstly analysing the factors that contribute to enhanced recovery and secondly, analysing the variables that could contribute to enhanced competition performance.

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Appendices

All questionnaires were translated in Greek.

Appendix I

THE GRONINGEN SLEEP QUALITY SCALE

(Mulder-Hajonides van der Meulen et al., 1980)

Name.....No..... date.....

Please answer the following questions using **true** or **false**

1. I had a deep sleep last night.....
2. I feel that I slept poorly last night.....
3. It took me more than half an hour to fall asleep last night.....
4. I woke up several times last night.....
5. I felt tired after waking up this morning.....
6. I feel that I didn't get enough sleep last night.....
7. I got up in the middle of the night.....
8. I felt rested after waking up this morning.....
9. I feel that I only had a couple of hours' sleep last night.....
10. I feel that I slept well last night.....
11. I didn't sleep a wink last night.....
12. I didn't have trouble falling asleep last night.....
13. After I woke up last night, I had trouble falling asleep again.....
14. I tossed and turned all night last night.....
15. I didn't get more than 5 hours' sleep last night.....

All items are scored true / false

The first question does not count for the total score

One point if answer is 'true': questions 2, 3, 4, 5, 6, 7, 9, 11, 13, 14, 15

One point if answer is 'false': questions 8, 10, 12

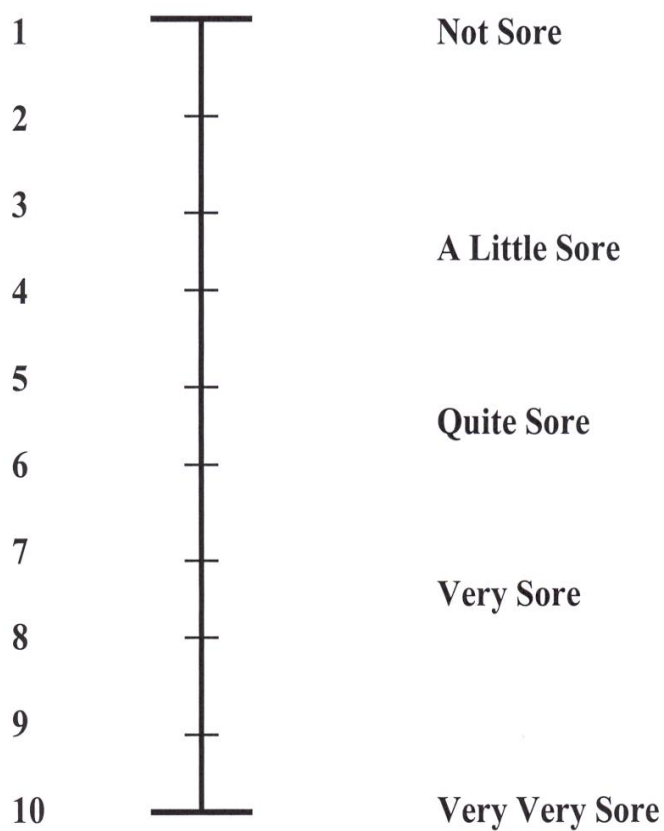
Maximum score 14 points, indicating poor sleep the night before

Appendix II

GENERAL MUSCLE SORENESS QUESTIONNAIRE

Name.....No.....week.....date.....

Rating of Perceived Soreness

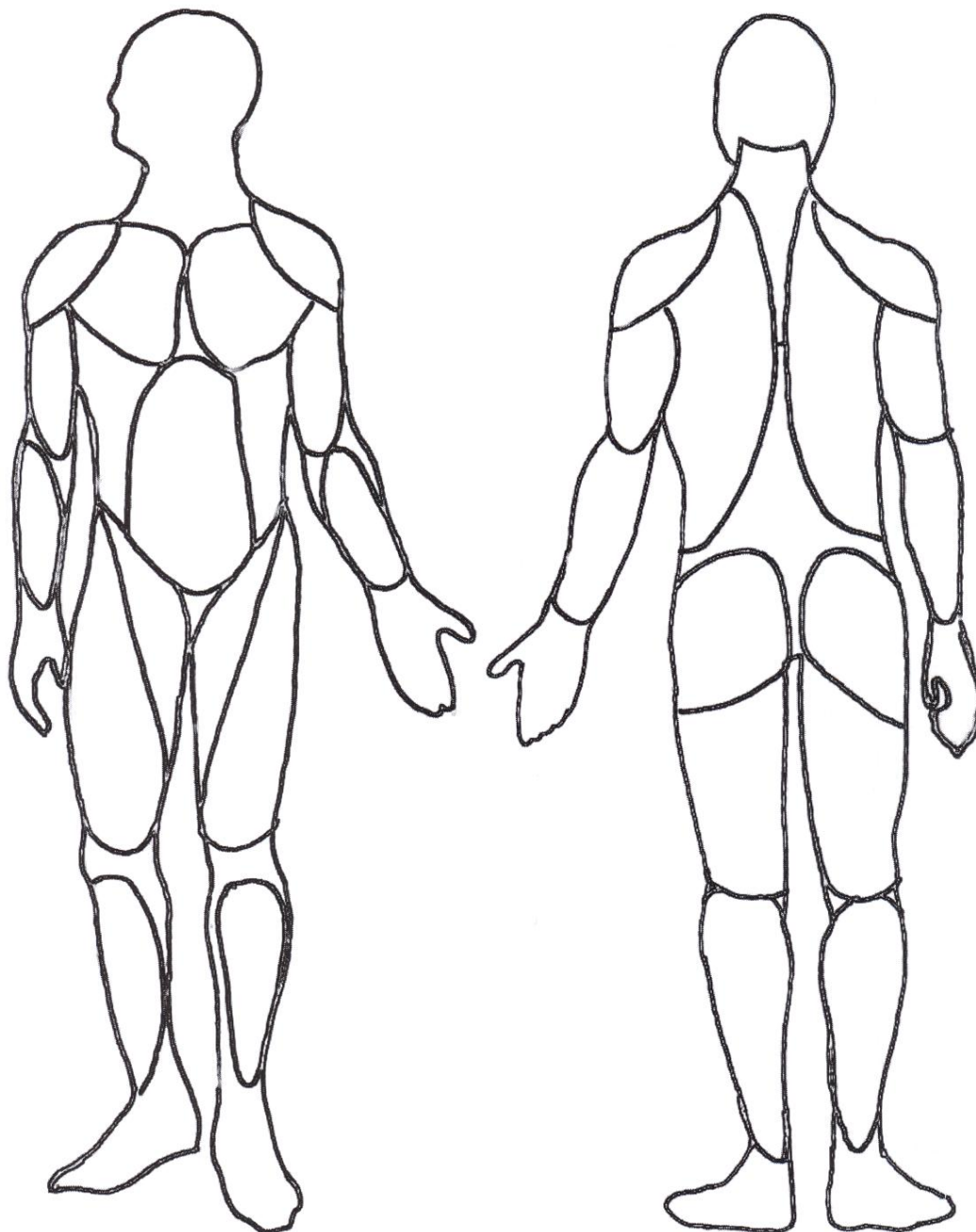


Above there is a line of 10 centimetres. Please rate the muscle soreness you feel at this moment when performing everyday activities, by making a cross on this line.

On one end is “not sore” (i.e. no muscle soreness) and on the other end is “very very sore” (i.e, extremely muscle soreness).

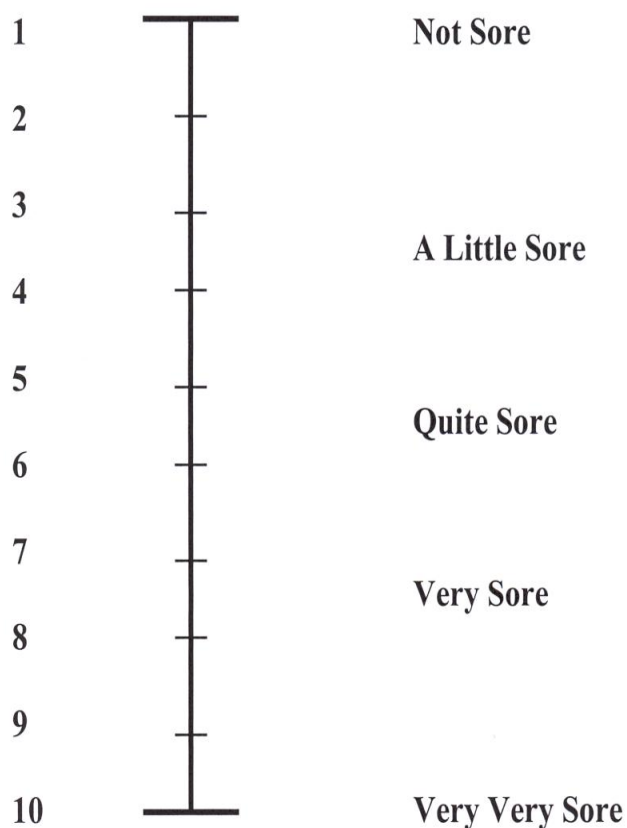
Muscle soreness location

Please rate with X the location of sore muscles.



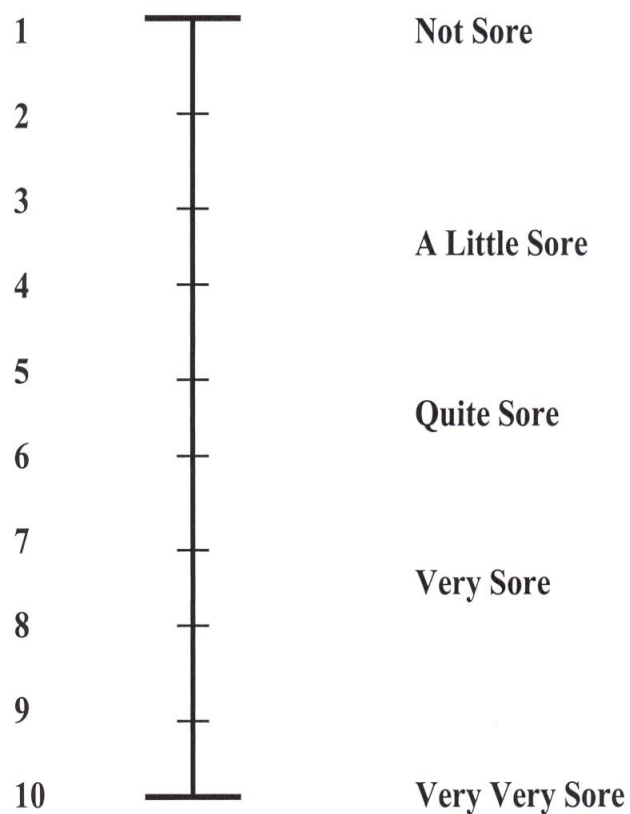
FRONT THIGH MUSCLE SORENESS DURING PALPATION QUESTIONNAIRE

Rating of Perceived Soreness



Above there is a line of 10 centimetres. Please rate the muscle soreness you feel at this moment while lightly palpating front thigh muscles, by making a cross on this line.

On one end is “not sore” (i.e. no muscle soreness) and on the other end is “very very sore” (i.e, extremely muscle soreness).

UPPER BODY MUSCLE SORENESS DURING PALPATION QUESTIONNAIRE**Rating of Perceived Soreness**

Above there is a line of 10 centimetres. Please rate the muscle soreness you feel at this moment while lightly palpating upper body muscles (arms, chest, trapezoids), by making a cross on this line.

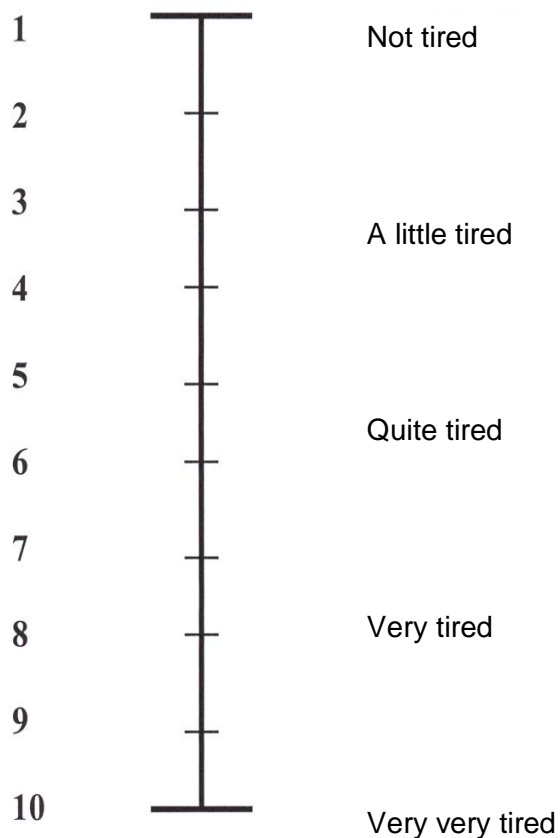
On one end is “not sore” (i.e. no muscle soreness) and on the other end is “very very sore” (i.e. extremely muscle soreness).

Appendix III

VISUAL ANALOGUE SCALE FOR GENERAL FATIGUE

Name.....No.....week.....date.....

Rating of general fatigue



Above there is a line of 10 centimetres. Please rate the fatigue you feel at this moment when performing everyday activities, by making a cross on this line.

On one end is “not tired” (i.e. not feeling tired) and on the other end is “very very tired” (i.e, extremely tired).

Appendix IV

The Profile of Mood States (POMS) Questionnaire

Name.....No.....week.....date.....

Below there is a list with words that describe certain feelings. Read each one of them carefully. Then CIRCLE the answer that describes best what you are feeling AT THIS MOMENT.

Make sure you answer all the questions.

	Not at all	A little	Moderately	Quite a bit	Extremely
1. Panicky	0	1	2	3	4
2. Sad	0	1	2	3	4
3. Lively	0	1	2	3	4
4. Confused	0	1	2	3	4
5. Furious	0	1	2	3	4
6. Worn out	0	1	2	3	4
7. Depressed	0	1	2	3	4
8. Downhearted	0	1	2	3	4
9. Annoyed	0	1	2	3	4
10. Exhausted	0	1	2	3	4
11. Mixed-up	0	1	2	3	4
12. Sleepy	0	1	2	3	4
13. Bitter	0	1	2	3	4
14. Unhappy	0	1	2	3	4
15. Anxious	0	1	2	3	4
16. Worried	0	1	2	3	4
17. Energetic	0	1	2	3	4
18. Miserable	0	1	2	3	4
19. Muddled	0	1	2	3	4
20. Nervous	0	1	2	3	4
21. Angry	0	1	2	3	4
22. Active	0	1	2	3	4
23. Tired	0	1	2	3	4
24. Bad tempered	0	1	2	3	4
25. Bushed	0	1	2	3	4
26. Alert	0	1	2	3	4
27. Uncertain	0	1	2	3	4

Appendix V

QUESTIONNAIRE: Revised Competitive State Anxiety-2 (CSAI-2R)

NAME.....

DATE

Directions: A number of statements that athletes have used to describe their feelings before competition are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you feel right now – **at this moment**. There are no right or wrong answers. Do not spend too much time on any one statement, but choose the answer which describes your feelings **right now**.

		Not at all	Some what	Moderately so	Very much so
1	I feel jittery	1	2	3	4
2	I am concerned that I may not do as well in this competition as I could	1	2	3	4
3	I feel self-confident	1	2	3	4
4	My body feels tense	1	2	3	4
5	I am concerned about losing	1	2	3	4
6	I feel tense in my stomach	1	2	3	4
7	I'm confident I can meet the challenge	1	2	3	4
8	I am concerned about choking under pressure	1	2	3	4
9	My heart is racing	1	2	3	4
10	I'm confident about performing well	1	2	3	4
11	I'm concerned about performing poorly	1	2	3	4
12	I feel my stomach sinking	1	2	3	4
13	I'm confident because I mentally picture myself reaching my goal	1	2	3	4
14	I'm concerned that others will be disappointed with my performance	1	2	3	4
15	My hands are clammy	1	2	3	4
16	I'm confident of coming through under pressure	1	2	3	4
17	My body feels tight	1	2	3	4