HEART RATE VARIABILITY AS A PHYSIOLOGICAL INDICATOR OF MENTAL TOUGHNESS

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Master's Thesis in Sport and Exercise Psychology
Spring 2016
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ABSTRACT

Papantoniou, Adamos (2015). Heart Rate Variability as a Physiological Indicator of Mental Toughness. Master's Thesis in Sport and Exercise Psychology. Department of Sport Sciences, University of Jyväskylä. 43p.

Mental toughness is gaining prominence in sport psychology since athletes themselves, coaches, members of the press, sports commentators and sports psychologists have cited mental toughness as one of the most important psychological characteristics in elite sports. Even so, an extensive review of the available literature leads to the conclusion that there is a lack of a precise and widely accepted definition of mental toughness, while its conceptualization remains challenging. Therefore, based on the existing literature concerning physiological toughness (Dienstbier, 1989), this study examines through an innovative psychophysiological perspective how mental toughness operates, and thus contributes to a better understanding of the concept of mental toughness.

The purpose of this study was to investigate athletes' (N = 18) and their respective coach's perceptions and appraisals of the athletes' levels of mental toughness (MT) in elite soccer. For this purpose, the Sports Mental Toughness Questionnaire (SMTQ) was used to assess perceptions and appraisals of MT. In addition, the levels of the athletes' Heart Rate Variability (widely used as an indicator of Autonomous Nervous System and therefore physiological marker of stressors; see Task Force, 1996) were measured, before and during the pre-season preparation period. Existing literature suggests that, the mental and physical demands of the preseason preparation period are relatively too high compared with the rest of the competitive season and this can explain the increased numbers of injuries occurring during that period (Woods, 2002).

Overall, results revealed significant associations between athletes' Heart Rate Variability and the three components of mental toughness (Control, Confidence and Constancy). Specifically, as appear from the Quick Recovery Tests, the Nocturnal Measurements and coach's subjective opinion on athletes' levels of mental toughness, coaches tend to perceive as more mentally tough the athletes who usually have a "suitable, positive stress" which keeps them "alert", in a "constant readiness" and "always ready for fight". From an applied perspective, this study suggests that sport psychologists and practitioners may identify a need to enrich an athlete's stress-coping techniques, just by observing heart rate variability patterns and the modulation of autonomous nervous system.

Key words: *elite sport, mental toughness, Heart Rate Variability, Autonomous Nervous System, psychophysiology*

ACKNOWLEDGMENTS

This study was carried out in the Department of Sport and Health Sciences, University of Jyväskylä, Finland in co-operation with KIHU – Research Institute for Olympic Sports, Jyväskylä, Finland. The completion of this project is accompanied by a deep sense of gratitude towards several persons who have contributed to my work.

First of all, I would like to express my sincere gratitude to my main supervisors, Senior Lecturer Maria Chasandra and Esa Hynynen, PhD, for the complete and active supervision they provided me. You literally let me stand on your shoulders. I honestly feel that I have been blessed and privileged to have you both as my supervisors.

This thesis would not have been completed without the constant support of the Coach Christakis Christoforou. The trust, the commitment and his overall contribution to the project was of a great importance and I owe him a lot.

I would also like to thank the company Firstbeat Technologies Ltd. and especially the manager Veli-Pekka Kurunmäki for believing me and my project and make it possible, by providing me with the necessary equipment, comments and advices until the successful completion of it.

I big thank you to my professors and my classmates from the Sport and Exercise Psychology Masters, for sharing this unforgettable two-year period together and being the reason behind the amazing memories I have experienced here in Finland.

In addition, a special thank you to JJK Jyväskylä football club and my players here, for allowing me be their coach and for giving me the opportunity to become an active member in their great family.

I owe my deepest gratitude to Katerina for always being on my side, willing to protect me and support me during fortunes and frustrations, and being ready to share my ambitions and triumphs throughout my life.

Finally, words can't express the gratitude I feel when I think about the persons closest to me, my friends, my parents and my siblings Thekla, Margarita, Maria and Antonis, for their unconditional love and their support that lead me to go further and further. Especially you Margarita… You constantly remind me what really is important in everyday life! Thanks a lot…

Adamos Papantoniou

February 2016

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1 INTRODUCTION

Mental Toughness as a psychological construct has been repeatedly recorded as *"the most important psychological characteristic in the pursuit of excellence"* (e.g. Goldberg, 1998; Gould, Hodge, Peterson, & Petlichkoff, 1987). However, mental toughness has been described as *"one of the most used but least understood terms in applied sport psychology"* (Jones et al., 2002). In order to explain mental toughness, innumerable definitions and plenty of possible relevant characteristics have been proposed. As a result, many positive psychological characteristics has been associated with mental toughness but unfortunately most of these characteristics have derived from anecdotal evidence and subjective personal experiences. Based on the aforementioned failure of scientists to provide well-established objective measures, Crust (2008) suggests that *"it is now time to shift our attention in more innovative research approaches and to investigate more in-depth the different aspects of mental toughness. Objective measurements will be achieved through more experimental studies, longitudinal researches, tests of mental toughness in contexts outside sport performance and finally through psychophysiological approaches."*

Surprisingly, the line of research exploring possible physiological indicators of mental toughness is only limited. It has been shown that the levels of arousal and the physiological toughness (Dienstbier, 1989) could be considered as indicators of physical toughness and thus components of mental toughness (Gucciardi et al., 2007). In 2016, Zahn et al. (Zahn, 2016) examined and evaluate the relationship between Heart Rate Variability and self-control and they ended up by publishing a meta-analysis. However, the physiological perspective of mental toughness has not yet been sufficiently explored and until recently no relevant research has been conducted. Therefore, this study aims to examine possible links between mental toughness and the function of Autonomous Nervous System (ANS). The measurements assessing the modulation of ANS are widely considered as indicators of physical and psychological stress (Hynynen, 2011). High-level professional athletes (*N*=18) of a Cyprus First Division football team completed questionnaires assessing their levels of mental toughness (Sheard et al., 2009). Additionally, their coach also subjectively assessed the athletes' individual levels of mental toughness. Heart rate variability was used as an indicator of the function of ANS and was measured through the First Beat Technologies equipment.

The establishment of links between mental toughness and physiological measures will assist to a better understanding on how exactly mental toughness operates and consequently a clearer view of mental toughness will be achieved. In addition, if significant evidence occurs then physiological measurements might be used as an alternative way to identify mentally tough and mentally sensitive athletes. Finally, this research should be considered as exploratory research since it is the first of its kind and therefore if significant findings appear, an in-depth investigation aiming to explore further the psychophysiological properties of mental toughness should then elicit.

2 Literature Review

2.1 Mental Toughness

The concept of Mental Toughness has started receiving more in-depth scientific attention only recently and therefore its conceptualization and definition are still under question (Andersen, 2011). Nevertheless, the majority of the scientific community seems to agree that *"mental toughness is a rather dispositional construct that allows individuals to deal with obstacles, distractions, pressure and adversity from a wide range of stressors"* (Bell, 2013, Clough & Strycharczyk, 2012; Gucciardi & Gordon, 2012). In addition, a plethora of research studies appear to associate the construct of mental toughness with higher levels of sporting achievement (Sheard, 2010), with a more effective coping in testing circumstances (Kaiseler, Polman, & Nicholls, 2009), with success in sports (Bull, Shambrook, James, & Brooks, 2005; Connaughton, Wadey, Hanton, & Jones, 2008; Jones, Hanton, Connaughton, 2007) and with greater pain tolerance (Crust & Clough, 2005).

There is an increasing tendency of many sports people, elite athletes, coaches and the media to refer to mental toughness as the mindset behind sporting achievement (Sheard, 2010). It is commonly accepted that athletes with extraordinary talents and great physical skills might reach only a certain level of success because of a lack of appropriate mentality. Related with that, Elka Graham, the Australian swimming legend stated that ''In training everyone focuses on 90 percent physical and 10 percent mental, but in the races it is 90 percent mental because there is very little that seperates us physically at the elite level.'' Therefore, it appears that is the mental toughness that differentiates the "good" performers from the "great" performers at the elite level (Gould, Jackson, & Finch, 1993; Orlick & Partington, 1988).

What is Mental Toughness?

Many researchers have attempted to define the concept of mental toughness and plenty definitions have been proposed. Some of these definitions refer to mental toughness as the ability to handle and cope with stress positively (Clough, Earle, & Sewell, 2002; Loehr, 1995; Williams, 1988) or the great persistence and the continuous refusal of a person to quit (Middleton, 2004a). Clough et al. (2002) emphasize on the ability of an athlete to overcome setbacks and rebound from failures. Finally, having an unshakable belief in oneself (Jones et al., 2002) or having superior mental skills (Bull, Albinson, &

Shambrook, 1996) have been used as definitions of mental toughness, without however avoiding criticism of using an absolute language (Andersen, 2011).

Another conceptualization issue and continuous debate among the researchers is whether mental toughness should be considered as personality trait (Kroll, 1967; Werner & Gottheil, 1966) or a state of mind (Gibson, 1998). In regard to the first position, it is important to be mentioned that Cattell (1957) considered tough-mindedness as one of the sixteen primary traits that described personality in the Sixteen Personality Factor Questionnaire (16PF) and as one of the most important personality traits for success. Specifically, according to Cattell, tough-minded individuals are characterized by a sense of independence, self-reliance, responsibility and realistic thought. Although this description appears to have certain similarities with the concept of mental toughness in sports (Crust, 2007), the debate whether mental toughness is a personality trait, state of mind, or a set of psychological characteristics is still vivid (Bull et al., 2005).

The efforts of the researchers (e.g Bull et al., 1996; Crust 2008; Goldberg, 1998; Gould et al., 1987; Gucciardi et al., 2009; Tutko & Richards, 1976) to describe, measure and develop mental toughness end-up with a list of key attributes, behaviors and characteristics which includes: determination, persistence, resilience, optimism, confidence, self-belief, commitment, control, self-awareness, focus and concentration, motivation and courage, work ethics and personal values, discipline, competitive desire and desire to success, tough thinking, handling failure and success, pushing back the boundaries of emotional and physical pain, exploited learning opportunities, superior decision making and emotional intelligence. Unfortunately, the continuous lack of consistency and agreement between the scientists in order to define effectively what mental toughness is and which are its main characteristics had consequently led to a lack of scientific rigor, contradiction and conceptual confusion.

One of the most important attempts and positive developments (Bull et al., 2005) in order to provide a common accepted definition and some conceptual clarity, was done by Jones et al. (2002, 2007) by interviewing in-depth elite and super-elite athletes. The resulting definition concludes that:

"Mental toughness is the natural or developed psychological edge that enables you to: generally, cope better than your opponents with the many demands (competition, training and lifestyle) that sport places on a performer; specifically, be more consistent and better than your opponents in remaining determined, focused, confidence, and in control under pressure. (p.247)"

Furthermore, a more concrete framework (Fig.1) was developed to facilitate a better understanding of what mental toughness is. This framework is consisted by four dimensions (attitude/mindset, training, competition, and post-competition). The 'attitude/mindset' dimension includes attributes that describe the general mental attitude of an athlete. The three other dimensions (training, competition, post-competition) are related to mental toughness attributes in different concepts. In these four dimensions are belonging ten overlapping subcomponents (belief, focus, using long-term goals as source of motivation, controlling the environment, pushing yourself to the limit, regulating performance, handling pressure, awareness and control of thoughts and feelings, handling failure, handling success). This framework together shapes the profile of a mentally tough athlete. Interestingly, the theories proposed by Jones et al., (2002, 2007) were further verified in a more robust framework with different samples and in different contexts (Bull et al., 2005; Thelwell, Westeon, & Greenless, 2005).

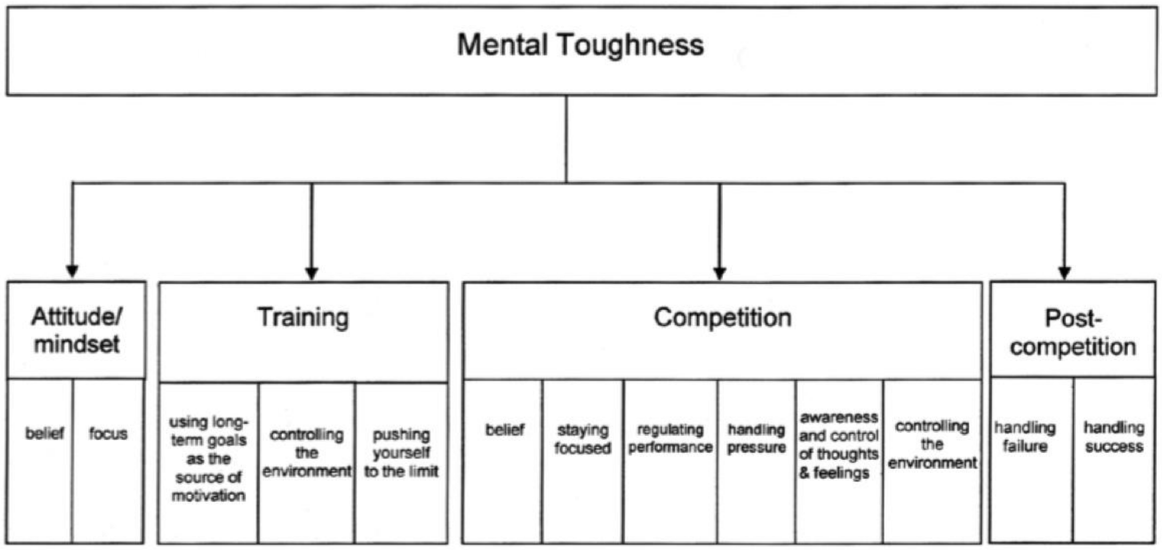

Figure 1. Mental toughness framework (Jones et al., 2007)

In an attempt to provide a more applied perspective of mental toughness Clough et al. (2002) get inspiration from their applied work and they paid particular attention on ecological validity by focusing on the opinions of elite athletes and coaches. They assumed that the concept of 'hardiness' which derives from the mainstream psychology could be applied in the sport context and might be a similar construct with mental toughness. As a result, a widely adopted applied model of mental toughness occurred, the 4C's model of mental toughness (Clough et al., 2002). The four components of mental toughness as proposed by the 4C's model are Control, Commitment, Challenge, and Confidence. The cognitive dimensions of the components of 4C's model are reflected on mentally tough athletes' beliefs that they can control their negative life experiences; they feel highly committed in order to achieve their personal goals; they consider negative happenings as great opportunities for growth and development; and they are confident in their abilities. Consequently, the proposed definition is that:

''Mentally tough individuals tend to be social and outing; as they are able to remain calm and relaxed, they are competitive in many situations and have lower anxiety levels than others. With a high sense of self-belief and an unshakeable faith that they can control their own destiny, these individuals can remain relatively unaffected by competition or adversity (Clough et al., 2002, p. 38)''.

2.2 Measuring Mental Toughness

The most common methodological approach in order to measure mental toughness has been through questionnaires. The first attempt to measure mental toughness was recorded by Loehr (1986) through the Psychological Performance Inventory (PPI; Loehr, 1986). This inventory was mainly created to operationalize Loehr's (1982) understanding of mental toughness. It was consisted by 42-items which actually measured seven components of mental toughness: self-confidence, motivation, attitude control, attention control, negative energy, positive energy, visual and imagery control. The lack of precision on the definition proposed by Loehr (1982) about mental toughness it was also reflected in the PPI as it contained rather inaccurate terms such as "positive and negative energy". In addition, the evidence from the psychometric assessment of the PPI (Middleton et al., 2004) found that PPI has insufficient psychometric properties and thus it could not be considered as a valid measurement of mental toughness.

Based on the 4C's model of mental toughness Clough et al. (2002) developed the Mental Toughness 48 Questionnaire (MTQ-48). The MTQ-48 contains 48 items and measures the levels of mental toughness via the four subscales of Control, Commitment, Challenge, and Confidence. The answers are given on a 5-point Likert scale ranging from (1) strongly agree to (5) strongly disagree. The overall test-retest coefficient of the MTQ-48 is 0.9 and the internal consistency of the four components of MTQ (Control, Commitment, Challenge, and Confidence) has been reported to be 0.73, 0.71, 0.71, and 0.8 respectively (Clough, et al., 2002). Interestingly, criterion validity for MTQ-48 has been supported from the studies, as participants who were characterized as mentally tough through MTQ-48, have reported lower ratings of exertion during a 30-minute cycle ride(Clough et al., 2002). In addition, a significant correlation between mental toughness and physical endurance has been observed and thus further support for the criterion validity has been attained (Crust & Clough, 2005). Despite the strong evidence which support the validity and reliability of the MTQ-48 many researchers have expressed concerns about the inventory. Specifically, Clough et al. were criticized due to the fact that MTQ-48 is based on a problematic conceptualization of mental toughness, as they do not differentiate sufficiently the concepts of hardiness and mental toughness (Crust et al., 2007). Finally, the MTQ-48 was characterized by a lack of independent scrutiny of the factor structure (Sheard et al., 2009).

Another mental toughness measurement that has been proposed recently by Middleton et al. (2004b) is the Mental Toughness Inventory (MTI). The questionnaire is quite long as it is consisted by 67-items which actually assess 12 components of mental toughness, as well as an overall global mental toughness score. The multidimensional measurements and information that MTI provides are probably of a great importance in an applied context as it gives the opportunity to the researchers to come into important conclusions related to the different mental aspects of an athlete's personality. However MTI has been criticized of lack of validation on different populations and age groups, as the strong psychometric properties that MTI possess, was extracted from participants of just one elite sports high school. Thus, future researches should be conducted in order to determine whether MTI can be used as a validate measurement with non-elite athletes or populations different than just adolescents athletes.

In another attempt to quantitatively measure mental toughness, Sheard et al. (2009), have created lately the Sports Mental Toughness Questionnaire (SMTQ; Sheard et al, 2009). The multidimensional measure that derived was based on past themes and quotes extracted from previous qualitative research on mental toughness. The authors get inspired by the so-called "positive psychology" approach (Seligman & Csikszentmihalyi, 2014) and they assumed that athletes who are proving constant growth and strengthening under physical, social and emotional stressors could be possible described as mentally tough athletes (Sheard et al., 2009). The SMTQ is a 14-item model consisted by three factors: Confidence, Control and Constancy. Participants respond to items using a 4-point Likert scale, ranging from *(1) not at all true, to (4) very true.* In total, the SMTQ provides an overall mental toughness score as well as a score for each one of the three subscales. The confidence dimension measures athlete's belief in their abilities in order to successfully reach their goals and whether they believe that they have qualities that set them apart from their competitors. The constancy dimension reflects athlete's determination to face challenging situations; personal responsibility to set goals and complete his daily tasks; an unswerving attitude, and strong ability to concentrate during trainings and competitions. Finally, the Control dimension assesses athletes' ability of being in control of the situations; their strength to overcome worries and self-doubt and their persistence to achieve desired outcomes. The psychometric properties of SMTQ have been examined in 26 different sports' contexts and found to be satisfactory since sufficient reliability, divergent validity and discriminative power has been found. Cronbach's αs computation revealed acceptable internal consistency for each of the three factors: Confidence = .80, Constancy = .74, and Control = .71 (SMTQ; Sheard et al., 2009). It was repeatedly shown that SMTQ distinguishes older, male and high-level athletes competing at international level from recreational athletes (Golby & Meggs, 2011; Kuan & Roy, 2007). Overall, the psychometric properties of SMTQ has been demonstrated to be satisfactory and encouraging, even though, further meaningful comparisons should be made on SMTQ data collected over time, in order to become a well-established tool.

2.3 Physiological Indicators of Stress

2.3.1 Autonomous Nervous System (ANS)

The ANS is consisted by the sympathetic nervous system (SNS) and parasympathetic nervous system (PNS) which act in a complementary manner and they literally control the cardiovascular system. The sympathetic nervous system prepares the organs for vigorous activity, external challenges and for "fight or flight" situations, by increasing for example breathing and heart rate. The parasympathetic nervous system has generally opposite function as it facilitates recovery and nonemergency activities. Both, SNS and PNS affect the heart rate (HR). Specifically, SNS increases the HR while the PNS decreases it. Although the two systems are in a constant opposition, both are working parallel but in a different degree, in order to achieve homeostasis and ensure the optimal function of the cardiovascular system.

2.3.2 Parasympathetic and Sympathetic Modulation of the Heart

Intense activation of the PNS results in a decrement of the HR. Consequently, the individual experiences a state of rest or recovery and this can be translated as the predominance of PNS on SNS. Indicatively, at rest the normal heart rate decreases from

110-120 bpm to 60-80 bpm. The heart rate is fluctuated according to the balance between PNS and SNS activity. A vagal (parasympathetic) predominance is indicated when the HR values are lower than the average values, while a sympathetic predominance is observed when HR values are higher than the average values. However, according to Winsley (2002) parasympathetic impulses influence faster the HR than sympathetic impulses (1sec versus 25sec).

2.4 Why the ANS is an indicator of stress?

The response to cognitive, emotional, physical or any other kind of perceived stressor is characterized by an immediate activation of the Autonomous Nervous System (ANS). Specifically, during stressful situations an increased activity of the sympathetic nervous system occurs (Julius, 1993) and concurrent to the increase in sympathetic nervous system (SNS) activity, a withdrawal of parasympathetic influence is observed (Brosschot & Thayer, 1998). The abovementioned description leads us to the conclusion that ANS is highly sensitive on the daily stressors and thus the measurement of its activation could be used as an indicator of the perceived stressors. At this point, it should be noted that although the word stress usually have a negative indication, physiologists also use it when referring to a stimulus or a challenge (Stansfeld, 2002). Heart rate variability (HRV) is a non-invasive, widely accepted measurement that can be used to study changes in autonomic nervous system activity through the interactions of SNS and PNS (Hautala et al. 2009; Hynynen, 2011; Task Force, 1996). Recent findings suggest that acute physical stress produced through endurance exercises is related to a decrement in nocturnal HRV while psychological stress is also associated with lower HRV (Hynynen, 2011). In other words, the results indicate that both physical and psychological stressors can diminish HRV especially when appear in a long-term horizon.

2.5 Methods for analyzing HRV

Different methods may be used to analyze HRV but the most validated and commonly used methods are time domain and conventional frequency domain methods. The analysis of the time domain method is relatively simple as it can be calculated just by recording the differences of RRI fluctuations. The most commonly used index stemmed from the differences of RRIs is the square root of the mean squared differences of successive RRIs (RMSSD). All in all, RMSSD compute high frequency variation in heart rate and is regarded to be mostly vagally mediated (Hartikainen et al., 1998).

On the other hand, frequency domain method analyzes the RRI data, decomposes them into its frequency components and finally it quantifies them in their relative intensity, termed power (Hynynen, 2011). As a result the three components which describe the overall variability of RRIs in frequency domain methods are: high frequency power (HFP, 0.15-0.40 Hz), low frequency power (LFP, 0.04-0.15 Hz) and very low frequency power (VLF, 0-0.03 Hz) (Hartikainen et al., 1998).

2.6 Rationale and Aim of the Study

The last decade, many studies have examined and found a relationship between the constructs of Heart Rate Variability and self-control (Burg, 2012; Cellini et al., 2013; Laborde, 2013). In 2016, the results of these studies have been summarized in a meta-analysis conducted by Zahn et al. (2016) and the authors concluded that higher HRV may be related to better self-control although the available evidence is not sufficient to conclusively determine the association between HRV and self-control. Additionally, the direction of this relationship is still under question and remains controversial among the researchers. Finally, although this meta-analysis sheds light on the relationship between HRV and self-control, it does not provide any direction on whether a relationship might exist between HRV and other psychological skills. Therefore, a remarkable reason rises for the research community to further examine whether there is a relationship between HRV and other psychological skills such as Confidence and Constancy, which together with Control "shape" the profile of a mentally tough athlete (Sheard et al., 2009).

The aim of this study was to further examine the direction and the relationship between Control and HRV and extend the current research by investigating two additional psychological constructs, Confidence and Constancy. These two psychological constructs have been suggested to be among the important human strengths which assist to a person's optimal functioning (Seligman & Csikszentmihalyi, 2000). Interestingly, the three psychological skills together, Control, Confidence and Constancy are the three main factors determine an athlete's subjective levels of mental toughness according to Sheard et al. (SMTQ; 2009). Consequently, the primary focus of this study was to examine whether the relationship found to exist between Control and HRV, could also exist between Confidence and Constancy since these three psychological components together compose the main factors of mental toughness (Sheard et al., 2009).

For the purposes of this study two main hypotheses have been raised:

1) Since Control and HRV measures have been previously examined and found to be associated, we hypothesize that a relationship between Control and HRV constructs will be also observed in this study

2) A significant relationship with HRV may also be observed for Confidence and Constancy since these two components together with Control are the main components of mental toughness.

3 METHODS

3.1 Research Design

In the present study, the autonomic regulation of Heart Rate Variability (HRV) and subjective levels of mental toughness were measured during a six-week, pre-season preparation period (July-August, 2015).

3.2 Participants

For the purposes of this project the researcher collected data from the players of a professional football team, competing at the Cyprus highest League Division, and their head coach. The team was asked to cooperate with the researcher and allowed their players and head coach to participate in this project. All the subjects were healthy volunteers free of hypertension or other systemic diseases. They did not take any medications or other drugs that would alter the activity of autonomic nervous system. The subjects were given their written informed consent form prior to their participation and they had the right to withdraw from the procedures at any time.

3.3 Data Collection

The data collection process took place during July and August 2015 (pre-season preparation period). Autonomic regulation of HRV was measured after resting days and after training days (physical and psychological challenges) with the First Beat Technologies monitoring system (Nocturnal Sleep Measurements and Quick Recovery Tests on relaxed position). During the night after both training and rest days, autonomic regulation of HRV was measured with Firstbeat Bodyguard 2 equipment (Firstbeat Technologies, Finland). Specifically, athletes were asked to attach two electrodes which detect HRV during night sleep. The one electrode needed to be placed just below the collar bone while the other one should be attached to the left side of the body below the heart (on the rib cage). For nocturnal HRV analysis, a continuous 4-hours period starting from half an hour after going to bed was selected.

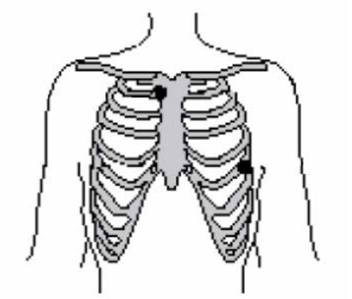

Figure 2. Locations of electrodes: the first one inferior to clavicle right side of the body, and the other one to the axillary line vicinity of fifth costa left side of the body.

Similarly, in the mornings both after Training and Rest days, autonomic regulation of HRV was measured with Firstbeat Team Sports Equipment (Firstbeat Technologies, Finland). The QRT were conducted in the morning right before the training session to assess the reaction of the ANS after a Rest day or a Training Day. During a QRT, a continuous 5-min period measuring HRV was recorded, however only 4-min period was included in the analysis since the first and the last 30 seconds of the QRT were excluded because of possible artifacts related to uncontrolled factors. Nevertheless, according to the literature (Hynynen, 2011) recordings of approximately 1 minute are needed in order to assess the HFP and 2 minutes are enough for the LFP assessments. Thus, the 4 minutes' QRT recorded for this study provide valid and reliable results.

The initial measurements (before the beginning of the pre-season preparation) were used as baseline measurements. The subjects took care of starting the measurements in accordance with verbal and written instructions. They also reported the times when they went to bed and woke up as well as the times when they started and ended the HR recordings.

Self-reported questionnaires were used to get information about players' subjective levels of mental toughness. The subjects were asked to answer the SMTQ inventory

(Sheard et al., 2009), at the end of the pre-season preparation period. Finally, the coach of the team was asked to fill in his subjective opinions about the levels of mental toughness of each athlete at the end of the pre-season preparation period.

3.4 Data Analyses

Heart Rate Variability Analyses: First Beat Technologies computer software application has been used to analyze the measured operation of ANS. The Firstbeat SPORTS Software uses time domain and frequency domain variables to accurately detect HRV. As it has been described already, such variables are: root mean square of successive R-R intervals (RMSSD), high frequency power (HFP, 0.15–0.40 Hz) and low frequency power (LFP 0.04–0.15 Hz). In order to examine the alteration of the aforementioned HRV parameters from the Training Days to the Rest Days, the Reaction between Training Day and Rest days was calculated (e.g. Average HR after Training Days – Average HR after Rest Days). Additionally, the Firstbeat SPORTS software provided automatically the recovery index scale and the quick recovery test scores of the athletes based on the measured and analysed data. Finally, the software detected abnormal RRI caused by movement or other artifacts and thus it has been used to correct the data. However, for better accuracy visual and manual control has been used to make data corrections when needed.

Before the analysis, the background information; age, gender, height, weight, VO_{2max} test score and smoking habits were set. According to this information the software detects subject's resting and maximal heart rate and estimates more accurately the physiological data concerning each athlete.

Subjective self-reported questionnaires: Descriptive statistics/analysis was performed with SPSS 22.0 for Windows statistical software.

4 RESULTS

4.1 Descriptive Statistics

Overall, reliability was satisfactory for the SMTQ, and this is so for both players' and coach's opinion. Reliability analyses revealed moderate and high Cronbach's alpha coefficients of .83 (Confidence), .81 (Constancy), .71 (Control), .80 (Total) for the coach's responses, and .77 (Confidence), .62 (Constancy), .76 (Control), .85 (Total) for the athletes' sample.

Descriptive data from responses to the SMTQ, Pearson correlations between coach' and athletes' SMTQ scores, as well as the alpha coefficients can be viewed in Table 1. As expected, elite athletes reported overall higher scores on their levels of mental toughness (Confidence, Constancy, Control) as compared to the coach's scores. Interestingly, both coach (M = 3.04, SD = .59) and athletes (M = 3.52, SD = .50) tend to agree on that constancy is players' strongest area. Similarly, both coach (M = 2.24, SD = .53) and athletes (M = 2.70, SD = .66) assess control dimension lower compared with the rest of the Mental Toughness components.

Distribution of mental toughness total scores of the elite athletes sample was more negatively skewed (-.45) than the coach' mental toughness scores of his athletes (-.31), indicating that athletes were assessing themselves relatively higher on mental toughness (M = 3.19, SD = .45) compared to coach' assessments (M = 2.69, SD = .33).

4.2 Correlations

The three factors' intercorrelations were examined. Based on coach's responses there was a high positive correlation between confidence and constancy (r = .83, p = < .001, n = 18). However, control was found to be negatively correlated with confidence (r = -.51,

$p = < .01$, $n = 18$) and constancy ($r = -.48$, $p = < .01$, $n = 18$). On the other hand, players' responses indicated only positive correlations between the three factors, although only the correlation between confidence and constancy was found to be significant ($r = .70$, $p = < .001$, $n = 18$). Interestingly, the results did not indicate any correlation between coach' and athletes' responses regarding athletes' levels of Mental Toughness

Table 1a. *Means, standard deviations, Cronbach's alpha and Correlations for SMTQ and QRT variables*

Variables	***N***	***M***	***SD***	***α***	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***
SMTQ Coach												
1. Confidence	18	2.81	.61	.83								
2. Constancy	18	3.04	.59	.81	.83**							
3. Control	18	2.24	.53	.71	-.51*	-.48*						
4. Coach Total	18	2.69	.33	.80	.84**	.86**	-.06					
SMTQ Players												
5. Confidence	18	3.35	.49	.77	-.33	-.14	.07	-.25				
6. Constancy	18	3.52	.50	.62	-.05	.11	-.08	-.01	.70**			
7. Control	18	2.70	.66	.76	-.00	-.15	-.07	-.13	.45	.40		
8. Players Total	18	3.19	.45	.85	-.14	-.09	-.04	-.16	.84**	.82**	.80**	
Quick Recovery Test Scores												
9. Reaction between Training Day and Rest Day for HR	18	4.27	11.92		-.69**	-.52*	.48*	-.48*	.36	.18	-.09	.15
10. Reaction between Training Day and Rest Day for LFP	18	17.06	53.19		.07	-.23	-.39	-.31	-.18	-.22	.28	-.01
11. Reaction between Training Day and Rest Day for HFP	18	4.33	51.91		.48*	.32	-.46	.23	-.32	-.27	.08	-.18
12. Reaction between Training Day and Rest Day for RMSSD	18	.67	30.11		.58*	.40	-.56*	.29	-.48*	-.32	-.07	-.30
13. Reaction between Training Day and Rest Day for QRT Score	18	-5.56	25.81		.62**	.47*	-.67**	.30	-.37	-.39	-.06	-.31

*Notes. *p < .05; **p < .01*

Table 1b. *Means, standard deviations, Cronbach's alpha and Correlations for SMTQ and Nocturnal Measurements variables*

Variables	***N***	***M***	***SD***	***α***	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***
SMTQ Coach												
1. Confidence	18	2.81	.61	.83								
2. Constancy	18	3.04	.59	.81	.83**							
3. Control	18	2.24	.53	.71	-.51*	-.48*						
4. Coach Total	18	2.69	.33	.80	.84**	.86**	-.06					
SMTQ Players												
5. Confidence	18	3.35	.49	.77	-.33	-.14	.07	-.25				
6. Constancy	18	3.52	.50	.62	-.05	.11	-.08	-.01	.70**			
7. Control	18	2.70	.66	.76	-.00	-.15	-.07	-.13	.45	.40		
8. Players Total	18	3.19	.45	.85	-.14	-.09	-.04	-.16	.84**	.82**	.80**	
Nocturnal Measurements												
9. Reaction between Training Day and Rest Day for HR	18	4.20	3.21		.34	.18	-.18	.22	.05	.14	-.06	.04
10. Reaction between Training Day and Rest Day for LFP	18	9.23	32.57		.24	.24	-.19	.19	.11	.34	-.04	.15
11. Reaction between Training Day and Rest Day for HFP	18	1.05	32.68		.12	.15	-.18	.06	.02	.05	.06	.05
12. Reaction between Training Day and Rest Day for RMSSD	17	6.32	33.58		.07	.01	-.16	-.03	-.08	-.17	.18	-.01
13. Reaction between Training Day and Rest Day for Recovery Index	18	1.87	69.65		-.19	-.06	-.07	-.19	.25	.28	.09	.24

*Notes. *p < .05; **p < .01*

Table 2. *Means, standard deviations and Correlations for HRV variables*

Variables	***N***	***M***	***SD***	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
Quick Recovery Test Measurements												
1. Reaction between Training Day and Rest Day for HR	18	4.27	11.92									
2. Reaction between Training Day and Rest Day for LFP	18	17.06	53.19	-.54*								
3. Reaction between Training Day and Rest Day for HFP	18	4.33	51.91	-.73**	.71**							
4. Reaction between Training Day and Rest Day for RMSSD	18	.67	30.11	-.81**	.63**	.85**						
5. Reaction between Training Day and Rest Day for QRT Score	18	-5.56	25.81	-.78**	.53*	.71**	.89**					
Nocturnal Measurements												
6. Reaction between Training Day and Rest Day for HR	18	4.20	3.21	-.05	-.13	-.13	-.10	-.05				
7. Reaction between Training Day and Rest Day for LFP	18	9.23	32.57	-.03	-.35	-.26	-.07	.05	.02			
8. Reaction between Training Day and Rest Day for HFP	18	1.05	32.68	-.02	-.28	-.28	-.02	.17	-.33	.77**		
9. Reaction between Training Day and Rest Day for RMSSD	17	6.32	33.58	-.11	-.05	-.13	.05	.27	-.50*	.56*	.93**	
10. Reaction between Training Day and Rest Day for Recovery Index	18	1.87	69.65	.31	-.44	-.49*	-.34	-.23	-.21	.77**	.76**	.60*

Table 2 describes the correlations between Heart Rate Variability variables of both nocturnal (unconscious) and day-time (conscious) measurements. Although the indices resulted from Quick Recovery Test Measurements were found to be highly correlated with each other, however no significant correlations were reported between nocturnal and day-time measurements. Related to that, Heart Rate Variability indices resulted from Nocturnal Measurements did not correlate with mental toughness and its sub-scales. In contrast, some Heart Rate Variability indices resulted from day-time measurements were found to moderately correlate with mental toughness and its sub-components (Table 1a). Interestingly, the results indicate moderate and statistically significant correlations between Heart Rate Variability and coach's subjective assessments on athletes' levels of mental toughness, while only few correlations appeared between Heart Rate Variability and players' mental toughness self-assessments.

Specifically, higher confidence seems to be related to lower nocturnal HRV. There is a moderate negative correlation between the variables Confidence and the Nocturnal Measurements' Overall RMSSD (r = -.62, n = 17, p = .009). A simple linear regression was calculated to predict Confidence based on Nocturnal Measurements' Overall RMSSD. A significant regression equation was found ($F_{(1,15)}$=9.137, p=.009) with an R^2 of 0.38 (Table 4, Figure 2). Additionally, confidence has been found to negatively correlated with Nocturnal Measurements' Average Training Day RMSSD (r = -.57, n = 17, p = .017). A simple linear regression was calculated to predict Confidence based on Nocturnal Measurements' Average Training Day RMSSD. A significant regression equation was found ($F_{(1,15)}$=7.274, p=.017) with an R^2 of 0.33. (Table 4, Figure 3). Similarly, a moderate negative correlation between Confidence and the Nocturnal Measurements' Average Rest Day HFP was recorded (r = -.55, n = 18, p = .017). A simple linear regression was calculated to predict Confidence based on Nocturnal Measurements' Average Rest Day HFP. A significant regression equation was found ($F_{(1,16)}$=7.078, p=.017) with an R^2 of 0.31 (Table 4, Figure 4). Finally, a moderate negative correlation between Confidence and the Nocturnal Measurements' Average Rest Day RMSSD was observed (r = -.65, n = 17, p = .005). A simple linear regression was calculated to predict Confidence based on Nocturnal Measurements' Average Rest Day RMSSD. A significant regression equation was found ($F_{(1,15)}$=10.926, p=.005) with an R^2 of 0.42. (Table 4, Figure 5)

Higher confidence seems to be related to increment in HR and decrement in HRV in the QRT from Training Day to Rest Day. Specifically, there is a moderate negative correlation between the variables Confidence and the Average Rest Day QRT Score (r = -.61, n = 18, p = .007). A simple linear regression was calculated to predict Confidence based on the Average Rest Day QRT Score. A significant regression equation was found ($F_{(1,16)}$=9.692, p=.007) with an R^2 of 0.38 (Table 5, Figure 6). Furthermore, a moderate negative correlation between the variables Confidence and the QRT' Reaction between Training Day and Rest Day for HR (r = -.69, n = 18, p = .001) was recorded. A simple linear regression was calculated to predict Confidence based on the QRT' Reaction between Training Day and Rest Day for HR. A significant regression equation was found ($F_{(1,16)}$=14.828, p=.001) with an R^2 of 0.48 (Table 5, Figure 7). In addition, a moderate positive correlation between the variables Confidence and the QRT' Reaction between Training Day and Rest Day for HFP (r = .48, n = 18, p = .046). A simple linear regression was calculated to predict Confidence based on the QRT' Reaction between Training Day and Rest Day for HFP. A significant regression equation was found ($F_{(1,16)}$=4.679, p=.046) with an R^2 of 0.23 (Table 5, Figure 8). Similarly, there is a moderate positive correlation between the variables Confidence and the QRT' Reaction between Training

Day and Rest Day for RMSSD (r = .58, n = 18, p = .012). A simple linear regression was calculated to predict Confidence based on the QRT' Reaction between Training Day and Rest Day for RMSSD. A significant regression equation was found ($F_{(1,16)}$=8.055, p=.012) with an R^2 of 0.34. (Table 5, Figure 9). Finally, a moderate positive correlation between the variables Confidence and the Reaction between Training Day and Rest Day for QRT Score (r = .62, n = 18, p= .006). A simple linear regression was calculated to predict Confidence based on the Reaction between Training Day and Rest Day for QRT Score. A significant regression equation was found ($F_{(1,16)}$=9.998, p=.006) with an R^2 of 0.39 (Table 5, Figure 10)

Higher constancy seems to be related to increments in HR in QRT and decrement in QRT score from Training Day to Rest Day. Specifically, a moderate negative correlation between the variables Constancy and the QRT' Reaction between Training Day and Rest Day for HR (r = -.52, n = 18, p = .029) was emerged. A simple linear regression was calculated to predict Constancy based on the QRT' Reaction between Training Day and Rest Day for HR. A significant regression equation was found ($F_{(1,16)}$=5.787, p=.029) with an R^2 of 0.27 (Table 2, Figure 11). Additionally, a moderate positive correlation between the variables Constancy and the Reaction between Training Day and Rest Day for QRT Score (r = .47, n = 18, p = .049) was found. A simple linear regression was calculated to predict Constancy based on the Reaction between Training Day and Rest Day for QRT Score. A significant regression equation was recorded ($F_{(1,16)}$=4.522, p=.049) with an R^2 of 0.22 (Table 2, Figure 12).

Higher control seems to be related to higher QRT score after Rest Day and decrements of QRT's score and RMSSD from Training Day to Rest Day. Specifically, a moderate positive correlation between the variables Control and the Average Rest Day QRT Score (*r* = .61, *n* = 18, *p* = .008) was found. A simple linear regression was calculated to predict Control based on the Average Rest Day QRT Score. A significant regression equation was observed ($F_{(1,16)}$=9.332, *p*=.008) with an R^2 of 0.37 (Table 2, Figure 13). Similarly, a moderate negative correlation between the variables Control and the QRT' Reaction between Training Day and Rest Day for RMSSD (*r* = -.56, *n* = 18, *p* = .016). A simple linear regression was calculated to predict Control based on the QRT' Reaction between Training Day and Rest Day for RMSSD. A significant regression equation was recorded ($F_{(1,16)}$=7.195, *p*=.016) with an R^2 of 0.31 (Table 2, Figure 14). Finally, a moderate negative correlation between the variables Control and the Reaction between Training Day and Rest Day for QRT Score (*r* = -.67, *n* = 18, *p*= .002) was recorded. A simple linear regression was calculated to predict Control based on the Reaction between Training Day and Rest Day for QRT Score. A significant regression equation was found ($F_{(1,16)}$=12.930, *p*=.002) with an R^2 of 0.45(Table 2, Figure 15)

Mentally tough players seem to have lower parasympathetic activity during nocturnal sleep after Rest Day. Specifically, a moderate negative correlation between the variables SMTQ Total Score and the Nocturnal Measurements' Average Rest Day RMSSD (*r* = -.48, *n* = 18, *p*= .045) was found. A simple linear regression was calculated to predict SMTQ Total Score based on the Nocturnal Measurements' Average Rest Day RMSSD. A non-significant regression equation was found ($F_{(1,15)}$=4.249, *p*=.057) with an R^2 of 0.22. (Figure 16)

Table 3. Results of the Multiple Regression Analyses

Variable	Mean	SD	F	Multiple Regression weights	
				b	*β*
Reaction between Training Day and Rest Day for Quick Recovery Test Score	-5.5556	25.80748	6.224*		
Confidence Coach	2.8148	.61007		24.215	.572
Constancy Coach	3.0417	.59563		-10.616	-.245
Control Coach	2.2407	.53389		-23.971	-.496*
Reaction between Training Day and Rest Day for RMSSD from QRT	.6667	30.11351	5.712*		
Confidence Coach	2.8148	.61007		12.339	.250
Control Coach	2.2407	.53389		-22.806	-.404
Confidence Players	3.3519	.49139		-22.863	-.373
Reaction between Training Day and Rest Day for HR (QRT)	4.2778	11.92035	7.302*		
Confidence Coach	2.8148	.61007		-16.800	-.860*
Constancy Coach	3.0417	.59563		4.000	.200

Notes. *p < .05; **p < .01

4.3 Multiple Regression Analysis

Based on the previous correlation and simple regression analyses and in order to further examine the relationships between physiological and psychological variables, several linear multiple regressions were performed and four of them revealed meaningful and significant relationships. All variables met the assumptions for linear regression analyses. As explanatory variables (predictors) were used the coaches' mental toughness evaluations for the players and as dependent variables were used the physiological indexes Reaction between Training Day and Rest Day for Quick Recovery Test Score, Reaction between Training Day and Rest Day for RMSSD from QRT and the Reaction between Training Day and Rest Day for HR.

Table 3 summarizes the descriptive statistics and all regression analyses results. The first multiple regression model used Reaction between Training Day and Rest Day for

Quick Recovery Test Score as dependent variable and Confidence Coach, Constancy Coach and Control Coach as explanatory variables. Results showed that all three predictors produced R=.756, R^2 = .571, $F_{(3, 14)}$ = 6.224, p = .007, meaning that all coach's mental toughness *estimations* for his players explained the 57% of Reaction between Training Day and Rest Day for Quick Recovery Test Score variance. Beta coefficients indicated that Confidence (*Beta* = .572, $t_{(19)}$ = 1.771, ns) and Constancy (*Beta* = -.245, $t_{(19)}$ = -.771, ns) were not significant, however control did significantly predict value of Reaction between Training Day and Rest Day for Quick Recovery Test Score (*Beta* = -.496, $t_{(19)}$ = -2.424, p < .05).

As can be seen in Table 3, the components of Mental Toughness (Constancy Coach and Control Coach) had significant negative regression weights (opposite in sign from its correlation with the Reaction between Training Day and Rest Day for Quick Recovery Test Score), indicating athletes with lower scores on these measurements were expected to have higher Reaction between Training Day and Rest Day for Quick Recovery Test Score, after controlling for the other variables in the model. The Confidence Coach variable has a significant positive weight, indicating that after accounting for Constancy Coach and Control Coach, those athletes with higher Confidence Coach were expected to have higher Reaction between Training Day and Rest Day for Quick Recovery Test Score.

The second multiple regression model used Reaction between Training Day and Rest Day for RMSSD (QRT) as dependent variable and confidence Coach, control Coach and players' confidence as explanatory variables. The multiple regression model showed that all three predictors produced R=.742, R^2 = .550, $F_{(3,14)}$ = 5.712, p = .009, meaning that all explanatory variables explained 55% of Reaction between Training Day and

Rest Day for RMSSD from QRT variance. Beta coefficients indicated that Confidence Coach (*Beta* = .250, $t_{(19)}$ = 1.128, ns), Control Coach (*Beta* = -.404, $t_{(19)}$ = -1.930, ns) and Players' Confidence (*Beta* = -.373, $t_{(19)}$ = -1.950, ns) did not significantly predict value of Reaction between Training Day and Rest Day for RMSSD (QRT).

As can be seen in Table 3, Control Coach and Players' Confidence had significant negative regression weight, indicating athletes with lower scores on these measurements were expected to have higher Average Rest Day RMSSD (Nocturnal Measurement), after controlling for the other variable in the model. The Confidence Coach variable has a significant positive weight, indicating that after accounting for the Control Coach and Players' Confidence variables, those athletes with higher Confidence Coach were expected to have higher Reaction between Training Day and Rest Day for RMSSD from QRT.

The third multiple regression model used Average Rest Day Quick Recovery Test Score as dependent variable and Mental Toughness (Confidence Coach, Control Coach) as explanatory variables. The multiple regression model showed that the two predictors produced R=.703, R^2 = .495, $F_{(2, 15)}$ = 7.344, p = .006, meaning that Control Coach and Confidence Coach explained 50% of Average Rest Day Quick Recovery Test Scores variance. Beta coefficients indicated that Confidence (*Beta* = -.412, $t_{(19)}$ = -1.937, ns) and Control Coach (*Beta* = .398, $t_{(19)}$ = 1.868, ns) did not significantly predict value of Average Rest Day Quick Recovery Test Score.

As can be seen in Table 3, the Confidence Coach variable had significant negative regression weights, indicating athletes with higher scores on these measurements were expected to have lower Average Rest Day Quick Recovery Test Scores, after controlling for the other variable in the model. The Control Coach variable has a significant positive weight, indicating that after accounting for the Confidence Coach variable, those athletes with higher Control Coach Score were expected to have higher Average Rest Day Quick Recovery Test Scores.

The fourth multiple regression model used Reaction between Training Day and Rest Day for HR as dependant variable and Confidence Coach and Constancy Coach as explanatory variables. The multiple regression model showed that the two predictors produced R=.702, R^2 = .493, $F_{(2, 15)}$ = 7.302, p = .006, meaning that Confidence Coach and Constancy Coach explained 49% of Reaction between Training Day and Rest Day for HR. Beta coefficients indicated that Constancy did not significantly predict value of Reaction between Training Day and Rest Day for HR (QRT) (*Beta* = .200, $t_{(19)}$ = .603, ns), however Confidence Coach did significantly predict value of Reaction between Training Day and Rest Day for HR (QRT) (*Beta* = -.860, $t_{(19)}$ = -2.596, $p < .05$).

As can be seen in Table 3, Confidence Coach had significant negative regression weight, indicating athletes with lower scores on these measurements were expected to have higher Reaction between Training Day and Rest Day for HR, after controlling for the other variable in the model. The Constancy Coach variable has a significant positive weight (opposite in sign from its correlation with the Reaction between Training Day and Rest Day for HR), indicating that after accounting for the Confidence Coach variable, those athletes with higher Constancy Coach were expected to have higher Reaction between Training Day and Rest Day for HR (a suppressor effect).

5 DISCUSSION

This study is an exploratory research aiming to investigate possible links between mental toughness and the modulation of autonomous nervous system in elite athletes. Specifically the purposes of this study were (a) to further examine the relationship between Control and HRV constructs and (b) to explore whether HRV components might reveal a significant relationship between Confidence and Constancy since these two components together with Control are the main components of mental toughness.

Coach evaluations of mental toughness were correlated better with the HRV constructs than athletes evaluations. The reason might be that they were more consistent and objective than the more subjective athletes self - evaluations. Moreover, since the athletes' and coaches' evaluations of mental toughness components were not related with each other them we can assume that what athletes think about themselves regarding those three constructs does not correspond of how others think for them for the same characteristics. This is in line with Cowden et al. (2014) findings which suggest an inconsistency between coaches' and athletes' perceptions on athletes' levels of mental toughness.

The findings from the series of data analyses supported the assumption that there is a relationship between mental toughness and the modulation of Autonomous Nervous System as reflected from Heart Rate Variability. Specifically, the present research findings verify the previous studies which indicated an association between HRV and control construct although the direction of the association remains controversial. According to Zahn et al., (2016) higher HRV may be related to better self-control. Contrary, the present findings suggest that lower HRV scores may be related to better self-control.

The negative correlation that the present study found between HRV and control construct, could be explained form the concept of stress-coping as it has been proposed by Lazarus & Folkman (1984). Specifically, Lazarus & Folkman (1984) defined coping as any *"conscious cognitive and behavioural effort to control a situation that has been appraised as stressful"* (Lazarus, 1999; Lazarus & Folkman, 1984). According to Jones et al. (2002), Jones et al. (2007), coping is one of the key constructs of mental toughness, while plethora of research identify mentally tough athletes as the ones who are being able to cope effectively (Bull et al., 2005; Nicholls, 2008; Thelwell et al., 2005). In our study, the pre-season preparation stage should be considered as a very demanding period, including high-intensity trainings, insufficient recovery, physiological and psychological challenges. Consequently, the findings of this study possibly indicate that the athletes perceived as mentally tough by their coach, managed to control their emotional responses towards stressors effectively (*emotion-focused coping;* Nicholls, 2008) or alternatively, they did not even perceive stressors in a negative manner but they rather interpreted stressors as opportunities (i.e. debilitative to facilitative) and positive challenges (*problem-focused coping;* Nicholls, 2008).

Furthermore, the results of this study indicate that athletes characterized by their coach as individuals "having high control of their emotions and the situations", seem to also have higher QRT score after Rest Day and increments of QRT's score and RMSSD from Training Day to Rest Day. These findings suggest that players with higher control seem to have some training related anticipatory autonomic stress symptoms. A more in-depth explanation of the anticipatory autonomic stress symptoms could be that the autonomous nervous system of athletes characterized as "being in control", reduces parasympathetic activity just before the training in order for the athlete to get ready for the upcoming demanding training session. Therefore, a relative increment of "readiness" and "alertness" could be recorded through the Quick Recovery Tests which took place right before the training session.

Regarding the confidence construct, the findings of this study provide evidence that higher confidence seems to be related to lower nocturnal HRV suggesting lower parasympathetic activity during first hours of nocturnal sleep. This seems to be true after both training days and rest days. Specifically, higher confidence found to be correlated with lower Nocturnal Measurements' Overall RMSSD, with lower Nocturnal Measurements' Average Training Day RMSSD, lower Nocturnal Measurements' Average Rest Day HFP and with lower Nocturnal Measurements' Average Rest Day RMSSD. The aforementioned findings are in the same line with previous studies since Crust and Clough (2005) found evidence that an athlete is significantly more likely to tolerate a physical endurance task for longer when scoring higher on total mental toughness and on the factors of control and confidence, compared to athletes who scored lower on these factors.

Similarly, the findings emerged from the Quick Recovery Tests suggest that higher confidence seems to be related to increment in HR and decrement in HRV in the QRT, suggesting lower parasympathetic activity during rest days than during training days. Consequently, a possible interpretation might be that players described by their coach as highly confident possibly feel more "relaxed" and have less stress effects on training days than on rest days. This is consisted with previous work (Sheard, 2009) which suggests that "*mentally tough athletes view training as an opportunity rather than a threat and perceive stressful situations and periods as challenges to become better instead of problems which could possibly prevent their development*" (Sheard, 2009).

Generally, it appears that mentally tough players and players described as highly confident seem to have lower parasympathetic activity during nocturnal sleep after both Training and Rest Days. In other words, the athletes characterized as mentally tough from their coach, do not necessarily have an advantageous function of Autonomous Nervous System which in turn will facilitate a faster or better recovery process. Although typically well-being and good recovery are related to low HR and high HRV (Hall et al., 2004; Vrijkotte et al., 2000), our findings suggest that mentally tough athletes tended to have elevated autonomic stress symptoms (high Heart Rate and low Heart Rate Variability) both after Training and Rest days. Therefore, one may assume that athletes characterized by their coach's as mentally tough, may have a "suitable, positive stress" which keeps them "alert", in a "constant readiness", in a "relevant preparedness" and "always ready for fight". These results are supported extensively from previous literature as Dienstbier (1989) first expressed the opinion that relaxation and relaxation techniques are not compatible with development of mental toughness. The idea behind Dienstbier's (1989) assumption stems from research supporting that mentally tough athletes are the ones who approach confidently the stressful situations and perceive them as positive challenges for improvement and further development rather than threatening circumstances (Nicholls, 2008).

Contradictory with the results indicating a relationship between control variable and training related anticipatory autonomic stress symptoms, higher constancy seems to be related to increments in HR in QRT and decrement in QRT score from Training Day to Rest Day suggesting that players with higher constancy don't seem to have training related anticipatory autonomic stress symptoms. In other words, athletes characterized by their coach as "constant" and "determine" to face challenging situations and complete their daily tasks, appear to have higher parasympathetic activity and lower sympathetic activity as recorded from the Quick Recovery Tests just before the trainings. Therefore, this “sense of calmness” and “relaxation” may stem from their strong self-confidence and their belief that they have what it takes to perform properly in the upcoming challenging situation. However, the contrast between constancy and the other two variables included in the SMTQ (control and confidence), may enhance any possible intentions for further research and future investigation.

5.1 Practical Implications

Exploring the physiological indices of mental toughness assists to a better understanding on how mental toughness operates. The results of this exploratory study contribute significantly to the current literature on mental toughness and suggest possible avenues for future research. A multidisciplinary, bio-psychophysiological approach is recommended for future research in order to achieve conceptual clarity and clearer view on the complexity of mental toughness.

Present research findings provide practical implications for sport practitioners and especially coaches and applied sport psychologists. Specifically, the research findings suggest possible associations between mental toughness, heart rate variability and stress-coping strategies. Therefore, sport psychologists may identify a need to enrich an athlete’s stress-coping techniques just by observing heart rate variability patterns and the modulation of autonomous nervous system, through quick recovery tests and nocturnal measurements. Certainly, future research needs to examine further these initial observations in order to provide more concrete and well-established practical implications.

Additionally, the results obtained from this study give us further information on the mechanisms undermine the way coach’s assess their athletes’ levels of mental toughness. Specifically, as appear from the Quick Recovery Tests, the Nocturnal Measurements and coach's subjective opinion on athletes' levels of mental toughness, coaches tend to perceive as more mentally tough the athletes who usually have a "suitable, positive stress" which keeps them "alert", in a "constant readiness" and "always ready for fight". Finally and based on how a coach may assess his athletes' levels of mental toughness, athletes could shape a better idea on how coaches perceive the concept of mental toughness and therefore adapt their behaviours, thoughts and actions in order to meet their coach's expectations.

5.2 Limitations and Future Directions

The present study is not without notable limitations which may give rise avenues for future research. The primary limitation concerns the low sample size, which although is consisted by elite and professional athletes and their coach, due to its restricted size may have partly attributed to the direction of the arising results. Nevertheless, in order to improve statistical power, future studies should be conducted with larger sample size. Additionally, the sample of elite and professional football players restricts the generalizability of the results in different contexts, sports and populations. Thus, a better understanding of the reported findings will be reached, if future researches will be directed to explore more in-depth the psychophysiological perspectives of mental toughness in a variety of different contexts.

Another limitation concerns the measurement tool that has been used to assess mental toughness. Although the psychometric properties of SMTQ have been found to be satisfactory, there is a vast of empirical and theoretical concerns with the instruments that have been used to assess mental toughness in the literature. For instance, the data collected from SMTQ only represent the subjective opinions of the athletes' and their coach regarding athletes' levels of mental toughness. In other words, one can argue that subjective self-assessments do not necessarily constitute a direct test of mental toughness. In addition, the SMTQ includes only three sub-factors/characteristics of mental toughness (Confidence, Control and Constancy) while other mental toughness' inventories such as the Psychological Performance Inventory (PPI; Loehr, 1986) or the MTQ-48 (Clough et al., 2002) measure seven components of mental toughness (self-confidence, motivation, attitude control, attention control, negative energy, positive energy, visual and imagery control) and four components of mental toughness (Control, Commitment, Challenge, and Confidence) respectively. Therefore, suggested characteristics of Mental Toughness, not included in the SMTQ, may have been elided.

Furthermore, this study was mainly conducted for exploratory purposes and therefore only limited physiological data were collected and for a short period of time (pre-season preparation period). Future studies should extend the findings by developing longer studies and collecting data throughout the competitive season. Although Heart Rate Variability is an innovative method reflecting the modulation of Autonomous Nervous System, its measuring remains challenging and sensitive to a variety of uncontrolled factors. Thus, more measurements during a longer period of time for an individual could increase the validity and the reliability of the study and shed light on how mentally tough athletes react to the psychological and physiological stressors during the different phases of a competitive season.

Finally, although the pre-season preparation period is a very demanding period for the athletes as it is full of emotional, physical and psychological challenges and consequently it consists an ideal period for this kind of studies, it sets an important limitation. During that period the coach does not usually have a concrete and wellshaped opinion for his athletes and therefore his responses regarding their levels of mental toughness might be sometimes inaccurate or imprecise estimations.

In spite of the aforementioned limitations, this study successfully extends the current mental toughness' framework by approaching the concept from a broader psychophysiological perspective. However, a clearer view on mental toughness will be achieved if future investigations will be focused on the bio-psychophysiological mechanisms of mental toughness. For instance, different hormones such as catecholamines (e.g., adrenaline) and cortisol have been found to be correlated with performance and psychophysiological stress respectively (Crust, 2007). Therefore, future studies on mental toughness may adopt a multidisciplinary approach in order to identify the possible associations between mentally tough individuals, stress' hormones secretion, Heart Rate Variability and effective stress-coping strategies. Specifically, the current literature (Clow, 2004; Dienstbier, 1989) suggests that mentally tough athletes are the ones' who deal with stressors more effectively. Thus, sharper catecholamines spikes and a quicker return to baseline are expected for mentally tough athletes compared to less mentally tough athletes. Finally, could be reasonably assumed that the levels of cortisol will be increased less and this increment will remain for a shorter time period in mentally tough athletes. Experimental trials, longitudinal researches, laboratory standard stress tests (e.g., Trier Social Stress Test) and stress manipulations should be implemented in the future study designs, to facilitate a better understanding on the mechanisms underlying mental toughness.

6 CONCLUSION

In conclusion, the present study assists to a better understanding of the relationship between HRV and self-control construct although the direction of this relationship remains under question. Additionally, together with the control construct, this study also assesses confidence and constancy construct, thus providing some initial findings for possible links between mental toughness and Heart Rate Variability. To our knowledge, the innovative research design was implemented in this study, was the first of its kind and the researchers attempted to extend the current knowledge through a psychophysiological approach. The arising results indicated that athletes' characterized by their coach as mentally tough, tended to approach more effectively stressful situations by being in a physiological state of "constant readiness and alertness". Such psychophysiological approaches and research designs assist to a better understanding on how mental toughness operates and rise avenues for future research and more in-depth investigation.

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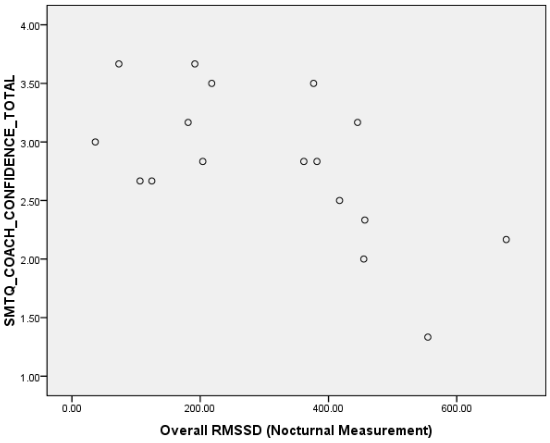
APPENDICES

Table 4. Correlations between SMTQ Coach Confidence and HRV indices (NM)

Variables	***1***	***2***	***3***	***4***
1. SMTQ Coach Confidence				
2. Overall RMSSD (NM)	-.615**			
3. Average Training Day RMSSD (NM)	-.571*	983**		
4. Average Rest Day HFP (NM)	-.554*	.954**	.929**	
5. Average Rest Day RMSSD (NM)	-.649**	.938**	.862**	.931**

Notes. *p < .05; **p < .01



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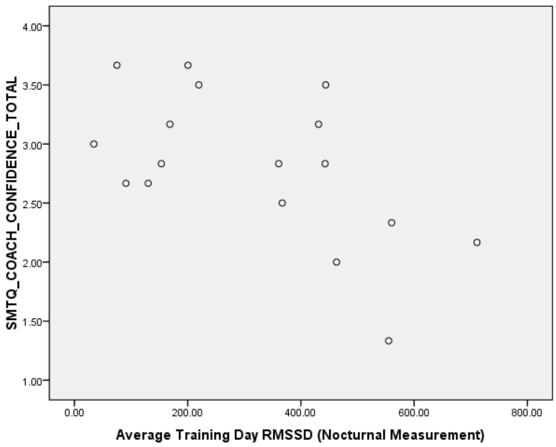

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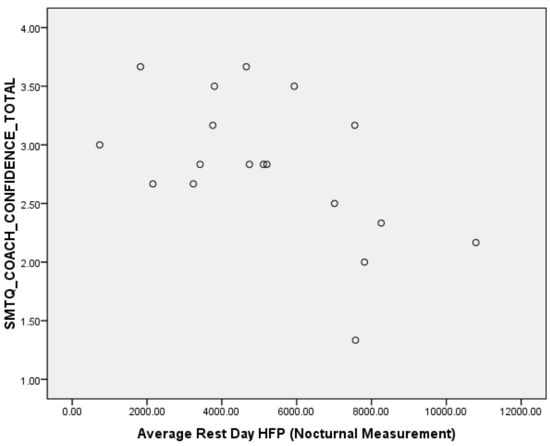

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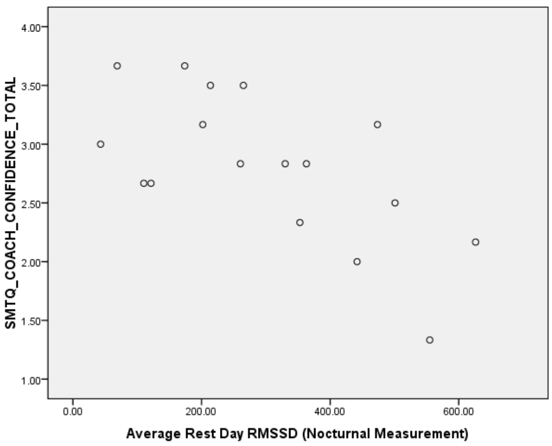
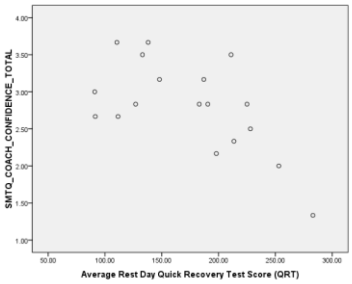


Figure 5.

Table 5. Correlations between SMTQ Coach Confidence and HRV indices (QRT)

Variables	***1***	***2***	***3***	***4***	***5***
1. SMTQ Coach Confidence					
2. Average Rest Day QRT	-.614**				
3. Reaction between Training Day and Rest Day for HR	-.694**	.646**			
4. Reaction between Training Day and Rest Day for HFP	.476*	-.724**	-.727**		
5. Reaction between Training Day and Rest Day for RMSSD	.579*	-.730**	-.806**	.853**	
6. Reaction between Training Day and Rest Day for QRT	.620**	-.613**	-.782**	.709**	.890**

Notes. *p < .05; **p < .01



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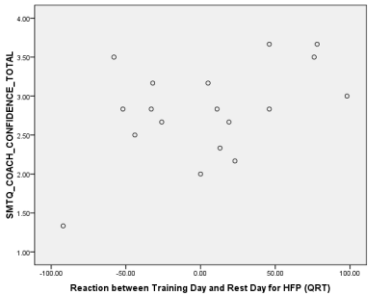

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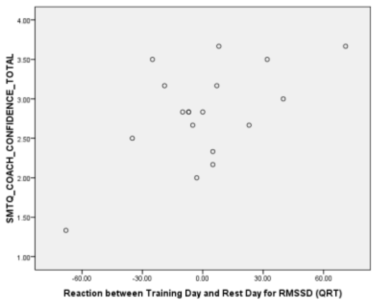

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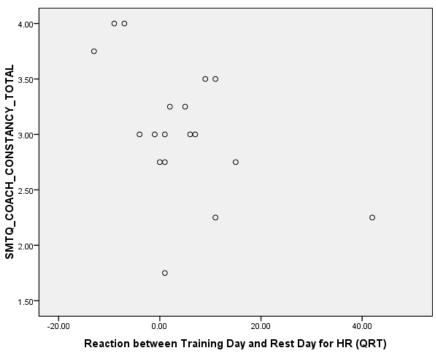

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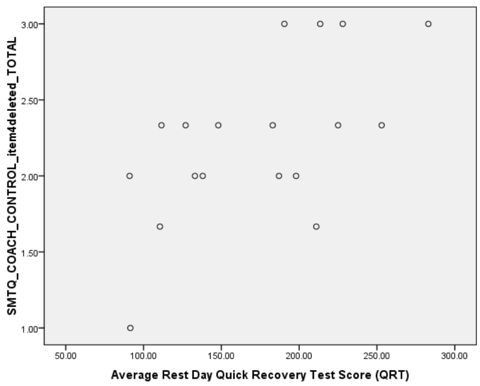

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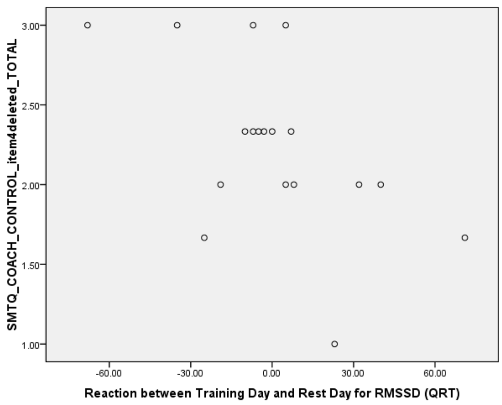

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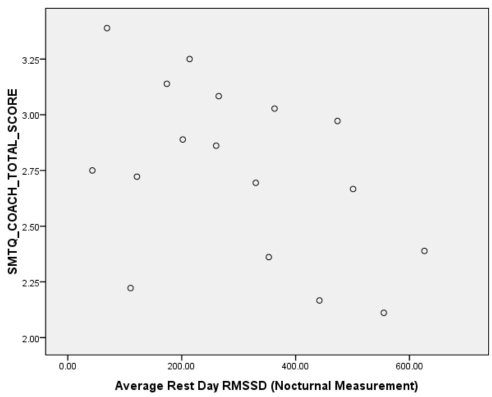

Figure 16.