The relationship between changes in well-being scores and physical performance test scores in student soccer players

by

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Table of Contents

List of Symbols and Abbreviations

10 m	10 m sprint test
20MST	20 metre multi-shuttle run test
40 m	40 m sprint test
5-0-5	5-0-5 agility test
5-0-5 L	5-0-5 agility test using the left leg
5-0-5 R	5-0-5 agility test using the right leg
C_1	comparative pair of testing observation 1 and 2
C_2	comparative pair of testing observation 2 and 3
C_3	comparative pair of testing observation 1 and 3
cm	centimetre
CSAI-2	competitive state anxiety inventory-2
d/wk	days per week
DALDA	daily analyses of life demands of athletes
DSC	derogatis symptom checklist
e.g.	for example
ELS	energy levels score
et al.	and others
FIFA	Fédération Internationale de Football Association
FS	fatigue score
G.A.S theory	Selye's general adaptation syndrome theory
HR	heart rate
HRV	heart rate variability
IOC	International Olympics Committee
IQR	interquartile range
JH	jump height
kg	kilogram
m	metre
Max.	maximum
Min.	minimum
mins	minutes
MOOD	mood questionnaire by Choi and Salmon
MS	motivation score
MSS	muscle soreness score
MTDS	multi-component training distress scale

n	number of participants in the sample
p	level of significance
P. age	number of years playing competitive soccer
POMS	profile of mood states
PSS	perceived stress scale
r	correlation coefficient
rho	Spearman’s rank order correlation coefficient
RESTQ	recovery stress questionnaire
RESTQ-S	recovery stress questionnaire for athletes
RPE	rate of perceived exertion
SD	standard deviation
s	second
SQS	sleep quality score
SS	stress score
STAI	state-trait anxiety inventory
STPI	state-trait personality inventory
T_1	testing observation one
T_2	testing observation two
T_3	testing observation three
TD	training duration
TF	training frequency
TWS	total well-being score
VJ	vertical jump test
VO_2max	maximum oxygen uptake
YO-YO	yo-yo intermittent recovery test level 1
%	percent
=	equals
±	plus-minus
<	less than
>	greater than
/	or

List of Figures

List of Tables

Abstract

Title:	The relationship between changes in well-being scores and physical performance test scores in student soccer players.
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Maximum physical performance tests appear to best reflect athletes' training status and readiness to perform; however, it is unfeasible for practitioners to implement physical performance tests while trying to minimise the effects of fatigue during training. Subjective self-reported well-being measures have therefore been purported as a tool for monitoring athletes' readiness to perform without exertion. The purpose of the current study was to establish the nature and strength of the relationship between changes in physical performance test scores and changes in well-being scores in student soccer players.

For the purpose of this investigation, the physical performance test scores (jump height (JH), 10 m and 40 m sprint tests, 5-0-5 and YO-YO) and well-being scores (fatigue, energy, stress, motivation, soreness, sleep and total well-being score (TWS)) were collected for 48 male student soccer players at three time points (testing observation one: T_1; testing observation two: T_2; testing observation three: T_3) over a period of two weeks in order to assess percentage change scores for physical performance test scores and well-being scores between T_1 and T_2, T_2 and T_3, and T_1 and T_3. Once percentage change scores (physical performance test scores and well-being scores) for each comparative pair of testing observations were calculated, Spearman's rank order correlation coefficients (r) were calculated to evaluate the nature and strength of the relationships between changes in well-being scores and physical performance test scores.

The principal findings of this study were that over two weeks of training, improved JH was associated with better motivation and worse fatigue, soreness and TWS. Faster 10 m and 40 m sprint times were associated with worse energy, stress, sleep and TWS. Faster 5-0-5 time was associated with worse fatigue, stress, sleep and TWS. Longer YO-YO distance was associated with worse motivation, stress, sleep and TWS. However, in many instances, correlations between physical performance test scores and well-being scores were small to trivial. Numerous contradicting correlations were also found across all comparative pairs of testing observations.

The take-home message of this study is that subjective measures of well-being may not be purported as good measures for assessing athletes' readiness to perform. Thus, physical performance tests are the ultimate indicator of athletes' readiness to perform in this regard. Our findings suggest that during pre-season, worse well-being may be reported; however, athletes' readiness to perform may not be negatively affected. Coaches and sport scientists should consider measuring both subjective self-reported measures of well-being and physical performance tests as these measures appear to be assessing two separate concepts.

Key words: soccer, physical performance, well-being, athlete readiness, athlete monitoring.

CHAPTER 1: INTRODUCTION AND OVERVIEW

1.1 Introduction

Soccer is a field-based intermittent sport and one of the most popular team sports in the world performed by both women and men, children and adults, and at different levels of expertise.[1] Soccer requires players to be able to walk, jog, sprint, change direction and tackle; thus, players have to be competent in several fitness components including flexibility, anaerobic power, muscular strength and endurance, and speed and agility.[2] Success in soccer is measured by the number of matches won per season and may be explained by a combination of factors such as individual skill execution, management tactics, attitude, decision-making and availability of resources, among other things.[3]

The locomotor demands of elite soccer have progressively increased in recent years. Teams are required to compete in a high number of matches over the season, therefore the management of training loads and implementation of effective recovery strategies are paramount in order to avoid the debilitating effects associated with overtraining and injury.[4] Thorpe *et al*.[4] note that increasing attention in the literature has therefore focused on evaluating the effectiveness of a range of monitoring tools which may serve as valid indicators of fatigue status of athletes.

According to Clark,[5] sports performance is a function of athlete skill, genetic endowment, training and health status. The interest of the current study was focused on delivery of a training program, particularly in terms of monitoring athletes' readiness to perform. In order for players to reach the top in professional soccer, extensive training coupled with appropriate recovery is necessary to elicit physiological adaptation for improved on-field performance[6] and to maximise athletes' readiness to perform.[7-8] However, it must be noted that an excessive training dose without rest and recovery will normally lead to reduced performance[9], while an insufficient training dose is likely to fail to elicit physiological adaptation for improved physical capacity.[10] Therefore, what is needed is a balance between training and recovery.

Gallo *et al*.[9] defined athlete readiness as the "immediate ability of athletes to perform and refers to the interaction between fitness and fatigue". According to the literature, contemporary monitoring of athletes' readiness to perform includes: determining fatigue, well-being and training status, and quantifying training and competition loads.[9] Objective measures (such as biochemical, physiological and performance) and subjective measures (self-reported perception of well-being) are all options for monitoring athletes' readiness to perform.[11] For the purpose of this study, the focus was on objective measures assessed through physical performance tests and subjective measures assessed through self-reported measures of perceived well-being.

Objective measures of physical performance may be conducted either in the laboratory or on the field. Laboratory tests are used sparingly because they are time consuming and expensive, while field tests can be reliable, are easy to administer, less time consuming, more specific to training interventions and provide a good indication of general and sport-specific fitness.[2] It appears that objective measures of physical performance (standardised and reproducible sport-specific maximum performance tests) are the ultimate indicator of athletes' readiness to perform; however, several authors[9,12-13] suggest that the practicality of employing maximum physical performance tests is questionable, as some tests are not team sport-specific and imposing a maximum test while attempting to minimise fatigue during the competition phase may be unfeasible.[11]

It is vital to note that individual physical performance test scores cannot be used to predict on-field soccer performance due to the complex nature of performance in competition.[2] Fitness and training status of athletes may be measured as a function of several fitness components (power, acceleration and speed, agility, and aerobic and anaerobic capacity, for example). For the purpose of this study, on-field physical performance tests that were employed included: vertical jump test (VJ),[3,14] used to assess jump height (JH); 10 m sprint test (10 m sprint) and 40 m sprint test (40 m sprint),[2] used to assess acceleration and speed; 5-0-5 agility test (5-0-5), used to assess change of direction speed; and the YO-YO Intermittent Recovery Test (YO-YO),[15-16] used to assess aerobic and anaerobic capacity. The validity and reliability of these tests has been well established in literature and have been proven to be able to differentiate between players of different standards and playing positions.[1-2,14,16-20]

Research focusing on subjective measures of perceived well-being as an alternative means of monitoring athletes' readiness without exertion is accumulating.[21] Coaches and sport scientists may employ self-reported measures with confidence, as these measures have been demonstrated to respond to training-induced changes associated with perceived well-being.[21] These subjective measures are inexpensive, non-invasive and simple to administer.[11] However, they depend heavily on athlete compliance and honesty and there is thus a risk of response distortion.[21] When administered effectively, subjective measures provide guidelines for coaches and sport scientists about the athletes' ability to perform on a day-to-day basis, hence informing individualised adjustments to prescribed training.[11]

According to Saw *et al.*[11], subjective measures of perceived well-being should include the following subscales: motivation/vigour, physical symptoms/injury, non-training and training stress, physical recovery, fatigue and general health. For the purpose of this study, subjective measures of perceived well-being were measured using the multi-component training distress scale (MTDS)[22] to determine the well-being scores of soccer players. The MTDS is a well-established tool and was developed to monitor athletes' psycho-behavioural responses to a training program.[22]

Research unequivocally endorses subjective self-reported measures as indicators of athletes' readiness to perform.[21] The potential efficacy of subjective measures for athlete monitoring has been established, however, optimal implementation practices are yet to be determined. This is due to differing practices among studies, particularly with regard to the frequency of administration, response set and rating scales and time taken for data capture and analysis.[21] However, maximum physical performance tests appear to best reflect the athletes' training status and readiness to perform. The purpose of the current study was to establish the nature and strength of the relationship between changes in well-being scores and physical performance test scores in order to aid practitioners in distinguishing whether or not subjective self-reported measures of well-being may be used to monitor athletes' readiness to perform. To the author's knowledge, no study to date has examined the relationship between changes in well-being scores and changes in physical performance test scores in student soccer players.

1.2 Problem statement

The relationship between physical performance tests and the perceived subjective well-being of monitoring athletes' readiness to perform is unclear. The problem of this research study was to determine the nature and strength of the relationship between changes in well-being scores (subjective measures) and physical performance test scores (objective measures) of student soccer players.

1.3 Aim and objectives

The aim of this study was to describe the nature and strength of the relationship between changes in well-being scores and changes in physical performance test scores in student soccer players.

The objectives of this research study were:

- To determine changes (percentage change) in well-being scores of student soccer players between three consecutive Mondays (testing observations: T_1, T_2, T_3) during the pre-season training.
- To determine changes (percentage change) in physical performance test scores of student soccer players between three consecutive Mondays (testing observations: T_1, T_2, T_3) during the pre-season training.
- To determine the nature and strength of the relationship between changes in well-being scores and changes in physical performance tests score in student soccer players.

1.4 Outline of the dissertation

The remainder of the dissertation consists of:

- Chapter 2: A literature review relating to the use of physical performance tests score and the use of subjective self-reported measures to monitor athletes' training status and readiness to perform and the interaction between the two variables.
- Chapter 3: Description of the research methodology (sample, setting, instruments and statistical analysis) and ethical consideration of this study.
- Chapter 4: Reporting of the research results (sample demographics, physical performance tests score, well-being scores and correlation analysis).
- Chapter 5: A discussion of the research results, along with the limitations of the study and recommendations for future research.

1.5 Conclusion

It is the coaches and sport scientists' responsibility to plan, prescribe and quantify training, understand how the players respond and adapt to different training loads, and be able to modify training loads to improve performance while minimising the risk of injury and illness. One of the reliable ways to monitor athletes' readiness to perform is through physical performance tests; however, it is impractical to implement these tests daily without affecting rest and recovery. Alternatively, can subjective measures of well-being be employed to monitor athletes' readiness to perform? In line with this, the purpose of the current research was therefore to describe the nature and strength of the relationship between changes in well-being scores and physical performance test scores in soccer players in order to establish whether subjective measures of well-being may be used to monitor athletes' readiness to perform.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The purpose of a training program is to provide a stimulus that will result in sport-specific adaptation and improved athletic performance.[23] When the demands of training (volume, intensity and frequency) increase without sufficient recovery and rest,[12] the athlete becomes more prone to the undesirable effects of training, such as injury,[24] acute or chronic fatigue, and overreaching or overtraining syndrome.[25] To minimise the undesirable effects of training or to ensure that the training program is resulting in performance maintenance or improvements, it is necessary to include regular physiological and physical performance tests[23] and/or subjective measures of well-being.[11,23]

Buchheit *et al.*[24] note that measures of monitoring athletes' well-being, training status and training load that have received interest in literature include the following: invasive (e.g. blood markers), exhaustive (e.g. (supra)maximal tests), perceived exertion (e.g. rate of perceived exertion (RPE)), non-invasive and non-exhaustive measures of assessing fitness, well-being (e.g. stress, fatigue), recovery status and physical performance (e.g. submaximal exercise heart rate and post-exercise cardiac autonomic activity as inferred from heart rate variability (HRV)).[24] Buchheit *et al.*[24] further note that psychological monitoring is purported to be an effective means of assessing athletes' training response.[24] Despite the possible advantages of psychological measures, it is still unclear how useful these measures are for monitoring athletes' readiness to perform.

2.2 Soccer

Soccer is a field-based intermittent sport composed of instances of high-intensity activities interspersed with periods of low-intensity activities. Mohr *et al*.[26] note that soccer players perform about 150 to 200 brief high-intensity actions during a match or practice (i.e. sprinting, changing pace/direction, tackling, accelerations/decelerations, jumping and kicking). Soccer is played on both natural and artificial surfaces (120 m length and 90 m width), with each team consisting of eleven players during a 90-minute-long match. Soccer is the most popular sport in the world, performed by women and men, children and adults, and at different levels of expertise.[1]

Soccer is a complex sport and performance depends on a number of factors including player techniques, tactics, physical fitness and psychological factors. The locomotor demands of elite soccer have progressively increased in recent years. Teams are required to compete in a high number of matches over each season, therefore managing training loads and implementing effective recovery strategies are paramount in order to avoid the debilitating effects associated with overtraining and injury.[27] Thorpe *et al.*[27] note that the literature has therefore increasingly focused on evaluating the effectiveness of a range of monitoring tools which may serve as valid indicators of fatigue status of athletes.

Soccer demands players to be competent in several fitness components such as flexibility, explosive power, aerobic and anaerobic capacity, muscular strength and endurance, speed and agility.[2] Soccer fitness components may be assessed either in the laboratory or on the field. Laboratory tests are used sparingly because they are time consuming and expensive, while field tests are easy to administer, are less time consuming, more specific to training interventions, more reliable and provide a good indication of athletes' readiness to perform in terms of general and soccer-specific fitness. However, whether these tests are conducted on-field or are laboratory based, individual test results cannot be used to predict match-play performance due to the complex nature of performance in competition.[2]

Nevertheless, the limited ability to predict on-field/match-play performance in soccer from physical performance tests does not mean that a team with superior fitness would not have a definite advantage when playing an opponent with less physically fit players.[28] Arnason[28] emphasised that if one team were to have a 10% higher maximal oxygen uptake than the other, it would almost amount to having one extra player on the pitch. However, the ability to transform this fitness advantage to a real performance advantage would depend on a number of factors, including tactics, technical skills and motivation.[28] In soccer, fitness and training status of athletes is measured as a function of several fitness components. Engaging in maximum physical performance tests may induce fatigue among the players; thus, as an alternative method for the monitoring of athletes' training status and readiness to perform, subjective measures of perceived well-being appear to be an option. The purpose of this study was to establish the relationship between changes in well-being scores and changes in physical performance test scores in student soccer players.

2.3 Training prescription

Performance depends on a number of factors, such as technique, tactics, physical fitness and psychological factors, as demonstrated in Figure 2.1.[29] The purpose of a training program as ‘physical stress’ is to cause disruption to homeostasis of the biological system, the intention being to stimulate adaptive responses to restore homeostasis beyond recovery until overcompensation (also known as super-compensation) is attained in other to improve physical performance capacities.[7] The general adaptation syndrome, as described by Selye[30] is used to explain how living species adapt to physical training as a stress (see Figure 2.2).

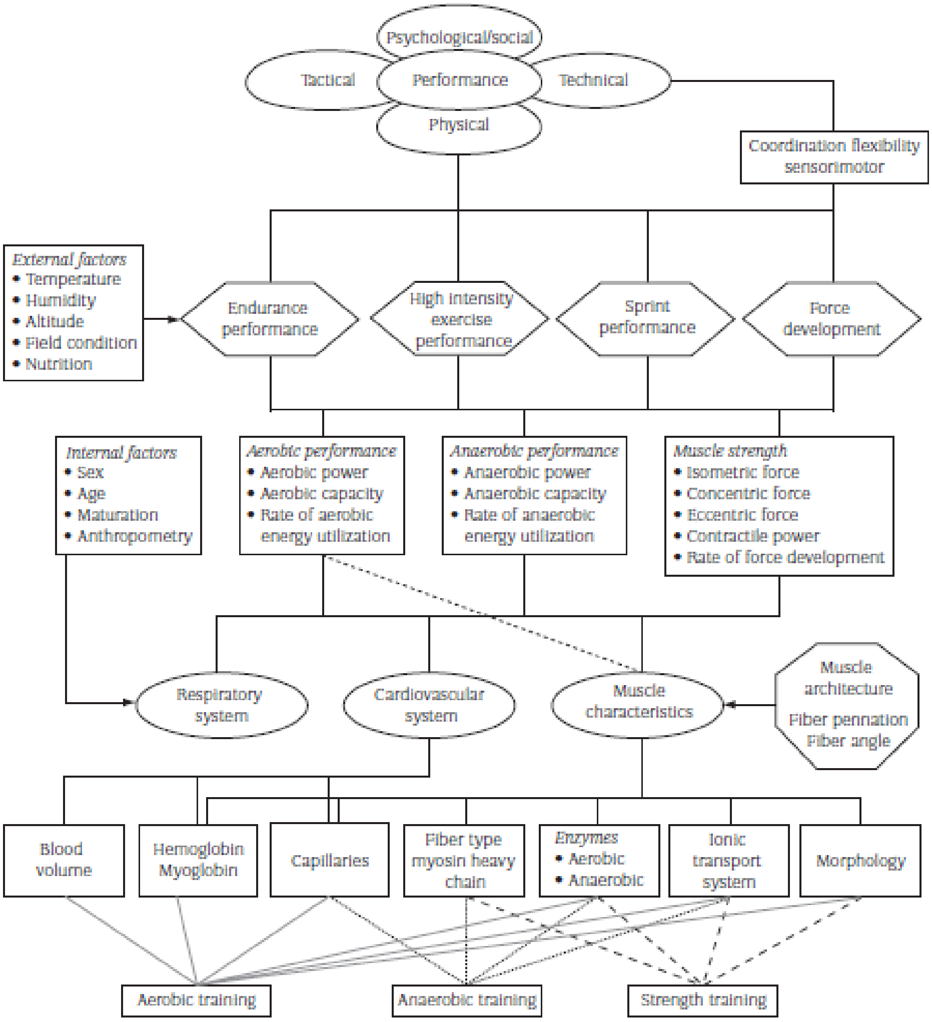

Figure 2.1 A holistic model of the determinants of sports performance (adapted from Bangsbo *et al.*[29]).

As demonstrated in Figure 2.2, the initial response following physical training is a negative ‘alarm phase’, where fatigue results in a diminished physiological state. Subsequently, with adequate recovery, regeneration occurs, being a positive resistance response resulting in a super-compensation effect. However, if the stress is greater than the organism's adaptive capabilities, exhaustion occurs (i.e. decrements in physical performance capacities).[30] The response phase is considered to be proportional to the magnitude of the stimulus, and with sufficient rest and recovery (regeneration) leads to improved physical performance capacities.[9,30]

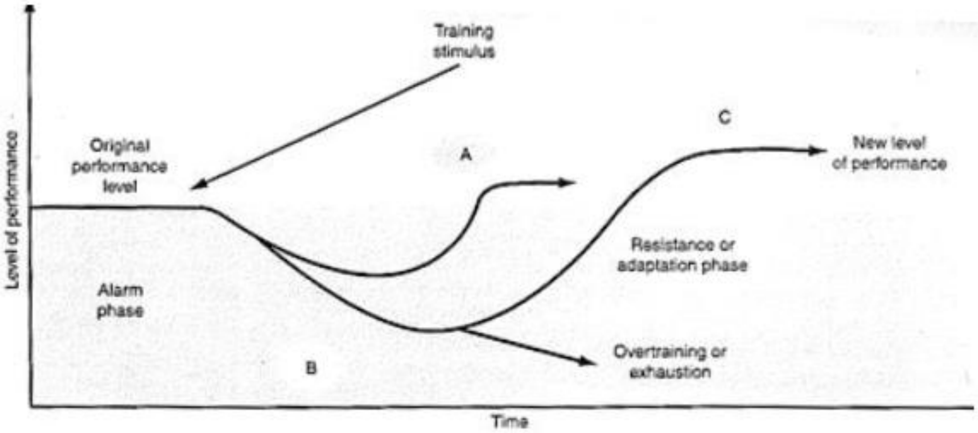

Figure 2.2 Selye's General Adaptation Syndrome (G.A.S.) Theory (adapted from Selye[30]).

A – typical training; B – overtraining; C – overreaching or super-compensation

To further explain how the theory of biological adaption among living species occurs, Banister *et al.*[31] developed the Fitness-Fatigue Model (see Figure 2.3). The authors proposed that performance could be determined from the interaction of fitness and fatigue. They proposed that training results in two responses: fitness (positive) and fatigue (negative); however, these responses differ in magnitude and duration, with fitness having a smaller magnitude but longer duration. The Fitness-Fatigue Model suggests that when sufficient time is given for the negative effects of fatigue to subside between bouts of exercise, the cumulative fitness effect of long-term training will result in improved physical performance capacity. It is important to note that specific stimuli will have different fatigue responses from the different systems of the body (e.g. immunological, musculoskeletal and metabolic), and it is the summation of the after-effects of fitness and fatigue on all systems of the body that ultimately represent athletes' readiness to perform (i.e. physical performance capacity).[7,9,31-33]

Considering both the General Adaptation Syndrome Theory (Figure 2.2) and Fitness-Fatigue Model (Figure 2.3), it is acceptable that training will result in induced fatigue. However, if sufficient rest and recovery is provided for the symptoms of fatigue to subside, regeneration occurs, resulting in improved physical performance capacities.[8,12-13]

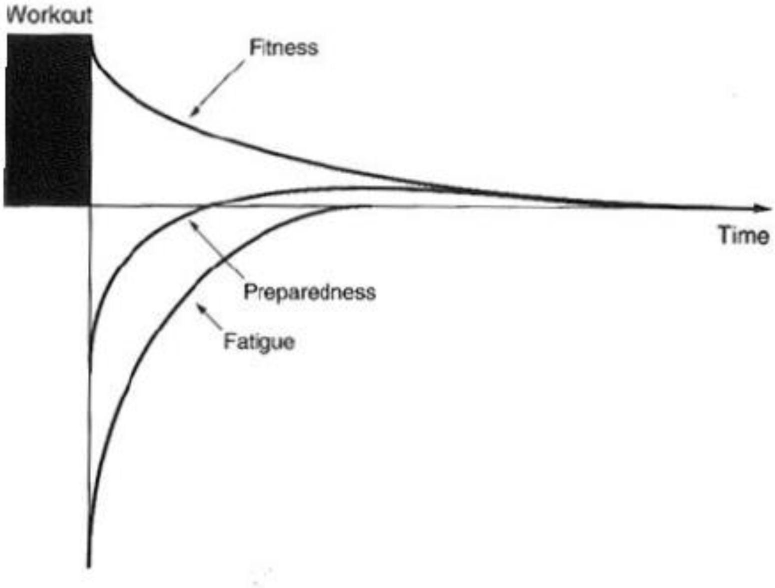

Figure 2.3 Fitness-Fatigue Model of Training (athlete preparedness improves because of fitness gain or worsens because of fatigue) (adapted from Banister *et al.*[31]).

Important to note is that it is the magnitude of the stimulus that plays a vital role. If the stimulus is inadequate, there will be no improvements in performance, whereas if the stimulus is too high and/or with insufficient recovery, the negative effects of fatigue will set in, and over time will result in a decrease in performance.[10,34] Coaches and sport scientists hence have to strike a balance between prescribing an appropriate individualised training dose with a proportionate amount of recovery.[9]

In team sports, success is determined by winning the premiership or league while performance is measured by the number of games won. The role of coaches and sport scientists is to optimally prepare athletes to be able to perform at the best of their ability throughout the season. Athletes' readiness is the "immediate ability of athletes to perform and refers to the interaction between fitness and fatigue".[9] The Fitness-Fatigue Model proposes that peak athletes' readiness to perform will occur at a delayed time point from the last intense training phase, when fitness effects are high and fatigue responses have diminished.[35]

It is the combination of factors such as high frequency of competitions, higher intensity of competitions, and increased demands of international competitions during in-season and off-season periods[36] that exposes athletes to high match and training loads. Coutts *et al.*[12] state that it is well established that when increased intensive physical training (high training loads) is completed without sufficient recovery and rest, fatigue may accumulate and result in a decrease in physical performance that can lead to either "functional (short-term) overreaching, non-functional (extreme) overreaching or overtraining syndrome".[12,37]

Overtraining may be described as an imbalance between stress (training or non-training) and recovery.[38] When higher training loads are coupled with appropriate rest and recovery, it is most likely to result in physiological adaptation that enhances physical performance capacities, a process known as functional overreaching. With prolonged intense training with insufficient recovery, and where performance capacities fail to rebound following a recovery period, this is termed non-functional overreaching.[8] The effects of non-functional overreaching include decreased physical performance, increased perceived effort during exercises, muscle soreness and overuse injuries, all of which may persist for months.[39] Overtraining syndrome is a neuroendocrine disorder characterised by persistent fatigue, reduced catecholamine excretion, inability to maintain training loads, poor performance in competition, frequent illness, alteration in mood state and disturbed sleep.[38] As a result, injury prevention strategies, modification of training load (frequency, duration and intensity), managing fatigue, managing stress and monitoring well-being and training adaptation are fundamental to the work of the player's support team.[36]

To strike a balance between stress and recovery in the practical setting, practitioners utilise periodisation plans. Periodisation is a planned process of applying systematic variations of exercise parameters (intensity, duration and frequency) to elicit adaptation that meets the demands of a particular sport.[7] The traditional methods of periodisation were based on individual sporting codes, where athletes worked towards peaking for a major competition in the season.[7,9] The objectives of any training program are to maximise learning and training effects (performance) while managing fatigue and preventing stagnation or overtraining (principle of progression). Luke *et al*.[40] found that decrements in performance can be attenuated through effective planning (periodisation), mental preparation of athletes (through effective communication between coaches and athletes), strength and conditioning sessions and constant monitoring of athletes' readiness to perform and perceived well-being.

Periodisation programs for team sport are meant to maintain or improve fitness levels achieved during pre-season training. However, application of such programs remains a challenge in team sport[7,9] due to differences in athletes' abilities to adapt to training and cope with levels of induced fatigue, which appear to be influenced by several factors such as exercise capacity, training and non-training stressors, stress tolerance and motivation.[9,37,41] For the purpose of improving physical performance, training programs should be between eight and 12 weeks in duration to allow structural and functional physiological adaptations to the training stimulus to occur,[42] as shorter programs (six to eight weeks) do not always produce significant physiological improvements.[43] Monitoring of physical and physiological adaptation to training can be done on a regular basis; however, it is recommended to wait until the residual fatigue associated with the training program has subsided before post-test evaluations.[43]

Currently, there is no model that has been designed to predict on-field performance outcome in team sport. This is attributed to a range of factors including the opposition, the lack of consideration of factors outside training, the difficulty of quantifying training in the real world, individual training response variations within and between athletes, and the assumption of an opposing negative and positive effect of training impacting on performance rather than stages or sequence of responses leading to adaptation, and hence improved performance capacity.[9]

Coaches and sport scientists should monitor athletes more regularly to gain a better understanding of the load elicited on an athlete, the response to that particular load, current training status of an athlete and be able to modify training to reduce the negative effects associated with fatigue.[9] Athlete monitoring systems have become customary in the elite and sub-elite sport setting.[9,24] For example, Taylor *et al.*[44] conducted a survey across Australian and New Zealand high-performance personnel and found that 70% of responders indicated the use of athlete monitoring systems that focused on load quantification and fatigue monitoring. In elite sport, monitoring tools are used extensively as indicators of the athlete’s training status and to inform coaches and sport scientists making decisions regarding the balance between training load and subsequent stress/recovery to optimise preparation and performance while minimising the risk of injury/illness.[45]

2.4 Physiological and physical performance tests

Several physiological systems have been suggested to be connected to training status and fatigue in the literature. These include inflammatory, cardiovascular, endocrine, immunological and neuromuscular, with arguably the most frequently measured being neuromuscular fatigue.[9,12,24,46-47] A review by Buchheit[48] demonstrated that heart rate (HR) at rest might be useful for assessing acute and chronic training status, while HR during exercises seems to relate to chronic positive physiological adaptation. Hormonal levels have been used to measure training response – for example, testosterone to cortisol ratio reflects the imbalance between the anabolic and catabolic states – and are potential indicators of training status.[9,49] Similarly, immunological and inflammatory markers, such as indirect markers of muscle damage (e.g. creatine kinase) are commonly explored in research.[9,46-47,49] Despite the considerable amount of research conducted using physiological parameters to determine training status and fatigue, these measures have shown inconsistent results. Presumably, this is due to the complex nature of the overtraining continuum and the uncertainty regarding the direction of physiological response, depending on where an athlete might be along the continuum (acute fatigue to overtraining syndrome).[9,11,13,50]

It appears that a sport-specific maximal performance test that is standardised and reproducible is most likely to reflect changes in training status and athletes' readiness to perform; however, the practicality of employing maximum performance tests is questionable. This is due to the fact that some maximal tests are not team sport-specific and imposing a maximum test while trying to minimise fatigue during the competition phase may be unfeasible. Coaches and sport scientists are often tasked with maximising physical performance with the aim of improving competitive success.[5] Physical performance test scores are used for: exercise prescription, monitoring athletes' training status and readiness to perform, determining individual strengths and weaknesses, evaluating the effectiveness of training preparation,[5] tracking progression or regression, planning of the training program, understanding athletes' physical performance capabilities or identifying physical fitness components that need improvement.[2]

Physiological and physical performance tests can be used to determine accurate values of anaerobic threshold, VO_2 max, maximum aerobic capacity, work economy, strength and power.[1] However, a physical performance test alone is not sensitive enough to predict on-field performance and therefore cannot be relied on for selection purposes, because soccer performance is a function of mental, physical, tactical and technical factors.[1] Field-based objective measures of athletes' readiness to perform (physical performance tests) that are commonly used in soccer research and practice include: vertical jump test (VJ),[14] used to assess JH to predict power output; 5-0-5 agility test,[18] used to measure change of direction speed; 10 m and 40 m sprint test,[2] used to assess rate of displacement; 20 m multi-shuttle run (20MST) test or YO-YO,[2,16-17] used to assess (an)aerobic capacity. These field tests have been proven to be able to differentiate between players of different standards of play and playing positions.[2]

2.4.1 Vertical jump test

Muscular power is an important prerequisite for sprinting and is commonly assessed in soccer players[51] through using the vertical jump test.[52] Lower limb power has been deemed to be functional to optimal performance in soccer and talent selection,[14] because jumping ability plays an integral role in soccer performance as players perform jumping movements[51] during the match when the soccer ball is launched into the air. In studies by Wisloff *et al.*[53] and Arnason *et al.*[28] of Scandinavian soccer clubs, VJ performance was able to discriminate between players of different competitive levels with higher-ranked team club players performing better in countermovement jumps and squat jumps.[28] Castagna and Castellini[14] found that in Italian male elite-standard players, VJ performance was not dependent on competitive level; however, these authors were able to detect competitive level differences between female players.[14] In a study conducted by Clark[5] on explosive power as measured by using the vertical jump performance test, no significant difference was found between players in successful and less successful teams in a South African professional league.[5]

2.4.2 40 m sprint test

In order to win critical moments or contests within a match, players require good acceleration and speed capabilities in making decisive runs in defence or attack.[5] During a soccer match, players sprint for an average of four to six seconds.[2] The ability to accelerate and reach maximum velocity in soccer is assessed using single sprint tests, which measure the time taken to cover a particular distance (10, 0-20, 0-30, or 40 m).[54] Single sprint tests can differentiate between different standards of players and different playing positions.[2,54] However, in a study by Clark[5] to determine meaningful differences in performance between players in successful and less successful squads in South Africa, only small significant differences were found between players using single sprint tests in successful and less successful squads; that is, no meaningful differences in performance were found.[5]

2.4.3 5-0-5 agility test

Draper and Lancaster[18] and Sheppard and Young[19] defined agility as “the ability to change direction or velocity of the body rapidly in response to a stimulus, and is a result of a combination of strength, speed, balance and coordination”. Sheppard and Young[19] note that agility has a direct relationship with trainable physical qualities (such as technique, strength and speed) and cognitive components (such as visual-scanning speed, visual-scanning technique and anticipation).[19] Agility testing is therefore confined to tests of cognitive components such as anticipation or pattern recognition, or physical components such as change of direction speed.[19] The 5-0-5 agility test has been shown to correlate with acceleration and is used to measure change of direction speed over 5 m. This test involves no decision-making or reactive component.[19]

2.4.4 YO-YO intermittent recovery test

The YO-YO intermittent recovery test (YO-YO) was designed to measure the ability to perform repeated bouts of intermittent running with short recovery periods.[2,17] The reliability and validity of the YO-YO was established by Krustrup *et al*.[16] in a study of elite Danish soccer players, where a significant correlation between performance on the YO-YO and the amount of high-intensity exercise performed during soccer match-play was observed. YO-YO appears to simulate both aerobic and anaerobic glycolysis similar to a soccer match, as the players' blood lactate concentration and heart rates were elevated at the end of the test.[16] Stolen *et al*.[1] further emphasised that performance on the YO-YO intermittent recovery test level 1 is associated with the amount of high-intensity running, sum of high-speed running and sprinting distance during a match, and the total distance covered during a soccer match.[1]

2.5 Subjective self-reported measures

Monitoring athletes' training response and life stressors plays a vital role in implementing favourable training routines and achieving optimal performances. There are several psychological tools (POMS, REST-Q and MTDS for example) used in the training contexts among athletes, each of which has been shown to deliver valuable information for athletes and coaches regarding individual responses to training, while also assisting to avoid maladaptive training responses by observing changes in mood, perceived stress and recovery, emotions and sleep quality.[55]

Mood disturbances can be assessed using the Profile of Mood States (POMS),[56] as per the classical work of Morgan *et al*.[57] who demonstrated that an increase in POMS mood disturbance scores was reliably associated with an increase in training load among swimmers, whilst a decrease in training load was associated with a decrease in mood disturbance scores. Monitoring mood fluctuations has been proposed as a useful tool for reducing the incidence of overtraining symptoms in athletes; for instance, an increase in training loads has been correlated with an increase in mood disturbances scores,[58-59] mood disturbances have been related to both performance decrements and physiological markers of overtraining in a range of studies,[9,46,57] an increases in depression seems to be related to stale athletes, while changes in the vigour and fatigue factors are most sensitive to training loads.[25,57,60]

Perceived stress is another self-reported approach to monitoring training distress. Perceived stress forms part of athlete monitoring because training-specific stressors, when combined with non-training sources of stress, may influence an athlete's mental and physical readiness to perform.[61] Rushall[62] suggested that it is particularly important to monitor perceived stress during periods of heavy training due to the potential for an increase in perceived stress to increase fatigue levels and, in turn, decrease performance capabilities. In order to actively measure the recovery process as well as the stress imposed by training, the Recovery-Stress Questionnaire (RESTQ-Sport) and Recovery-Cue were developed.[63-64] Grove *et al*.[61] demonstrated that an increase in perceived stress is associated with an increase in fatigue. Correlations between POMS and RESTQ-Sport indices have been reported in detail for collegiate swimmers and elite rowers. In each study, the vigour scale from the POMS was positively correlated to the recovery scales in the RESTQ-Sport, while tension, depression, anger, fatigue and confusion negatively correlate to recovery.[9,63-64]

Training distress symptoms checklists are based on observations of loss of appetite, general lethargy, muscle soreness and/or susceptibility to minor illness during periods of high-intensity training[22,46] and have been proposed to monitor both recovery and overtraining.[65] Fry *et al*.[46] noted that symptoms related to physical complaints, sleep difficulties, changes in appetite, general fatigue and poor concentration were more pronounced during periods of high-intensity overload training among military personnel. These findings were consistent with those of Hooper *et al.* [66], who concluded that self-reported ratings for quality of sleep, fatigue, stress and muscle soreness could provide an efficient means of monitoring both overtraining and recovery.

According to Main *et al*.,[58] several investigators have assessed more than one of the three general categories (mood disturbances, perceived stress and symptoms checklists) of training distress, however, to date the only self-report measurement tool for monitoring well-being that combines all three categories in an efficient and athlete-friendly manner is a six-factor MTDS.[22] Using a range of existing tools including the Perceived Stress Scale,[67] the Brunel Mood State Scale,[68] the Training Stress Scale[69] and Athlete Burnout Questionnaire,[70] a six-factor multi-component model of training distress was established.[22] The MTDS was developed to monitor athlete psycho-behavioural responses to training stimuli and consists of six factors related to psycho-behavioural signs and symptoms: depression, vigour, physical symptoms, sleep disturbances, stress and fatigue.[22] Main *et al*.[58] note that strong and consistent relationships have been observed between self-report measures and performance, but that athlete monitoring to enhance performance still remains a challenge due to the limitations of self-report measures such as timeliness of administration, measurement error and conscious bias[71] and potential time burden for athletes.[21] Main and Grove,[22] in a study for monitoring training distress among athletes using a measurement model covering three broad response domains (stress, mood and behavioural/physical symptoms) suggest combining assessment of the symptom clusters with selected physical performance tests and/or biochemical markers as a logical direction for future research.

According to Saw *et al*.[21], the most common subjective measures of athlete well-being are: the Profile of Mood States (POMS),[56,72] including derivatives of the POMS,[73] the Recovery Stress Questionnaire for Athletes (RESTQ-Sport)[63] and the Daily Analyses of Life Demands of Athletes (DALDA).[62] Other measures include: State-Trait Anxiety Inventory (STAI),[74] Perceived Stress Scale (PSS),[67] Multi-Component Training Distress Scale (MTDS),[22] Competitive State Anxiety Inventory-2 (CSAI-2),[75] Derogatis Symptom Checklist (DSC),[76] State-Trait Personality Inventory (STPI)[77] and a mood questionnaire by Choi and Salmon (Mood).[78]

A growing body of knowledge exists in support of self-reported measures of well-being. In order to foster compliance and improve specificity, coaches and sport scientists have been encouraged to use customised, shortened versions of these tools for athlete monitoring.[9,21,24,49,66] A survey of Australian and New Zealand high-performance sport practitioners on current trends of fatigue monitoring reported that 84% of responders use self-report questionnaires, the majority (80%) of which use custom designs consisting of four to 12 item.[44] Self-reported subjective measures of well-being that appear fundamental to the interpretation of athletes' readiness to perform take psychology into perspective because individual athletes might respond differently to the same training stress. These measures utilise Likert scales (e.g. very low (1) to very high (5)) and may be characterised by: "(1) whether or not they are designed for athletes, (2) if they evaluate single or multiple constructs and (3) whether the constructs are based on stressors, or resulting symptoms".[11] Saw *et al*.[11] suggest that athlete-specific subjective measures evaluating multiple constructs may better reflect performance capacities, therefore recommending the MTDS over the RESTQ-S due to the inclusion of perceived stress, mood disturbance and behavioural symptom subscales with a smaller number of items.[11]

Research focusing on utility of subjective self-reported measures is accumulating, however, these measures are heavily depended on athlete compliance and honesty; as such, there is a risk of response distortion.[21] Saw *et al.*[79] examined the use of self-report measures for monitoring athletes and explored the inter-relations of factors associated with implementation of self-reported measures through a qualitative investigation involving coaches, sport scientists and athletes from a national institute. Furthermore, a four-step process in utilising self-report measures was determined as: (1) record data, (2) review data, (3) contextualise and (4) act. The 'act' component of their utilisation is suggested to include feedback to the athlete/coach and training prescription modification.[79] Subjective self-reported measures are proposed as valid indicators of training status, however their impact on subsequent exercise output and performance is yet to be determined. Hooper and Mackinnon[66] emphasise that with well-developed designs and considered processes, an item as simple as athlete self-report measures may effectively enhance a training program.[9,66]

Thorpe[80] further stipulates that there appears to be a possible dose-response relationship between training loads and subjective self-reported measures, as daily subjective self-reported measures have been demonstrated to correlate with daily fluctuations in training load. For example, Main *et al.*[22] found that PSS and DALDA have been shown to change in a predictable manner as a function of variations in training load and performance demands. POMS have been demonstrated to exhibit dose-response sensitivity to training loads in different sports and POMS-derived items are sensitive to exercise-related mood changes among dancers.[81] REST-Q has been demonstrated to provide useful information about changes in training distress levels;[81] however, its length could reduce compliance in situations where repeated assessments are required. In the current study, MTDS was used to monitor changes in well-being scores in relation to changes in physical performance test scores. The MTDS is a shorter self-reported tool that can be used to assess multiple aspects of training distress simultaneously in a user-friendly manner. The MTDS is a well-established tool and was developed to monitor athlete psycho-behavioural responses to a training program.[22]

For the purpose of monitoring acute changes in training status, well-being and readiness to perform, subjective measures should include the following subscales: motivation/vigour, physical symptoms/injury, non-training stress, physical recovery, fatigue and general well-being/health.[11] These subscales provide guidelines for coaches and sport scientists regarding the athlete's ability to perform on a day-to-day basis and for guiding adjustments to prescribed training on an individual basis.[11] According to Halson,[13] monitoring tools can provide coaches and sport scientists with useful information; however, monitoring tools should be intuitive, provide efficient data analysis and interpretation, and enable efficient reporting of simple, yet scientifically valid feedback.[13]

2.6 Athlete monitoring

Biochemical, physiological, performance and subjective measures are all options for athlete monitoring;[11] however, self-reported subjective measures appear to be more useful, sensitive and consistent compared to objective measures for athlete monitoring and reflect acute and chronic training-related changes in athlete well-being.[11] Saw *et al.*[11] state that "training imposes stress on an athlete, shifting their physical and psychological well-being along a continuum that progresses from acute fatigue to overreaching and ultimately overtraining syndrome."

Contemporary monitoring of athlete preparedness and readiness to perform, including determining health, well-being and training status, along with quantifying training and competition loads is commonly employed in elite and sub-elite sporting environments.[9] However, before employing any form of tool or model for an athlete monitoring system, Kenttä and Hassmén[37] defined three important phases for consideration: (1) identifying the stimulus, (2) the perception of the stimulus and (3) the response to the stimulus.[37] Therefore, a valid and reliable method for athlete monitoring should be able to quantify the load to identify the stimulus, assess an athlete's perception of the stimulus and monitor the response to that stimulus. Practical examples of the phases of consideration before selecting any model for athlete monitoring are: (1) quantification of training load; external exercise load (i.e. the physical output, e.g. distance run), and internal exercise load (i.e. the psychobiological response experienced by the athlete, e.g. rating of perceived exertion);[12,41] (2) monitoring the athlete's response (i.e. use of psychometric inventories as markers of athlete training status, e.g. customised athlete self-report measures);[21-22,57,66] and (3) modifying or adjusting planned training according to an athlete's current fatigue/training state (e.g. tailored questionnaires).[82] Gallo[9] notes that there are gaps in the literature at each of these three phases of athlete monitoring; in particular, the measurable influence that monitoring practices have on match performance in team sport is vastly unexplored.[9,83]

In professional sports, practitioners commonly incorporate customised athlete self-report measures into their monitoring systems.[6,12,22,66] Halson *et al.*[84] maintain that there are numerous physiological variables that have been identified and investigated as potential markers of training distress including endocrine, metabolic, cardiovascular, immunological and neuromuscular measures; however, these variables have shown weak or inconsistent relationships with training distress, while psychological and behavioural measures are efficient, inexpensive, non-invasive and have demonstrated stronger and more consistent relationship with training distress.[47] Psychological measures of training distress tend to stem from one of three perspectives: mood disturbances, perceived stress, or training distress symptoms.[22] For example, MTDS[61] combines measures of perceived stress, mood disturbance and symptom intensity to analyse six key training distress indicators, namely: general fatigue, perceived stress, depressed mood, energy and vigour, somatic symptoms and sleep disturbances. MTDS has a clean factor structure, and all of the factors exhibit positive correlations with measures of burn-out risk among athletes.[61]

According to Saw *et al.*,[21] studies indicate that subjective measures responded with superior sensitivity and consistency as compared to objective measures; i.e., sensitivity, consistency and/or timing differed in 46% of the studies, 85% of which favoured subjective measures in experimental overload and observational studies, as compared to objective measures.[21] For instance, Saw *et al.*[21] found moderate evidence that creatine kinase (objective measure) increases and decreases with acute training load. Subjective well-being typically has the opposite response to acute loads; however, only four subjective measures of stress (general stress, emotional stress, fatigue and emotional exhaustion) were moderately associated with creatine kinase. The lack of an association between creatine kinase and subjective measures may be explained by the different responses of these measures to chronic training. The lack of association between subjective and objective measures provides support for the inclusion of both in different yet complementary athlete monitoring systems.[21]

Within the current body of knowledge, the potential efficacy of subjective measures for athlete monitoring has been established but optimal implementation practices are yet to be determined. This is due to differing practices among studies particularly with regard to the frequency of administration, response set and rating scales, and time taken for data capture and analysis.[21] Therefore, in practice, subjective measures should be athlete-specific, evaluate multiple constructs, and cater for different circumstances and responses of individuals, capturing both non-training and training-related stressors.[21] Saw *et al.*[21] state that in order to monitor acute changes in athlete well-being, the following subscales may be useful: “vigour/motivation, physical symptoms/injury, non-training stress, fatigue, physical recovery, general health/well-being, and being in shape.” These subscales provide the practitioner with insight into the athlete’s ability to perform training that day, hence this information may be useful for guiding adjustments to prescribed training on an individual basis.

Coaches and sport scientists continuously seek ways to improve physical performance; however, identifying when physical training becomes maladaptive is the challenge that they face. Meyers and Whelan[85] emphasise that when a balance between work/rest cannot be achieved or when the physical stress of training combines with psychosocial stressors (experienced by athletes), the negative effects of training that affect both the physical and mental state of athletes as well as performance capabilities may result.[85] Thus, the negative effects of training can be minimised through scheduled tapering phases, temporary reductions in workload, and active and passive recovery methods. In order for the above-mentioned interventions to be implemented, one needs to constantly monitor both physical and psychological well-being of athletes[21] in conjunction with the non-training sources of stress; for example, competitive pressure experienced by athletes in a performance-focused setting, the time invested in meeting training and competition demands, self-deprivation and compromises of social commitments.[86] Training and non-training sources of stress place athletes at risk of suffering from loss of motivation and burnout.[86] Therefore, early detection of training distress symptoms (through monitoring tools) plays an integral role in helping coaches and sport scientists adjust training programs before short-term overreaching results in long-term effects associated with overtraining syndrome.[50,61]

Athlete monitoring is essential to guide training and detect any progression towards negative health outcomes and associated poor performance. Objective and subjective measures are both options for athlete monitoring;[11] however, there is still poor understanding as to whether these measures can be used interchangeably for monitoring athletes’ readiness to perform. Saw *et al.*[11] state that physical performance is the ultimate indicator of athletes’ physical and psychological well-being and readiness to perform, though it is impractical to assess athletes on a day-to-day basis via physical performance tests. Athlete monitoring provides coaches and sport scientists with valuable information on how an athlete is coping and adapting to training interventions or training and non-training stressors, thereby optimising the training outcomes by minimising the likelihood of illness, injury and overtraining.[87]

Psychological monitoring has been purported to be an effective means of assessing players' responses to training loads; however, despite the possible advantages of the aforementioned variables, it is still unclear how useful these measures are for monitoring readiness to perform, recovery status and, in turn, fitness during an intense training period in elite team sport players.[24] Importantly, the relationship between psychological variables and physical performance has only been assessed under standardised exercise conditions (i.e. HR-derived measures vs. incremental test, 10 km run or YO-YO).[24] Whether psychological measures can also track changes in running performance during less controlled but more sport-specific conditions such as during outdoor ball games is unknown.[24]

It is well established that athletes may respond differently to the same training program and that the outcome of training is influenced by each individual's psychobiological predispositions.[88] Furthermore, the same individual may not respond equally to the same training stimulus, and due to the complex nature of fatigue it is also important for coaches and sport scientists to: monitor global athlete fatigue levels (physical, mental and emotional) in response to the prescribed training stress/stimulus in order to minimise the risk of injury/illness,[45] monitor training loads, understand each athlete's response to training, design individualised training programs that take into consideration each athlete's current state of fitness and schedule recovery sessions to limit unplanned fatigue in order to maximise physical capacity and skill gains.[89-92] There is a variety of practical suggestions for athlete monitoring in the literature, however, there is no strong evidence supporting the use of subjective self-reported measures as a method for monitoring athletes' readiness to perform, training and fatigue, particularly in team sport.[9,93]

The start of this chapter focused on creating a picture of the interactional relationship between physical training and performance and monitoring athlete well-being status through objective and subjective measures, with evidence-based research finding of the tools used to monitor athlete readiness. Subsequently, a summary of research focused on the use of physical performance tests for monitoring athletes' readiness to perform is highlighted in order to achieve a better understanding of the two components (objective and subjective self-reported measures). The end of this chapter focuses on the multi-component training distress scale and the relationship between athlete monitoring and performance.

2.7 Conclusion

According to Gallo,[9] research unequivocally endorses subjective self-reported measures as indicators of athletes' training status and a possible tool for monitoring athletes' readiness to perform. Subjective self-reported measures are non-invasive and inexpensive[9] tools to monitor athletes without exertion;[11,23] however, maximum physical performance tests appear to best reflect athletes' current training status and readiness to perform. Main and Grove[22] suggested combining assessment of the symptom clusters with selected physical performance tests and/or biochemical markers as a logical direction for future research. The relationship between subjective self-reported measures of well-being and physical performance tests has not been well studied. Establishing the strength and nature of the relationship between changes in well-being scores and changes in physical performance test scores will assist coaches and sport scientists in making decision with regard to whether or not athletes' readiness to perform may be monitored through subjective self-reported measures.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter will discuss the chosen methodology used to investigate the relationship between changes in well-being scores and changes in physical performance test scores in student soccer players. The chapter begins with a description of the research design. Subsequently, the research sample is described along with the measurement instruments, data collection and analysis. This chapter is summed up with a discussion of the ethical considerations of the study.

3.2 Research design

This study employed an observational longitudinal cohort study design involving repeated measurements in a group of participants at three time points over a period of two weeks.

3.3 Population and sampling

The target population consisted of male student soccer players who were recruited from a university soccer club. The inclusion criteria for participation in this protocol were solely based on the premise that the participants were: (a) members of the men's student soccer team at the University of Pretoria; (b) soccer players playing at student level; (c) players aged between 18 and 25 years old; and (d) registered club members. Potential participants were excluded if they were: (a) declared unfit to play/participate due to injury or illness as diagnosed by a medical practitioner; (b) not able to engage in maximum effort physical activity without pain/discomfort as per individual subjective feedback; and (c) unwilling to participate and/or complete the necessary testing procedures and signed informed consent documents.

All participants who were included in the study were given verbal instructions about the aim, purpose and procedures of the study. The risk and benefits of the study were verbally explained to the participants during the period of the study and the participants were subsequently requested to volunteer as participants in this research. The university sports organisation (TuksSport) gave permission for data to be collected and used for the study. A copy of the permission letter from TuksSport to the principle investigator, Mr B. Maluleke is attached (see Annexure 3). TuksFootball under TuksSport provides soccer programs for aspiring student-athlete soccer players who partake at amateur, student and semi-professional level of competition. This was coordinated by the Department of Physiology at the University of

Pretoria (see Annexure 4). The study was conducted at the Burnett Street, LC De Villiers, TuksFootball Club Soccer Field B, Hillcrest Campus, University of Pretoria. Forty-eight (48) male student soccer players at the University of Pretoria, TuksFootball provided informed consent to participate in the study.

3.4 Measurement instruments

The purpose of the study was to establish the nature and strength of the relationship between changes in well-being scores and changes in physical performance test scores in soccer players. Therefore, the study was composed of two categories of variables: well-being scores (fatigue, energy levels, stress, motivation, muscle soreness, sleep quality and total well-being score) and physical performance test scores (JH, 10 m, 40 m, 5-0-5 and YO-YO). All the equipment used for the study was calibrated prior to each testing observation (T_1, T_2, T_3). All the participants were given verbal instructions regarding the well-being questionnaires, were encouraged to answer questions with honesty and reminded that information about how they perform or answer the questionnaire will not be provided to the coaching staff.

The following measurements tools were used:

- MTDS Questionnaire
- VJ
- 10 m, 40 m
- 5-0-5
- YO-YO

In order to determine the nature and strength of the relationship between changes in well-being scores and changes in physical performance test scores, well-being scores were defined as the predictor variable (based on the assumption that this variable might influence the results of physical performance test scores), while physical performance test scores were defined as outcome variables as shown in Table 3.1.

Table 3.1 Predictor and response/outcome variables

Predictor variables	**Outcome variables**
Fatigue score	Jump height (cm)
Energy levels score	0 – 10 m sprint time (s)
Motivation score	0 – 40 m sprint time (s)
Stress score	5-0-5 agility test time (left and right) (s)
Muscle soreness score	YO-YO intermittent recovery test distance (m)
Sleep quality score	
Total well-being score	

3.4.1 Well-being scores

The MTDS questionnaire (see Annexure 3) was administered through pen and paper 30 minutes before physical performance tests were administered at the training field. The MTDS questionnaire posed questions pertaining to motivation, fatigue, energy levels, stress, muscle soreness and sleep quality. Participants were asked to rate how they are feeling on each item stated above. That is, (a) Fatigue: Are you feeling tired, sleepy, worn out? (b) Energy levels: Are you feeling energetic, active and alert? (c) Stress: Are you feeling stressed, under pressure, having difficulty coping? (d) Motivation: Are you feeling motivated, eager? (e) Soreness: Are you experiencing muscle soreness, heaviness, stiffness? (f) Sleep quality: Are you falling asleep easily and not experiencing restlessness? Each of the items were rated by the participants on a five-point scale as very low, low, average, high or very high. A numerical score for each question was assigned with one being the best condition and five being the worst (Table 3.2). The sum of each item was calculated to produce an overall TWS out of 30.

Table 3.2 Scoring of the well-being questionnaire responses

	Very low	Low	Average	High	Very High
Fatigue	1	2	3	4	5
Energy Levels	5	4	3	2	1
Stress	1	2	3	4	5
Motivation	5	4	3	2	1
Soreness	1	2	3	4	5
Sleep Quality	5	4	3	2	1

Total well-being score = /30

3.4.2 Physical performance tests

A summary of performance tests variables is shown in Table 3.3.

Table 3.3 Physical performance tests

PHYSICAL PERFORMANCE TESTS	ABBREVIATION	Measure	Units
Vertical Jump Test	VJ	Displacement	cm
Sprint Test	10 m, 40 m	Time	s
5-0-5 Agility Test	5-0-5	Time	s
YOYO Intermittent Recovery Test	YO-YO	Distance	m

3.4.2.1 Vertical jump

The vertical jump (VJ) test was used to measure the players JH. Equipment needed: Vertec jumping device (Sports Imports, Columbus, USA), which was calibrated to the nearest centimetre (cm). The test was conducted as per the suggested procedures of Ellis *et al.*[94] During the test, the participant stood (using athletic shoes) next to the Vertec (facing away from the device), either on the right or left side so that the leaves of the vertex were alongside his upper dominant limb. The participant then reached with the right/left hand to touch the vertex leaves at the highest point possible (with heels of the feet on the ground), and this point was recorded as 'reaching height'. Standing in the same position and using a two-footed take-off, the participant then flexed at the hip and knee joints and used an arm swing to jump as high as possible. At the highest point of the jump the participant touched the leaves and this point was recorded as 'jumping height' in cm. The score for the jump is the difference between the reaching height and the JH. The highest JH of two separate trials (with two minutes rest between trials) was recorded as the player's maximum score. It should be noted that if the participant took any form of step or shuffle prior to the jump, the score was rendered invalid.[94]

3.4.2.2 10 m and 40 m sprint test

The purpose of this test was to determine the participant's time taken to cover 10 m and 40 m from a stationary position. Equipment needed: photoelectric sensors, electronic sprint time gate (Smartspeed, Fusion Sport), marking cones and tape measure. A standardised 15-minute warm-up was undertaken before this test was conducted, as it required the participant to produce an all-out effort. For these tests, as described by Ellis *et al.*[94], an electronic sprint time gate with photoelectric sensors was set at hip height and placed at 0 m, 10 m and 40 m intervals and 1.5 m width between sensor and reflector from the start line. The participant was instructed to position him/herself in a crouched start position, 30 cm from the start line. The participant sprinted maximally for 40 m through the sensors. The participant completed two maximum effort runs separated by a three minute recovery period.[94] The fastest times of two trials were recorded in seconds for each 10 m and 40 m sprint times.

3.4.2.3 5-0-5 agility test

The 5-0-5 agility test (5-0-5) measured the participant's ability to make a right and left turn over five metres as quickly as possible (change of direction speed). Equipment needed: cones, tape measure, photoelectric sensors (timing gates, Smartspeed, Fusion Sport) and non-slippery flat surface. Two testers aligned cones at 0 m, 5 m and 15 m perpendicular to a horizontal line which was set and marked with cones. Once one sprint line was measured, the testers measured another alongside this approximately 1.5 m apart to create a running lane for the participant. The timing gates (photoelectric sensors) were then aligned with measured cones and set up as per the system required as shown in Figure 3.1. The participant started from 15 m away from the horizontal line, which is perpendicular to the participant. The participant was instructed to sprint maximally to the horizontal line, first turning on their right foot by placing this foot on the line or over it and turning to sprint back to the starting cone line. The same was done for the left foot turn with approximately three-minute intervals apart. It is important to note that no turn was recorded if the foot was not placed on the line or over it, that is, if the participant turned short of the line. An extra tester was present on this line watching for this common error. The fastest times for both lower limbs (left and right) was recorded in seconds.[95]

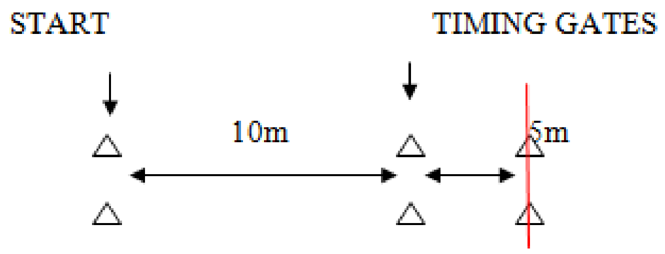

Figure 3.1 5-0-5 Agility Test (adapted from Tanner and Gore.[95])

3.4.2.4 YO-YO intermittent recovery test level 1

The YO-YO intermittent recovery test level 1 (YO-YO) was used to assess the ability to undertake intermittent exercise. As described by Krustrup *et al.*[16] and Bangsbo *et al.*,[17] the test evaluated an individual's ability to repeatedly perform intermittent interval runs over a prolonged period of time. The test starts at 13 km/hr. Equipment needed: 25 m flat non-slippery surface, an audio system with the test recorded, measuring tape, marker cones and recording sheets. As suggested, the tester to athlete ratio was at least 1:4. Cones were used to mark out three lines at 0 m, 5 m and 25 m to form two zones (see Figure 3.2): a 20 m zone (running zone) and a 5 m zone (recovery zone). Before the test began, instructions were given on the test and the warning procedures (listed below).

The lead tester had sufficient help aligned across the two end lines of the test to cope with the number of participants within the testing squad. The test was divided into stages. Each stage consisted of a pair of 20 m shuttle runs (between B & C) followed by 10 seconds of active recovery (between A and B). The participant lined up on or behind the start/finish line (B). When signalled by the audio (on the beep), the participant began running to the 20 m line (C). The participant signalled by the audio beep turned (at C) and returned to the starting point (B). So, the participant ran 20 m out, touched the outbound line with their foot (one foot on or over the line), and ran 20 m back without stopping. This was done in time with the beeps (i.e. the participant had to try and pace each level of speed). After each 20 m out and 20 m back shuttle there was an active recovery period (10 seconds), during which the participant had to walk or jog to line (A) and return to the starting line (B), before the next stage began. The participant would return to the start/finish line and await the cue for the next stage. Each participant kept pace with the audio cues in order for the test to continue.

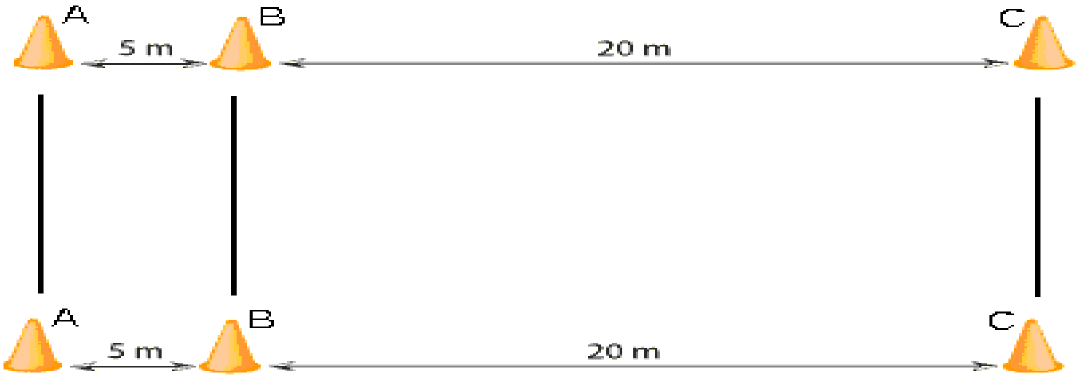

Figure 3.2 YO-YO intermittent recovery test level 1 (As described by Krustrup *et al.*[16] and Bangsbo *et al.*[17])

Warnings: a warning was given when the participant did not complete a successful out and back shuttle in the allocated time, and the participant was removed the next time they did not complete a successful shuttle. No participant could commence running before the audio beep sounded for the start of each stage (a warning was given for athletes who left early).

The participant had to complete the given distance, however, no matter where the pacing beep was heard. If a participant failed to keep pace with the audio cues, used a running start on any stage (i.e. failed to be set at the start/finish line before the beep) or failed to touch the outbound line with his foot, he was assigned a warning. On the second consecutive warning, the test was over for that participant. The participant score was the speed level reached (and corresponding total distance accumulated recorded in metres) before the participant was unable to keep up with the recording or voluntarily withdrew from the test.[16-17]

3.5 Ethical considerations

Prior to the commencement of the study, the principle researcher Mr B. Maluleke submitted the research protocol for the current study to the Ethics Committee of the Faculty of Health Science at the University of Pretoria for approval. Ethical approval for the study was obtained from the Ethics Committee of the Faculty of Health Sciences at the University of Pretoria (see Annexure 15). All the potential participants were invited to an information session to ensure that all research participants fulfilled all the necessary aforementioned inclusion criteria. During the information session, the participants received comprehensive information above the purpose and procedures of the study.[96] The participants received detailed information regarding their rights as participants, confidentiality, ethical approval, informed consent, benefits, risks and study withdrawal procedures. The participants were also informed that any assessments conducted in this research study would not influence team selection as the results were not made known to the coaching staff during the course of the study.

3.5.1 Informed consent and confidentiality

Once the aforementioned was complete, time was then allocated for potential participants to ask any questions related to the current research study. Those who willingly volunteered to be research participants provided written informed consent (See Annexure 2 of informed consent given to the participants). Participants' confidentiality was maintained through the use of a numbering system whereby each participant was referred to throughout the study. The participants' names were only recorded on the master sheet that was used to randomly allocate numbers to the participants as "athlete codes" as well as on their consent forms, which could only be linked to their results by the principle researcher. The master sheet or document containing each participant's name and details was stored away in a locked cabinet and a copy was stored within a secure password protected desktop.[96]

3.5.2 Risks and benefits of the study

The nature of the current research is such that participants were at risk of possible harm to their musculoskeletal and cardiorespiratory system, to name just two examples, as a result of participating in maximum physical performance tests. Participants were also exposed to some form of discomfort or feelings of fatigue; however, the participants were familiar with all physical performance tests and the intensity was less than that of a training/match. Immediate first aid care by a qualified professional was available if participants required any assistance.

With regard to benefits from this study, these include possible gain of scientific knowledge that will benefit all parties involved in soccer through providing players, coaches and sport scientists with a basis for future training program design as well as guidelines for athlete monitoring and physical performance tests. After the course of the study, individual participants were provided with their current physical performance test scores and total well-being scores. In addition, the members of coaching staff were given feedback about the findings of the study and current best practice for athlete monitoring.

3.6 Data collection

Data quality relied on the participant delivering a maximum effort performance during testing and completing the questionnaire as instructed. To enhance the validity and reliability of the study, a familiarisation session was carried out a week prior to the first testing session to ensure that the participants understood the questionnaire and were familiar with physical performance test requirements. The study was conducted over a period of two weeks, on three consecutive Mondays referred to as testing observation one (T_1), testing observation two (T_2) and testing observation three (T_3). The testing protocols were standardised and carried out on the same time of the day, 5pm on each Monday. Questionnaires were completed physically on paper 30 minutes before the physical performance tests at each testing session. The vertical jump test was conducted first without warm-up; then, a 15-minute warm-up was conducted before participants took part in the 10 m and 40 m sprint, 5-0-5 and YO-YO tests. The warm-up was composed of light to moderate aerobic drills, followed by dynamic stretching and finished off with moderate to 90% perceived effort sprints to mimic the intensity of the physical performance tests. The participants were given a three-minute resting period between attempts of each physical performance test.

The players had four on-field team practice sessions (± 120 minutes) per week, and on Saturdays they played a 90-minute practice match. Sundays were passive rest and recovery days during the course of the study. The participants rated each component of well-being using a Likert scale (very low, low, average, high and very high). Numerical scores were computed thereafter (see Table 3.2) and the sum of the six components was calculated out of 30 as the total well-being score (TWS). Once the well-being questionnaire was completed, the participants engaged in the physical performance tests. Table 3.4 shows a summary of each variable recorded at each testing observation.

3.7 Data analysis

Once both physical performance test scores and well-being scores for each variable were recorded, the percentage change scores were calculated for each variable between comparative testing observations: T_2 and T_1, T_3 and T_2 and T_3 and T_1 (see Table 3.4).

The percentage change (C) for each variable was calculated as follows:

$$C_1 = \frac{x_2 - x_1}{x_1} \times 100$$

$$C_2 = \frac{x_3 - x_2}{x_2} \times 100$$

$$C_3 = \frac{x_3 - x_1}{x_1} \times 100$$

With x defined as the measured variables in Table 3.4

$$x_1 = Measured\ Variable\ @\ T_1$$

$$x_2 = Measured\ Variable\ @\ T_2$$

$$x_3 = Measured\ Variable\ @\ T_3$$

Once the percentage change between testing observations for each variable was calculated, the data was transferred to a spreadsheet for analysis. A correlation analysis was used to quantify and describe the nature and strength of the relationship between changes in well-being scores and changes in physical performance test scores. The Spearman's correlation coefficient was determined for the three comparative pairs (T_2 and T_1, T_3 and T_2, T_3 and T_1) using SPSS (IBM). The strength of the correlations was described using the following thresholds: 0–0.1 is trivial, 0.1–0.3 is small, 0.3–0.5 is moderate, 0.5–0.7 is large, 0.7–0.9 is very large, and 0.9–1.0 is nearly perfect.[97] All results were recorded and conclusions confirming or rejecting whether a relationship between changes in well-being scores and changes in physical performance test scores were made.[97]

Table 3.4 Total well-being scores and physical performance test scores variables

	T_1 = Testing observation 1	T_2 = Testing observation 2	T_3 = Testing observation 3
Fatigue score (FS)	FS_1	FS_2	FS_3
Energy levels score (ELS)	EL_1	EL_2	EL_3
Stress score (SS)	S_1	S_2	S_3
Motivation score (MS)	M_1	M_2	M_3
Muscle soreness score (MSS)	SN_1	SN_2	SN_3
Sleep quality score (SQS)	SQ_1	SQ_2	SQ_3
Total well-being score (TWS)	TWS_1	TWS_2	TWS_3
Vertical Jump test (VJ)	VJ_1	VJ_2	VJ_3
10 m sprint test (10 m)	10 m_1	10 m_2	10 m_3
40 m sprint test (40 m)	40 m_1	40 m_2	40 m_3
505 agility test (5-0-5)	$5\text{-}0\text{-}5_1$	$5\text{-}0\text{-}5_2$	$5\text{-}0\text{-}5_3$
YO-YO	$YOYO_1$	$YOYO_2$	$YOYO_3$

T_1 = Testing observation 1, T_2 = Testing observation 2, T_3 = Testing observation 3, FS = fatigue score, ELS = energy levels score, SS = stress score, MS = motivation score, MSS = muscle soreness score, SQS = sleep quality score, TWS = total well-being score, 10 m = 10 m sprint test, 40 m = 40 m sprint test, 5-0-5 = 5-0-5 agility test, YO-YO = YO-YO intermittent recovery test level 1.

3.8 Conclusion

This chapter discussed the study methods that were used to investigate the relationship between changes in well-being and changes in physical performance test scores in student soccer players. The aim and objectives of the study provided the guidelines about the study design, sampling approach, data collection and analysis. An observational longitudinal cohort research design was utilised in which participants were recruited through a convenience sampling approach. Ethical approval was obtained from the University of Pretoria's Health Science Ethics Committee and the research was conducted accordingly.

CHAPTER 4: RESULTS

4.1 Introduction

This chapter focuses on descriptive statistics of the sample population and results obtained from statistical analysis conducted on the sample population. The descriptive summary of the demographic information, physical performance test scores and well-being scores are followed by the results of the correlation analysis.

4.2 Demographic information

Thirteen players participated in at least two testing observations and were therefore included in the analysis. Not all participants were present at all three testing observations (testing observation one: T_1, testing observation two: T_2, and testing observation three: T_3), hence the data were included for participants who attended both testing observations in each comparative pair (i.e. both T_1 and T_2, both T_2 and T_3, or both T_1 and T_3). The descriptive statistics in Table 4.1 show the demographic information of the participants who completed each pair of testing observations. Across the three pairs of testing observations, the mean number of years playing competitive soccer ranged from 6.5 ± 1.5 to 7.9 ± 1.4 years, mean body mass ranged from 66.2 ± 10.0 to 69.5 ± 8.8 kg, and mean stature ranged from 168.9 ± 7.4 to 172.9 ± 8.9 cm.

Table 4.1 Demographic information of participants

	Demographics	Mean	SD	Minimum	Maximum
T_1 and T_2 (n = 6)	Age (y)	19.3	1.8	18.0	22.0
	Stature (cm)	171.4	6.1	163.1	181.7
	Mass (kg)	66.2	10.0	54.3	80.9
	TF (d/wk)	4.0	0.0	4.0	4.0
	TD (min)	110.0	15.5	90.0	120.0
	P. age (y)	6.5	1.5	5.0	9.0
T_2 and T_3 (n = 7)	Age (y)	19.6	1.5	18.0	22.0
	Stature (cm)	172.9	8.9	163.1	193.2
	Mass (kg)	69.5	8.8	54.3	80.5
	TF (d/wk)	4.0	0.0	4.0	4.0
	TD (min)	105.0	13.0	90.0	120.0
	P. age (y)	7.6	1.0	7.0	9.0
T_1 and T_3 (n = 7)	Age (y)	20.0	2.2	18.0	23.0
	Stature (cm)	168.9	7.4	160.4	185.0
	Mass (kg)	65.1	9.2	54.3	81.5
	TF (d/wk)	4.0	0.0	4.0	4.0
	TD (min)	108.8	15.5	90.0	120.0
	P. age (y)	7.9	1.4	6.0	10.0

SD = standard deviation; T_1 = test observation 1; T_2 = test observation 2; T_3 = test observation 3; n = number of participants in the sample; TF = training frequency; d/wk = days per week; TD = training duration; P. age = number of years playing competitive soccer.

4.3 Physical performance test and well-being scores

The descriptive statistics that follow show the physical performance test scores and well-being scores information of the participants who completed each pair of testing observations.

4.3.1 Physical performance test scores

The summary statistics in Table 4.2 to Table 4.4 show the physical performance test scores of the participants who completed each pair of testing observations. Between T_2 and T_3 ($n = 7$) mean jump height was 60.8 ± 7.5 cm, between T_1 and T_2 ($n = 6$) mean 40 m sprint test was 5.36 ± 0.15 seconds, and between T_1 and T_3 ($n = 7$) mean YO-YO distance was 1875 ± 449 m.

Table 4.2 Physical performance test scores of participants completing T_1 and T_2 ($n = 6$)

Test observation	Tests	Median	IQR	Mean	SD	Min.	Max.
T_1	JH (cm)	59.0	8.0	58.3	5.6	52.0	66.0
	10 m (s)	1.77	0.04	1.78	0.04	1.74	1.85
	40 m (s)	5.46	0.19	5.44	0.14	5.24	5.61
	5-0-5 L (s)	2.46	0.22	2.53	0.23	2.34	2.94
	5-0-5 R (s)	2.46	0.17	2.44	0.14	2.26	2.65
	YO-YO (m)	1520	800	1593	516	1000	2240
T_2	JH (cm)	59.0	5.0	58.3	5.0	50.0	64.0
	10 m (s)	1.80	0.06	1.81	0.04	1.76	1.86
	40 m (s)	5.35	0.24	5.36	0.15	5.16	5.53
	5-0-5 L (s)	2.18	0.06	2.22	0.12	2.11	2.44
	5-0-5 R (s)	2.24	0.10	2.27	0.18	2.07	2.60
	YO-YO (m)	1480	520	1500	455	1000	2240

SD = standard deviation; IQR = interquartile range; Min. = minimum; Max. = maximum; T_1 = test observation 1; T_2 = test observation 2; JH = jump height; 10 m = 10 m sprint test; 40 m = 0–40 m sprint test; 5-0-5 L = 5-0-5 agility test turning using the left leg; 5-0-5 R = 5-0-5 agility test turning using the right leg; YO-YO = YO-YO intermittent recovery test level 1 distance covered.

Table 4.3 Physical performance test scores of participants completing T_2 and T_3 ($n = 7$)

Test observation	Tests	Median	IQR	Mean	SD	Min.	Max.
T_2	JH (cm)	58.0	7.0	58.0	5.0	50.0	64.0
	10 m (s)	1.75	0.07	1.76	0.06	1.70	1.86
	40 m (s)	5.30	0.17	5.30	0.14	5.12	5.52
	5-0-5 L (s)	2.25	0.12	2.27	0.11	2.11	2.44
	5-0-5 R (s)	2.36	0.16	2.32	0.17	2.07	2.60
	YO-YO (m)	1240	540	1280	543	400	2240
T_3	JH (cm)	59.0	10.0	60.8	7.5	52.0	72.0
	10 m (s)	1.70	0.13	1.71	0.08	1.62	1.83
	40 m (s)	5.24	0.29	5.29	0.21	5.05	5.67
	5-0-5 L (s)	2.33	0.12	2.36	0.15	2.16	2.61
	5-0-5 R (s)	2.34	0.22	2.35	0.15	2.17	2.62
	YO-YO (m)	1320	500	1205	345	760	1760

SD = standard deviation; IQR = interquartile range; Min. = minimum; Max. = maximum; T_2 = test observation 2; T_3 = test observation 3; JH = jump height; 10 m = 10 m sprint test; 40 m = 0–40 m sprint test; 5-0-5 L = 5-0-5 agility test turning using the left leg; 5-0-5 R = 5-0-5 agility test turning using the right leg; YO-YO = YO-YO intermittent recovery test level 1 distance covered.

Table 4.4 Physical performance test scores of participants completing T_1 and T_3 (n = 7)

Test observation	Tests	Median	IQR	Mean	SD	Min.	Max.
T_1	JH (cm)	58.0	3.5	57.0	6.3	46.0	68.0
	10 m (s)	1.75	0.03	1.75	0.04	1.69	1.80
	40 m (s)	5.40	0.20	5.39	0.12	5.21	5.54
	5-0-5 L (s)	2.42	0.16	2.51	0.21	2.34	2.94
	5-0-5 R (s)	2.41	0.23	2.42	0.16	2.23	2.65
	YO-YO (m)	1840	420	1875	449	1000	2480
T_3	JH (cm)	58.0	8.0	59.5	8.6	50.0	78.0
	10 m (s)	1.70	0.08	1.74	0.10	1.64	1.96
	40 m (s)	5.30	0.20	5.37	0.17	5.21	5.72
	5-0-5 L (s)	2.30	0.08	2.32	0.13	2.16	2.61
	5-0-5 R (s)	2.28	0.11	2.33	0.14	2.21	2.62
	YO-YO (m)	1620	520	1655	328	1280	2080

SD = standard deviation; IQR = interquartile range; Min. = minimum; Max. = maximum; T_1 = test observation 1; T_3 = test observation 3; JH = jump height; 10 m = 10 m sprint test; 40 m = 40 m sprint test; 5-0-5 L = 5-0-5 agility test turning using the left leg; 5-0-5 R = 5-0-5 agility test turning using the right leg; YO-YO = YO-YO intermittent recovery test level 1 distance covered

4.3.2 Well-being scores

The descriptive statistics in Table 4.5 to Table 4.7 show the well-being scores of the participants who completed each pair of testing sessions. Between T_1 and T_2 mean TWS ranged between 14.0 ± 2.6 to 18.0 ± 4.1, between T_2 and T_3 mean TWS ranged between 16.4 ± 2.6 to 17.6 ± 2.1, and between T_1 and T_3 mean TWS ranged between 14.0 ± 3.0 to 15.6±2.6.

Table 4.5 Well-being scores of participants completing T_1 and T_2 (n = 6)

Test observation	Well-being	Median	IQR	Mean	SD	Min.	Max.
T_1	Fatigue	2.5	1.0	2.5	1.1	1.0	4.0
	Energy	3.0	0.7	2.7	0.5	2.0	3.0
	Stress	2.5	1.0	2.7	0.8	2.0	4.0
	Motivation	1.5	1.8	1.8	1.0	1.0	3.0
	Soreness	2.0	1.5	2.0	0.9	1.0	3.0
	Sleep	2.0	0.8	2.3	0.5	2.0	3.0
	TWS	13.5	3.3	14.0	2.6	11.0	18.0
T_2	Fatigue	3.5	1.0	3.5	0.6	3.0	4.0
	Energy	3.0	1.5	3.0	0.9	2.0	4.0
	Stress	3.0	0.8	3.0	1.1	1.0	4.0
	Motivation	2.5	1.0	2.3	0.8	1.0	3.0
	Soreness	2.5	1.8	2.7	1.2	1.0	4.0
	Sleep	3.5	1.0	3.5	0.6	3.0	4.0
	TWS	19.5	5.5	18.0	4.1	12.0	22.0

SD = standard deviation; IQR = interquartile range; Min. = minimum; Max. = maximum; T_1 = test observation 1; T_2 = test observation 2; TWS = total well-being score

Table 4.6 Well-being scores of participants completing T_2 and T_3 (n = 7)

Test observation	Well-being	Median	IQR	Mean	SD	Min.	Max.
T_2	Fatigue	3.0	0.0	3.0	0.5	2.0	4.0
	Energy	3.0	1.0	2.6	0.5	2.0	3.0
	Stress	3.0	1.0	2.5	0.8	1.0	3.0
	Motivation	2.0	1.0	2.3	0.7	1.0	3.0
	Soreness	2.5	1.3	2.6	1.1	1.0	4.0
	Sleep	3.0	1.0	3.4	0.5	3.0	4.0
	TWS	17.0	1.5	16.4	2.6	12.0	21.0
T_3	Fatigue	3.0	0.3	3.3	0.5	3.0	4.0
	Energy	3.0	0.0	3.0	0.0	3.0	3.0
	Stress	2.0	1.3	2.6	0.9	2.0	4.0
	Motivation	3.0	1.0	2.6	0.9	1.0	4.0
	Soreness	2.5	1.0	2.6	0.7	2.0	4.0
	Sleep	3.5	1.0	3.5	0.5	3.0	4.0
	TWS	17.5	2.5	17.6	2.1	15.0	21.0

SD = standard deviation; IQR = interquartile range; Min. = minimum; Max. = maximum; T_2 = test observation 2; T_3 = test observation 3; TWS = total well-being score.

Table 4.7 Well-being scores of participants completing T_1 and T_3 (n = 7)

Test observation	Well-being	Median	IQR	Mean	SD	Min.	Max.
T_1	Fatigue	2.5	1.0	2.4	0.7	1.0	3.0
	Energy	2.0	1.0	2.3	0.7	1.0	3.0
	Stress	2.5	1.3	2.8	1.3	1.0	5.0
	Motivation	1.5	1.3	1.8	0.9	1.0	3.0
	Soreness	2.0	1.3	1.9	0.8	1.0	3.0
	Sleep	3.0	0.3	3.0	0.9	2.0	5.0
	TWS	13.5	5.3	14.0	3.0	10.0	18.0
T_3	Fatigue	3.0	0.3	2.9	0.6	2.0	4.0
	Energy	3.0	0.0	3.1	0.4	3.0	4.0
	Stress	2.0	0.3	2.4	1.2	1.0	5.0
	Motivation	2.0	1.3	2.1	0.8	1.0	3.0
	Soreness	2.0	0.3	2.3	0.9	1.0	4.0
	Sleep	3.5	2.3	2.9	1.4	1.0	4.0
	TWS	15.5	2.0	15.6	2.6	12.0	20.0

SD = standard deviation; IQR = interquartile range; Min. = minimum; Max. = maximum; T_1 = test observation 1; T_3 = test observation 3; TWS = total well-being score.

4.4 Changes in physical performance test and well-being scores

The statistics in Table 4.8 and 4.9 show the percentage change in physical performance test and well-being scores of each comparative pair (T_1 and T_2, T_2 and T_3, T_1 and T_3) between testing observations. Across all physical performance test, the largest percentage change score observed was 12.0 ± 4.7 % for the 5-0-5 agility test between T_1 and T_2. The percentage change in well-being scores were much higher, with the maximum being 63.9 ± 76.3 % for fatigue score between T_1 and T_2.

Table 4.8 Percentage change in physical performance test scores; mean (SD)

	Percentage Change		
Physical Performance Tests	T_1 and T_2 (n = 6)	T_2 and T_3 (n = 7)	T_1 and T_3 (n = 7)
JH (cm)	0.5 (10.5)	3.8 (7.5)	4.5 (10.6)
10 m (s)	1.5 (2.0)	-2.1 (5.2)	-0.3 (5.1)
40 m (s)	-1.5 (0.6)	0.3 (2.3)	-0.4 (2.0)
5-0-5 L (s)	12.0 (4.7)	-5.0 (5.4)	7.1 (5.3)
5-0-5 R (s)	-6.9 (4.1)	2.6 (4.4)	-3.5 (5.6)
YO-YO (m)	0.2 (31.5)	6.5 (46.6)	-6.7 (27.4)

SD = standard deviation; T_1 = test observation 1; T_2 = test observation 2; T_3 = test observation; n = number of participants in the sample; 3; JH = jump height; 10 m = 10 m sprint test; 40 m = 40 m sprint test; 5-0-5 L = 5-0-5 agility test turning using the left leg; 5-0-5 R = 5-0-5 agility test turning using the right leg; YO-YO = YO-YO intermittent recovery test level 1 distance covered.

Table 4.9 Percentage change in well-being scores; mean (SD)

	Percentage Change		
Well-being	T_1 and T_2 (n = 6)	T_2 and T_3 (n = 7)	T_1 and T_3 (n = 7)
Fatigue	63.9 (76.3)	13.5 (38.3)	40.5 (34.5)
Energy	11.1 (17.2)	18.8 (25.9)	54.2 (62.8)
Stress	15.3 (42.3)	16.7 (56.3)	-5.4 (38.4)
Motivation	41.7 (49.2)	18.8 (37.2)	31.3 (45.8)
Soreness	44.4 (77.9)	16.7 (52.0)	31.3 (49.2)
Sleep	55.6 (39.0)	6.3 (24.7)	-0.42 (54.4)
TWS	28.5 (18.6)	9.5 (16.8)	14.5 (21.6)

SD = standard deviation; T_1 = test observation 1; T_2 = test observation 2; T_3 = test observation 3; n = number of participants in the sample; TWS = total well-being score.

4.5 Correlation between changes in physical performance test and well-being scores

4.5.1 Jump height and well-being

The correlations between changes in JH scores and changes in well-being scores are shown in Table 4.10. For JH and fatigue percentage change scores, there was a nearly perfect positive correlation between T_1 and T_2 (r = 0.986, p < 0.001), and moderate positive correlations between T_1 and T_3 (r = 0.487, p = 0.268) and between T_2 and T_3 (r = 0.337, p = 0.460). For JH and energy percentage change scores, there was a moderate negative correlation between T_1 and T_2 (r = -0.414, p = 0.414); however, there was a moderate positive correlation between T_1 and T_3 (r = 0.394, p = 0.382) and a large positive correlation between T_2 and T_3 (r = 0.510, p = 0.243). For JH and motivation percentage change scores, there was a nearly perfect negative correlation between T_1 and T_2 (r = -0.926, p = 0.008).

For JH and soreness percentage change scores, there was a very large positive correlation between T_1 and T_2 ($r = 0.772$, $p = 0.072$). For JH and sleep percentage change scores, there were moderate positive correlations between $T_1 – T_2$ ($r = 0.353$, $p = 0.492$) and between T_2 and T_3 ($r = 0.331$, $p = 0.469$); however, there was a very large negative correlation between T_1 and T_3 ($r = -0.793$, $p = 0.033$). For JH and TWS percentage change scores, there was a moderate positive correlation between T_1 and T_2 ($r = 0.486$, $p = 0.329$).

Table 4.10 Correlation between changes in jump height and well-being scores

Well-being	Jump height					
	T_1 and T_2 (n = 6)		T_2 and T_3 (n = 7)		T_1 and T_3 (n = 7)	
	r	*p*	*r*	*p*	*r*	*p*
Fatigue	0.986	0.000	0.337	0.460	0.487	0.268
Energy	-0.414	0.414	0.510	0.243	0.394	0.382
Stress	0.188	0.824	0.019	0.968	0.158	0.736
Motivation	-0.926	0.008	0.090	0.848	-0.267	0.562
Soreness	0.772	0.072	0.019	0.969	0.075	0.873
Sleep	0.353	0.492	0.331	0.469	-0.793	0.033
TWS	0.486	0.329	0.291	0.527	0.000	1.000

n = number of participants in the sample; T_1 = test observation 1; T_2 = test observation 2; T_3 = test observation 3; TWS = total well-being score.

4.5.2 Sprint test and well-being

The correlations between changes in 10 m sprint test and well-being scores are shown in Table 4.11. For 10 m sprint test and fatigue percentage change scores, there was a large negative correlation between T_1 and T_2 ($r = -0.551$, $p = 0.257$). For 10 m sprint test and energy percentage change scores, there were large and very large negative correlations between T_1 and T_3 ($r = -0.517$, $p = 0.235$) and between T_2 and T_3 ($r = -0.866$, $p = 0.012$). For 10 m sprint test and stress percentage change scores, there was a moderate negative correlation between T_1 and T_2 ($r = -0.500$, $p = 0.312$).

For 10 m sprint test and motivation percentage change scores, there were moderate positive correlations between T_1 and T_2 ($r = 0.463$, $p = 0.355$) and between T_2 and T_3 ($r = 0.356$, $p = 0.433$); however, a moderate negative correlation between T_1 and T_3 ($r = -0.494$, $p = 0.259$) was found. For 10 m sprint test and soreness percentage change scores, there were moderate to large negative correlations between T_2 and T_3 ($r = -0.477$, $p = 0.279$) and between T_1 and T_2 ($r = -0.617$, $p = 0.192$). For 10 m sprint test and sleep percentage change scores, there was a large negative correlation between T_1 and T_2 (r = -0.736, p = 0.096). For 10 m sprint test and TWS percentage change scores, there was a nearly perfect negative correlation between $T_1 – T_2$ (r = -0.943, p = 0.005).

Table 4.11 Correlation between changes in 10 m sprint time and well-being scores

Well-being	10 m sprint time					
	T_1 and T_2 (n = 6)		T_2 and T_3 (n = 7)		T_1 and T_3 (n = 7)	
	r	*p*	*R*	*p*	*r*	*p*
Fatigue	-0.551	0.257	0.134	0.775	-0.245	0.596
Energy	-0.207	0.694	-0.866	0.012	-0.517	0.235
Stress	-0.500	0.312	0.206	0.658	-0.129	0.782
Motivation	0.463	0.355	0.356	0.433	-0.494	0.259
Soreness	-0.617	0.192	-0.477	0.279	-0.198	0.670
Sleep	-0.736	0.096	-0.193	0.679	0.100	0.831
TWS	-0.943	0.005	-0.216	0.641	-0.288	0.531

n = number of participants in the sample; T_1 = test observation 1; T_2 = test observation 2; T_3 = test observation 3; TWS = total well-being score.

The correlations between changes in 40 m sprint test and well-being scores are shown in Table 4.12. For 40 m sprint test and fatigue percentage change scores, there were moderate to very large positive correlations between T_2 and T_3 (r = 0.401, p = 0.373) and between T_1 and T_2 (r = 0.841, p = 0.036). For 40 m sprint test and energy percentage change scores, there were moderate to very large negative correlations between T_1 and T_3 (r = -0.355, p = 0.435), between T_2 and T_3 (r = -0.577, p = 0.175) and between T_1 and T_2 (r = -0.828, p = 0.042). For 40 m sprint test and stress percentage change scores, there was a moderate negative correlation between T_1 and T_2 (r = -0.383, p = 0.454).

For 40 m sprint test and motivation percentage change scores, there was a very large negative correlation between T_1 and T_2 (r = -0.833, p = 0.039), a large negative correlation between T_1 and T_3 (r = - 0.535, p = 0.216) and a moderate positive correlation between T_2 and T_3 (r = 0.356, p = 0.433). For 40 m sprint test and soreness percentage change scores, there was a large positive correction between T_1 and T_2 (r = 0.525, p = 0.285) and there were moderate to large negative correlations between T_2 and T_3 (r = -0.330, p = 0.469) and between T_1 and T_3 (r = -0.505, p = 0.247). For 40 m sprint test and TWS percentage change scores, there was a moderate negative correlation between T_1 and T_3 (r = -0.321, p = 0.482).

Table 4.12 Correlation between changes in 40 m sprint time and well-being scores

Well-being	40 m sprint time					
	T_1 and T_2 (n = 6)		T_2 and T_3 (n = 7)		T_1 and T_3 (n = 7)	
	r	*p*	*r*	*p*	*r*	*p*
Fatigue	0.841	0.036	0.401	0.373	0.037	0.937
Energy	-0.828	0.042	-0.577	0.175	-0.355	0.435
Stress	-0.383	0.454	0.206	0.658	-0.236	0.610
Motivation	-0.833	0.039	0.356	0.433	-0.535	0.216
Soreness	0.525	0.285	-0.330	0.469	-0.505	0.247
Sleep	-0.265	0.612	0.193	0.679	0.180	0.699
TWS	-0.143	0.787	0.072	0.878	-0.321	0.482

n = number of participants in the sample; T_1 = test observation 1; T_2 = test observation 2; T_3 = test observation 3; TWS = total well-being score.

4.5.3 5-0-5 and well-being

The correlations between changes in the 5-0-5 agility test using the left leg (5-0-5 L) and well-being scores are shown in Table 4.13. For 5-0-5 L and fatigue percentage change scores, there was a nearly perfect negative correlation between T1 and T2 (r = -0.986, p < 0.001). For 5-0-5 L and energy percentage change scores, there was a large positive correlation between T1 and T2 (r = 0.621, p = 0.188). For 5-0-5 L and stress percentage change scores, there was a moderate negative correlation between T2 and T3 (r = -0.356, p = 0.434). For 5-0-5 L and motivation percentage change scores, there was a nearly perfect positive correlation between T1 and T2 (r = 0.926, p = 0.008), a very large positive correlation between T1 and T3 (r = 0.757, p = 0.049), and a moderate negative correlation between T2 and T3 (r = -0.401, p = 0.373). For 5-0-5 L and soreness percentage change scores, there was a very large negative correlation between T1 and T2 (r = -0.770, p = 0.072) and a moderate positive correlation between T2 and T3 (r = 0.385, p = 0.393). For 5-0-5 L and TWS percentage change scores, there was a moderate negative correlation between T1 and T2 (r = -0.314, p = 0.544).

The correlations between changes in the 5-0-5 agility test using the right leg (5-0-5 R) and well-being scores are shown in Table 4.14. For 5-0-5 R and fatigue percentage change scores, there were moderate to very large negative correlations between T_1 and T_2 (r = -0.406, p = 0.425), between T_2 and T_3 (r = -0.535, p = 0.216) and between T_1 and T_3 (r = -0.842, p = 0.017). For 5-0-5 R and energy percentage change scores, there was a large negative correlation between T_2 and T_3 (r = -0.577, p = 0.175). For 5-0-5 R and stress percentage change scores, there was a large negative correlation between T_1 and T_2 (r = -0.588, p = 0.219). For 5-0-5 R and motivation percentage change scores, there was a large negative correlation between T_1 and T_3 (r = -0.223, p = 0.631) and a large positive correlation between T_1 and T_2 (r = 0.617, p = 0.192). For 5-0-5 R and soreness percentage change scores, there was a moderate positive correlation between T_1 and T_3 (r = 0.356, p = 0.434). For 5-0-5 R and TWS percentage change scores, there were moderate negative correlations between $T_2 – T_3$ (r = -0.360, p = 0.427) and $T_1 – T_3$ (r = -0.357, p = 0.432).

Table 4.13 Correlation between changes in 5-0-5 L and well-being scores

Well-being	5-0-5 agility test using left leg					
	T_1 and T_2 (n = 6)		T_2 and T_3 (n = 7)		T_1 and T_3 (n = 7)	
	r	*p*	*r*	*p*	*r*	*p*
Fatigue	-0.986	<0.001	-0.134	0.775	0.094	0.842
Energy	0.621	0.188	0.289	0.530	0.217	0.641
Stress	0.147	0.781	-0.356	0.434	0.236	0.610
Motivation	0.926	0.008	-0.401	0.373	0.757	0.049
Soreness	-0.770	0.072	0.385	0.393	0.150	0.749
Sleep	-0.088	0.868	0.039	0.935	0.180	0.699
TWS	-0.314	0.544	-0.108	0.818	0.250	0.589

n = number of participants in the sample; T_1 = test observation 1; T_2 = test observation 2; T_3 = test observation 3; TWS = total well-being score.

Table 4.14 Correlation between changes in 5-0-5 R and well-being scores

Well-being	5-0-5 agility test using right leg					
	T_1 and T_2 (n = 6)		T_2 and T_3 (n = 7)		T_1 and T_3 (n = 7)	
	r	*p*	*r*	*p*	*r*	*p*
Fatigue	-0.406	0.425	-0.535	0.216	-0.842	0.017
Energy	0.207	0.694	-0.577	0.175	-0.158	0.736
Stress	-0.588	0.219	-0.112	0.811	-0.177	0.704
Motivation	0.617	0.192	0.045	0.924	-0.223	0.631
Soreness	0.123	0.816	-0.275	0.550	0.356	0.434
Sleep	-0.235	0.653	-0.501	0.252	0.000	1.000
TWS	0.029	0.957	-0.360	0.427	-0.357	0.432

n = number of participants in the sample; T_1 = test observation 1; T_2 = test observation 2; T_3 = test observation 3; TWS = total well-being score.

4.5.4 YO-YO and well-being

The correlations between changes in YO-YO and well-being scores are shown in Table 4.15. For YO-YO and energy percentage change scores, there was a moderate negative correlation between T_1 and T_2 (r = -0.414, p = 0.414) and a moderate positive correlation between T_1 and T_3 (r = 0.374, p = 0.408). For YO-YO and stress percentage change scores, there was a very large positive correlation between T_1 and T_3 (r = 0.808, p = 0.028). For YO-YO and motivation percentage change scores, there were moderate to large positive correlations between T_2 and T_3 (r = 0.401, p = 0.373) and between T_1 and T_3 (r = 0.535, p = 0.216). For YO-YO and soreness percentage change scores, there was a moderate negative correlation between T_2 and T_3 (r = -0.459, p = 0.300); however, there was a large positive correlation between T_1 and T_3 (r = 0.580, p = 0.172). For YO-YO and sleep percentage change scores, there was a moderate positive correlation between T_1 and T_3 (r = 0.360, p = 0.427). For YO-YO and TWS percentage change scores, there was a large positive correlation between T_1 and T_3 (r = 0.679, p = 0.094).

Table 4.15 Correlation between changes in YO-YO and well-being scores

Well-being	YO-YO intermittent recovery test					
	T_1 and T_2 (n = 6)		T_2 and T_3 (n = 7)		T_1 and T_3 (n = 7)	
	r	*p*	*r*	*p*	*r*	*p*
Fatigue	-0.174	0.742	0.134	0.775	-0.075	0.873
Energy	-0.414	0.414	-0.144	0.758	0.374	0.408
Stress	-0.147	0.781	0.262	0.570	0.808	0.028
Motivation	0.247	0.637	0.401	0.373	0.535	0.216
Soreness	-0.247	0.637	-0.459	0.300	0.580	0.172
Sleep	-0.029	0.956	0.077	0.869	0.360	0.427
TWS	-0.086	0.872	0.198	0.670	0.679	0.094

n = number of participants in the sample; T_1 = test observation 1; T_2 = test observation 2; T_3 = test observation 3; TWS = total well-being score.

4.5.5 Summary of correlation results

The correlation between physical performance test percentage change scores and well-being percentage change scores for each comparative pair of testing observations is shown in table 4.16. Note that a positive correlation between well-being percentage change scores and JH and YO-YO percentage change scores indicates that worse well-being was associated with improved performance, whereas a positive correlation between well-being percentage change scores and 10 m, 40 m and 5-0-5 percentage change scores indicates that worse well-being was associated with impaired performance.

Summary of the relationship between changes in well-being scores and changes in physical performance test scores between each comparative pair of testing observations:

- There was a moderate to nearly perfect positive correlation between JH and fatigue for each of the three comparative pairs. Moderate to large correlations between JH and sleep, and JH and energy were also found in all three comparative pairs; however, the direction of the relationship was inconsistent. Motivation, soreness and TWS only demonstrated moderate to nearly perfect correlations with JH in one of the three comparative pairs, while all correlation between JH and stress were trivial or small.
- A moderate to nearly perfect negative correlation was found between 10 m sprint test and fatigue, energy, stress, soreness, sleep and TWS in one or two of the three comparative pairs. Moderate to large correlations between 10 m sprint test and motivation were also found in all three comparative pairs; however, the direction of the relationship was inconsistent.
- There was a moderate to nearly perfect negative correlation between 40 m sprint test and energy for each of the three comparative pairs. Moderate to nearly perfect correlation between 40 m sprint test and motivation, and 40 m sprint test and soreness was also found in all three comparative pairs; however, the direction of the relationship was inconsistent. A moderate to large negative correlation was found between 40 m sprint test and stress and TWS in one of the three comparative pairs, while all correlations between 40 m sprint test and sleep were trivial or small.
- Moderate to nearly perfect correlation between 5-0-5 L and motivation, and 5-0-5 L and soreness was also found in two or three comparative pairs; however, the direction of the relationship was inconsistent. A moderate to nearly perfect negative correlation was found between 5-0-5 L and fatigue, stress and TWS in one of the three comparative pairs, while all correlations between 5-0-5 L and sleep were trivial or small. A moderate to large positive correlation was found between 5-0-5 L and energy in one of the three comparative pairs.
- There was a moderate to nearly perfect positive correlation between 5-0-5 R and fatigue for each of the three comparative pairs. A moderate to large negative correlation was found between 5-0-5 R and energy, stress, sleep and TWS in one or two of the three comparative pairs. Moderate to large correlations between 5-0-5 R and motivation were also found in two of the three comparative pairs; however, the direction of the relationship was inconsistent. A moderate to large positive correlation was found between 5-0-5 R and soreness in one of the three comparative pairs.

- There was a moderate to large correlation between YO-YO and energy, and YO-YO and soreness in two of the three comparative pairs; however, the direction of the relationship was inconsistent. A moderate to nearly perfect positive correlation was found between YO-YO and stress, sleep and TWS in one of the three comparative pairs. All correlations between YO-YO and fatigue were trivial or small.

Table 4.16 Summary of correlations between physical performance tests and well-being change scores for each comparative pair of testing observations

Well-being	JH			10 m			40 m			5-0-5L			5-0-5R			YO-YO		
	C_1	C_2	C_3	C_1	C_2	C_3	C_1	C_2	C_3	C_1	C_2	C_3	C_1	C_2	C_3	C_1	C_2	C_3
Fatigue	+*	+	+	-			+*	+		-*			-	-	-*			
Energy	-	+	+		-*	-	-*	-	-	+				-		-		+
Stress				-			-				-		-					+*
Motivation	-*			+	+	-	-*	+	-	+*	-	+	+		-		+	+
Soreness	+			-	-		+	-	-	-	+				+		-	+
Sleep	+	+	-*	-										-				+
TWS	+			-*					-	-				-	-			+

JH = jump height, 10 m = 10 m sprint test, 40 m = 40 m sprint test, 5-0-5 L = 5-0-5 agility test using left leg, 5-0-5 R = 5-0-5 agility test using right leg, YO-YO = YO-YO intermittent recovery test level 1, TWS = total well-being score, C_1 *= comparative pair of testing observation 1 and 2,* C_2 *= comparative pair of testing observation 2 and 3,* C_3 *= comparative pair of testing observation 1 and 3, - = moderate to large negative correlation between variables, + = moderate to large positive correlation between variables, -* = very large to nearly perfect statistically significant correlation between variables, +* = very large to nearly perfect statistically significant correlation between variables.*

4.6 Conclusion

In this study, improved JH scores had a moderate to nearly perfect association with worse fatigue ($r = 0.34$ to 0.99; $p = 0.00$ to 0.46), soreness ($r = 0.77$; $p = 0.07$), and TWS ($r = 0.49$; $p = 0.33$) scores, and better motivation ($r = -0.93$; $p = 0.01$) scores. Improved JH scores had a trivial to small association with worse stress ($r = 0.02$ to 0.19; $p = 0.78$ to 0.99) scores, while improved JH scores had inconsistent association with energy and sleep scores. Improved 10 m and 40 m sprint test scores had a moderate to nearly perfect association with worse energy ($r = -0.36$ to -0.87; $p = 0.01$ to 0.94), stress ($r = -0.38$ to -0.50; $p = 0.31$ to 0.45), sleep ($r = -0.74$; $p = 0.10$) and TWS ($r = -0.32$ to -0.94; $p = 0.01$ to 0.48) scores. 10 m and 40 m sprint test scores were inconsistently associated with fatigue, motivation and soreness scores. Improved 5-0-5 scores had a moderate to nearly perfect association with worse fatigue ($r = -0.41$ to -0.99; $p = 0.00$ to 0.43), stress ($r = -0.36$ to -0.59; $p = 0.22$ to 0.43), sleep ($r = -0.50$; $p = 0.25$) and

TWS scores (r = -0.31 to -0.36; p = 0.43 to 0.54). 5-0-5 scores were inconsistently associated with energy, motivation and soreness scores. Improved YO-YO scores had a moderate to large association with worse motivation (r = 0.40 to 0.54; p = 0.22 to 0.37), stress (r = 0.81; p = 0.03), sleep (r = 0.36; p = 0.43) and TWS (r = 0.68; p = 0.09) scores. YO-YO scores were inconsistently associated with fatigue, energy and soreness scores.

The principal finding of this study were that over two weeks of training, in many instances the results demonstrated trivial to small or inconsistent associations between physical performance test scores and well-being scores. However, in some instances, where the results demonstrated moderate to nearly perfect associations, worse well-being scores were associated with improved physical performance test scores. The following chapter provides a detailed interpretation and discussion of the results.

CHAPTER 5: DISCUSSION AND CONCLUSION

5.1 Introduction

The primary aim of this study was to describe the nature and strength of the relationship between changes in well-being scores and changes in physical performance test scores in student soccer players. The principal findings of this study were that over two weeks of training during pre-season, improved JH was associated with better motivation and worse fatigue, soreness and TWS. Faster 10 m and 40 m sprint times were associated with worse energy, stress, sleep and TWS. Faster 5-0-5 time was associated with worse fatigue, stress, sleep and TWS. Longer YO-YO distance was associated with worse motivation, stress, sleep and TWS. However, in many instances, correlations between physical performance tests and well-being measures were trivial or small. Numerous contradicting correlations were also found across all comparative pairs of testing observations. In instances of at least moderate correlations, these tended to be in the direction that indicated an association between improved physical performance and worse well-being. The present chapter will provide a discussion of the main findings of the study in relation to the research objectives and aim. The limitations of the current study, recommendations for future research and a study conclusion will follow.

5.2 Physical performance test scores and well-being scores

As indicated in Chapter 2, section 2.3, performance is affected by several factors. As a result, physical performance tests have been used as a surrogate for on-field performance, as such tests have been shown to be the ultimate indicator of athletes' readiness to perform. Subjective measures of well-being take psychology into perspective and have been shown to respond to acute changes in training load and have been proposed as indicators of athletes' readiness to perform, as individual athletes might respond differently to the same training stimulus.[11] Saw *et al.*[11] suggested athlete-specific subjective measures of well-being (evaluating multiple constructs such as MTDS) as reflectors of performance capacities. In this study, contradicting relationships were found between physical performance test scores and well-being; however, in numerous instances, where there were at least moderate relationships, improved physical performance test scores were associated with worse well-being scores (see Table 4.16).

According to the author's knowledge, this is the first study to investigate the nature and strength of the relationship between changes in well-being scores and changes in physical performance test scores. Therefore, it is difficult to compare the results obtained from this study to those found in other studies. This is due to differing practices among studies particularly with regard to the frequency of administration, response set and rating scales and time taken for data capture and analysis.[21] Subjective self-reported measures of well-being stem from three broad response domains: (1) perceived stress, (2) mood disturbance and (3) behavioural/physical symptoms. Thus, the main findings of this study will be discussed based on these domains.

Perceived stress (1): Rushall[62] was amongst the first to emphasise the importance of monitoring perceived stress during periods of heavy training due to the potential for stress to increase fatigue and decrease performance capabilities. Rushall[62] found that perceived stress increases during periods of heavy training. In the current study, improved 10 m and 40 m sprint tests, 5-0-5 and YO-YO scores were associated with higher perceived levels of stress, which is in contrast to Rushall's[62] view and not consistent with subsequent research found in the literature. Perceived stress has been demonstrated as one of the better indicators of training distress for competitive swimmers.[81] Main *et al.*[22] found significant relationships between perceived stress, immune system functioning, and fatigue and exhaustion among athletes.

Mood disturbance (2): Main and Grove[22] note that when specific elements of mood disturbances are examined, it appears that an increase in depression is often accompanied by an increase in fatigue and a decrease in perceived energy levels. It is therefore not surprising that measures of generalised fatigue and lack of psychological vigour appear to be good indicators of training distress. In the current study, improved 10 m and 40 m sprint test scores were associated with lower perceived energy levels, but contradictory associations were found between physical performance tests: JH, 5-0-5 and YO-YO and perceived levels of energy. In the current study, contradictory findings were observed between physical performance test scores: JH and YO-YO scores and motivation scores. Improved JH was associated with better perceived levels of motivation; however, improved YO-YO scores were associated with worse perceived levels of motivation. This may imply that perceived motivation might fluctuate depending on the type and duration of the physical performance tests.

Behavioural/physical symptoms (3): Fatigue has been shown to result in an altered gait strategy during running,[98] which has been associated with reduced sprint and jump performance.[99] In this study, improved JH and 5-0-5 scores were associated with worse fatigue scores; however, running and jumping techniques were not monitored in this study. In the current study, 10 m and 40 m sprint tests, 5-0-5 and YO-YO scores were associated with poor perceived quality of sleep. Improved JH scores were associated with higher perceived levels of muscle soreness.

In this study, worse perceived well-being measured as TWS was moderately to nearly perfectly associated with improved JH, 10 m and 40 m sprint test performance, 5-0-5 and YO-YO performance during pre-season training. In contrast to the current study, Noon *et al.*[100] found moderate to large deteriorations in perceptions of well-being (motivation, sleep quality, recovery, appetite, fatigue, stress, muscle soreness), a moderate decrease in 30 m sprint performance, a large improvement in Yo-Yo intermittent recovery test performance and small decreases in countermovement jump and arrowhead agility performance with an increase in training exposure as the season progressed in English elite youth footballers across a season. This may be due to the fact that Noon *et al.*[100] assessed perception of well-being using a seven-point scale and that physical performance tests were carried out every six to 13 weeks across the entire season, while the current study was conducted over two weeks (three consecutive Mondays).

Overall, improved physical performance test scores in JH, 10 m and 40 m sprint tests, 5-0-5 and YO-YO tended to be associated with worse perceived well-being (TWS) scores over two weeks of training. This inverse relationship between physical performance test scores and well-being scores may be the result of an effective periodisation plan during pre-season training for student athletes of the University of Pretoria, implying that players were exposed to high training loads (as suggested by observed worse perceived well-being); however, appropriate rest and recovery strategies were implemented for regeneration to occur (thus the observed improved physical performance).

5.3 Measurement properties of physical performance tests and well-being measures

Physical performance tests such as YO-YO, vertical jump and 5-0-5 have been reported to have coefficient variation within and between sessions of about 5 – 8%.[17,101-102] Buchheit *et al.*[103] reported a CV of 6 – 18% between days for well-being measures among elite football players. Thus, it appears that the reliability and sensitivity of physical performance tests is better than that of well-being measures, which may explain why several inconsistent relationships were found between physical performance test scores and well-being scores. In a study by Fitzpatrick *et al.*[104] to establish sensitivity of subjective well-being measures to training-induced fatigue, subjective well-being measures (fatigue, muscle soreness, stress, mood and total wellness score) were unable to detect a reproducible fatigue response, potentially calling into question their use in the monitoring of fatigue in athletes.

The MTDS uses a five-point Likert scale, with one-point increments, which gives a limited number of outcomes that can be selected. A change from one to a score of two may subjectively not be that great to an athlete, however it amounts to a 20% increase.[104] In the current study, mean fatigue change score was 2.5 ± 1.1 in testing observation one while mean fatigue change score for testing observation two was 3.5 ± 0.6, which was a 20% increase (see Table 4.5). The percentage change score between test observation one and two for fatigue change score was 63.9 ± 76.3 (see Table 4.9). Therefore, using a 10-point Likert scale with one-point increments may improve the reliability and sensitivity of these measures by making detectable changes more accessible and hence improving the usefulness of subjective well-being measures.[104]

Lee *et al.*[105] found that when monitoring fatigue and energy using a simple instrument such as a Visual Analogue Scale/Line (using 100 mm lines) may be more appropriate than a Likert Scale as they are easily understood, require very little reading skill, are simple to administer and need little time for completion. Such a tool allows participants to respond with as little bias and as much discrimination as they wish by not restricting participants to arbitrary intervals.[105] Data collected from visual analogue scales/lines does not need to be processed as it is recorded as continuous intervals; however, it is a time-consuming measurement process for research teams, albeit a valid and reliable instrument for assessing fatigue.[105]

The current study was conducted in the pre-season where the aim was to expose athletes to high training loads, thus worse well-being was somewhat anticipated in order to improve overall performance. Patterns in well-being responses are unique to each athlete, and undesirable responses may not necessarily indicate maladaptation. Given the substantial inter-individual variability among athletes, it is important that assessment of well-being should be considered case by case. It appears that well-being measures fluctuate based on the cycle of peaks and troughs within the training cycles, and therefore only lead to changes in fatigue status that are largely representative of previous days' training and not on-the-day performance.

5.4 Training adaptation and readiness to perform

In the current study, worse well-being scores tended to be associated with improved physical performance scores in JH, 10 m and 40 m sprint tests, 5-0-5 and YO-YO, which is in support of the suggestion by Main *et al.*[22] that in the short term, somatic symptoms are likely to serve as an adaptive function and assist with recovery, but their continuous activation over a long period of time may be associated with a variety of training distress problems. Smith *et al.*[106] note that when athletes are mentally fatigued, perceived running at a given speed becomes more effortful. In contrast to these findings, the current study demonstrated that worse perceived well-being was associated with improved physical performance in YO-YO. This may be due to the fact that mental fatigue limits exercise tolerance in humans through higher perception of effort rather than cardiorespiratory and musculoenergetic mechanisms, implying that fitness may mask the effect of fatigue when athletes are experiencing impaired perceived well-being.[106-107]

It is possible that participants of the current study were exposed to high training loads as part of pre-season training, along with psychosocial pressures of being a student athlete and being selected for the inter-collegiate league (Varsity Cup). It may be that impaired well-being is merely a reflection on training and non-training stressors experienced by student athletes but is not related to athletes' readiness to perform. Therefore, in the short term, one should consider monitoring training adaptation and athletes' readiness to perform through physical performance tests.

In addition, it must be remembered that the purpose of training is to induce some form of disruption to the homeostasis state of the body in order for physiological adaptations to occur. Thus, unless the body is challenged with a load that it is not accustomed to, which is likely to manifest as fatigue, then the possibility of training adaptation is significantly reduced.[108] Accordingly, perceived worse well-being scores might be necessary in eliciting physiological adaptations for improved performance in the short term, as demonstrated in this study.

Performance may be influenced by several factors, such as environmental temperature, diet and perceived well-being. When monitoring athletes' readiness to perform, it may be effective and feasible to take multiple measures (objective and subjective) into consideration before making adjustments to training stress, such that an athlete must score below normal on two tests (subjective and objective) before modifying training intensity.

It is important to note that data gathered from both physical performance tests and subjective self-reported measures may be analysed to check for peaks and troughs in performance, and thereby support coaches and sport scientists in making decision about how best to adjust an athlete's training intensity. Turner *et al.*[108] stipulate that data collected from both physical performance tests and subjective self-reported measures may simply act as a prompt, alerting coaches and sport scientists to have a discussion with the athlete regarding training and to reflect on progress.

5.5 Limitations of the study

The first limitation of the study was the lack of compliance by participants in attending testing sessions. Thirteen players participated in the current study and not all of these players were present in all test observations (T_1, T_2 and T_3), i.e., between T_1 and T_2 there were six participants, between T_2 and T_3 there were seven participants and between T_1 and T_3 there were seven participants. This affects the significance of the study, as on average a soccer team is composed of at least 18 players. The second limitation of the study was associated with MTDS as it depended highly on participants' compliance and honesty, thus there is a risk of response distortion with subjective measures of well-being.

5.6 Recommendations for future research

Future research extending this topic is encouraged. Specifically, it is recommended that future research: (1) investigates the relationship between physical performance test scores and well-being scores of soccer players using a large sample population including players at junior, college, semi-professional and professional level; (2) investigates the cause and effect between training loads, well-being, physical performance and on-field performance, and (3) investigates the relationship between biochemical markers, perceived well-being and physical performance during the competition phase.

5.7 Conclusion

This study contributes to the body of knowledge on some of the factors and processes that have been discussed more generally by researchers interested in the connection between performance, stress, recovery, health and well-being. The current study has demonstrated how changes in well-being scores relate to changes in physical performance test scores.

Monitoring athlete well-being through subjective self-reported measures on a regular basis will provide information about athletes' perceived physical and mental state; however, it may not be the most appropriate tool for monitoring athletes' readiness to perform, as worse perceived well-being tended to be associated with improved physical performance in this study. It is important to note that the MTDS was developed to monitor athletes' psycho-behavioural responses to training stimuli.[22] Therefore, MTDS may not be a good indicator for athletes' readiness to perform on a short-term basis. The published literature contains several examples of the systematic use of self-reported well-being measures in relation to training loads, but less in terms of performance predictors or markers of athlete readiness.

The take-home message of this study is that subjective measures of well-being may not be good measures for assessing athletes’ readiness to perform. Thus, physical performance tests are the ultimate indicator of athletes’ readiness to perform in this regard. The findings suggest that during pre-season, worse well-being may be reported; however, athletes’ readiness to perform may not be negatively affected. Coaches and sport scientists should consider measuring both subjective self-reported measures of well-being and physical performance tests, as these measures appear to be measuring two separate concepts.

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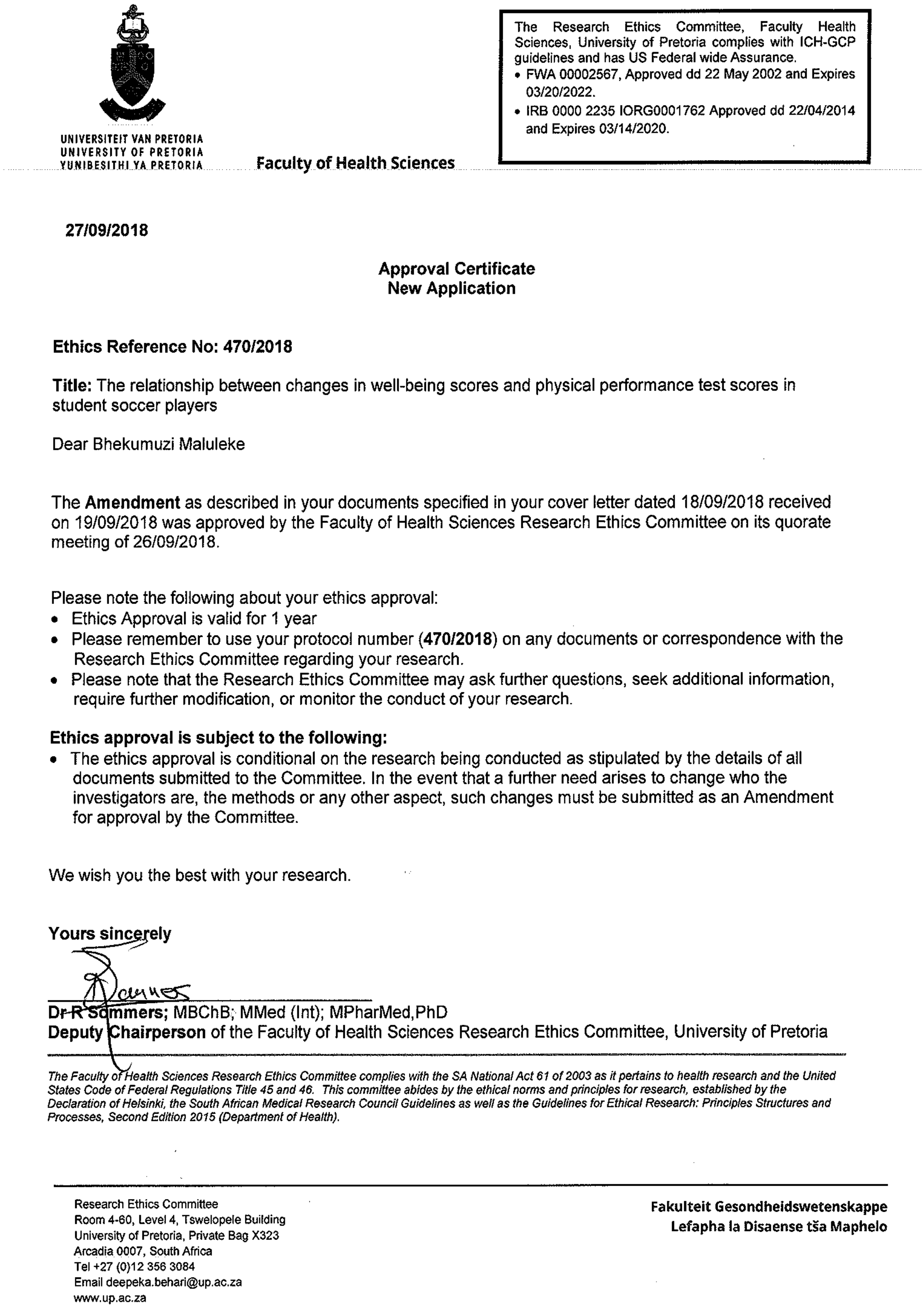
ANNEXURE 1: CONFIRMATION OF ETHICAL APPROVAL



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Health Sciences

The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 22 May 2002 and Expires 03/20/2022.
- IRB 0000 2235 IORG0001762 Approved dd 22/04/2014 and Expires 03/14/2020.

27/09/2018

Approval Certificate
New Application

Ethics Reference No: 470/2018

Title: The relationship between changes in well-being scores and physical performance test scores in student soccer players

Dear Bhekumuzi Maluleke

The **Amendment** as described in your documents specified in your cover letter dated 18/09/2018 received on 19/09/2018 was approved by the Faculty of Health Sciences Research Ethics Committee on its quorate meeting of 26/09/2018.

Please note the following about your ethics approval:

- Ethics Approval is valid for 1 year
- Please remember to use your protocol number (**470/2018**) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, or monitor the conduct of your research.

Ethics approval is subject to the following:

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

Dr R Sommers; MBChB; MMed (Int); MPharMed,PhD
Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health).

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ANNEXURE 2: PARTICIPANT INFORMATION AND INFORMED CONSENT

Student athlete health, well-being and sports performance: A prospective study over 5 years

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ADULT PARTICIPANT INFORMATION AND INFORMED CONSENT DOCUMENT

Introduction

You are invited to volunteer to participate in a research study. This leaflet is to help you to decide if you would like to participate. Before you agree to take part in this study you should fully understand what is involved. If you have any questions that are not fully explained in this leaflet, do not hesitate to contact the investigators.

The nature and purpose of this study

Researchers from the Sport, Exercise Medicine and Lifestyle Institute at the University of Pretoria will conduct a study entitled “Student athlete health, well-being and sports performance: A prospective study over 5 years”. The study aims to identify factors that affect student athlete health (Illness, injury), well-being (psychological status), academic performance and sports performance.

Explanation of procedures to be followed

Your participation in this research study is entirely voluntary. A number of the components described below are part of the routine assessment and monitoring procedures for your sport. Should you agree to participate, you would be asked to give consent to participate in the following components of the study:

Functional movement and musculoskeletal screening assessment: This is a series of tests to assess your movement quality, mobility and strength. The assessment will be completed 1 – 2 times per year by a sport scientist.

Sport-specific physiological testing: Sport scientists conduct a series of tests to assess physiological components that are relevant to your sport, which may include body composition, flexibility, explosive power, muscular strength, muscular endurance, speed, agility, aerobic or anaerobic capacity, or sports-specific performance related tests. You will receive the results of all tests, which may be used by your coaches to inform your training program. The testing will take place 1 – 4 times per year.

Biomechanical analysis: Motion capture techniques, are used to analyze athletic movement qualities and sport-specific technique. These assessments take place 1 – 4 times per year.
Complete an annual online medical history questionnaire. You will be provided with a unique user account to an online athlete management system where the form will be completed, and this will take less than 1 hour in total.

Undergo a standard physical examination, based on recommended procedures for athletes by international bodies such as IOC and FIFA. The examination will be completed annually by a sports physician at the University of Pretoria sports campus. Donate a blood sample (15ml or 3 teaspoons). This sample will be used for the extraction and analysis of genetic material (DNA). The DNA will only be used for scientific research purposes relating to determination of the risk of injuries and illness. Samples will be destroyed on completion of the study.
Complete an illness/injury monitoring questionnaire. Once a week, you will complete a short online questionnaire where you will be asked a few questions about any injuries or illnesses that have occurred. The questionnaire will take no more than 15 minutes to complete.
Physical load and training response monitoring through a daily questionnaire that will take no more than 5 minutes to complete. Complete the Nutritional and Dietary Supplement Assessment monitoring questionnaire once a year. Provide the research team with access to your academic records. All questionnaires may be completed on your personal computer, a computer at the university, a tablet, or a smart phone. If using a tablet or smart phone, it can be completed off-line and uploaded when Wi-Fi connection is available.

Potential risks of this study

The completion of questionnaires or a physical examination is not associated with any risk. Questionnaires and other clinical data (paper and electronic) will be kept confidential and secure, and will not be made available to any party other than the research team without the consent of the individual participant.

Musculoskeletal, physiological and biomechanical assessment requires physical tasks that involve some risk of musculoskeletal injury. However, all tasks will involve similar loads and movements that you engage in during regular training and competition. These types of tests are standard procedure in elite sport. You will be allowed to complete a full warm-up routine of your choice before beginning the testing. All reasonable precautions to reduce the risk of injury will be taken, and all testing will be conducted by appropriately qualified staff.

All medical conditions will be treated as usual by your doctor or physiotherapist, and training will continue as usual under your strength and conditioning trainer.

The potential risks during the 5 ml (1 teaspoon) blood collection include: infection, delayed healing, haematoma, physical pain, mental discomfort and injury to a nerve or a vessel. These risks are small and will be minimized by the use of trained phlebotomists, use of sterile techniques and the use of disposable, single-use materials.

Genetic information: To make sure that your specific genetic information is kept secure and confidential, the following procedures will be adopted: 1) all the blood samples will be labelled on collection using a numerical coding system that is linked to player details on a master list that will be placed in a sealed envelope, 2) this sealed master list will then be kept in a secure facility and in a separate location, 3) only the principle investigator and senior co-investigators will have access to this master list, 4) the master list will only be opened if a sample needs to be destroyed, should a participant request this. All data will be analysed anonymously and DNA samples will be destroyed on completion of the study. Your personal genetic information will not be made known to you, your teammates, team medical staff, coaches, or management. The information will be kept secure, anonymous and will only be used for research purposes. Because this area of research is still in the exploratory phase, we will not be able to provide individual feedback with regard to the results and implications of genetic testing.

You may withdraw from this study at any time without question.

Potential benefits of this study

You will be provided with the results of your musculoskeletal, physiological and biomechanical assessments, which you may share with your coach or strength and conditioning trainer. The research questions that will be addressed by this study have been identified to have a direct impact on improving health, well-being and performance in student athletes. The anticipated benefits of this study are that the results will further our understanding of the possible cause/s of medical conditions and injuries in athletes.

Ethical Approval

This Protocol was submitted to the Faculty of Health Sciences Research Ethics Committee, University of Pretoria (telephone number 012 356 3084) and written approval has been granted by that committee. The study has been structured in accordance with the Declaration of Helsinki (last update: October 2013), which deals with the recommendations guiding doctors in biomedical research involving human/subjects. A copy of the Declaration may be obtained from the investigator should you wish to review it.

Confidentiality

All records obtained whilst in this study will be regarded as confidential. Once we have analyzed the information no one will be able to identify you. Results will be published or presented in such a fashion that participants remain unidentifiable.

Contact

Please feel free to contact a member of the research team or the University of Pretoria Health Sciences Research Office should you have any questions related to the study. You can contact the principal investigator on the following number: (012) 420 1804.

Faculty of Health Sciences - Research Ethics Committee

Tswelopele Building, Level 4, Rooms 4-59 and 4-Faculty of Health
Sciences, Dr Savage Road, Gezina, Pretoria Tel: (012) 356 3084 or (012)
356 3085 Fax: (012) 354 1367

Email: manda.smith@up.ac.za / deepeka.behari@up.ac.za / fhsethics@up.ac.za

University of Pretoria Research Ethics approval number: 83/2016

Consent to participate in this study

I confirm that I have received, read (or had read to me) and understood the above written information regarding the nature, process, risks, discomforts and benefits of the study. I have been given opportunity to submit questions and am satisfied that they have been answered satisfactorily. I agree that research data provided by me or with my permission during the study may be included in a thesis, presented at conferences and published in journals on the condition that neither my name nor any other identifying information is used. I understand that if I do not participate it will not alter my management in any way. I understand that I may withdraw from this study at any time without further question.

I hereby consent to participate in the following components of the study as described in the participant information that I received Please initial under either "yes" or "no" for each component:

	Yes	No
Functional movement and musculoskeletal screening		
Sport-specific testing		
Biomechanical assessment		
Annual Online Medical History Questionnaire		
Annual Medical Screening Examination		
Weekly illness/injury monitoring questionnaire		
Physical load and daily training response monitoring		
Nutritional and Dietary Supplement Assessment		
Genetic component of this study		
Access to my academic records		

Please complete the participant and witness columns:

	Participant	**Witness**	**Investigator**
Name			
Signature			
Date			

ANNEXURE 3: PARTICIPANT QUESTIONNAIRE

Well-being questionnaire (adapted from the multi-component training distress scale score (MTDS))

Investigator
Mr B. Maluleke
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University of Pretoria
Tel: 012 484 1717 x 1760
Email: muzi.maluleke@selmi.co.za

Supervisor
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Email: helen.bayne@up.ac.za

Co-supervisor
Mr J. Clark
Department of Physiology
University of Pretoria
Tel: 012 420 6932
Email: jimmy.clark@up.ac.za

ATHLETE CODE: ________________________________

DATE: ____

Instructions to the athlete

Fatigue: Are you feeling tired, sleepy, worn out?
Energy Levels: Are you feeling energetic, active, alert?
Stress: Are you feeling stressed, under pressure, having difficulty coping? Motivation: Are you feeling motivated, eager?
Soreness: Are you experiencing muscle soreness, heaviness, stiffness?
Sleep quality: Are you falling asleep easily and not experiencing restlessness?

	RATING				
	Very low	Low	Average	High	Very high
Fatigue					
Energy Levels					
Stress					
Motivation					
Soreness					
Sleep Quality					

ANNEXURE 4: PARTICIPANT INSTRUCTIONS

Investigator
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Tel: 012 420 6932
Email: jimmy.clark@up.ac.za

To improve the accuracy of your test results in the study, the following standardized preparations should be adhered to during the study.

Training

Ensure that no severe exercise, new exercise or resistance training exercise is performed in the 24 hours prior to any testing. A day of testing should not include any training before testing. You may continue with scheduled training during the study period as planned by the coaching staff.

Environment

Avoid exposing yourself to dramatic changes in your environmental conditions in the days preceding any. Unaccustomed exposure to different environmental temperatures, pressures, or travel should be limited. For example, refrain from air travel and long drives, sauna, or altitude changes before and during the testing period.

Equipment

You must bring the correct exercise gear and wear light and comfortable clothing. Clothing should permit freedom of movement and appropriate test procedures. Typical soccer training kit is ideal, along with a towel, water bottle and training shoes to jump with.

Health

You must be in good health on each day of testing, and fully recovered from any previous injuries or illnesses. Anything which might limit maximum effort in an exercise test must be mentioned to the investigator and may result in your exclusion from the testing and/or study. Ensure good quality sleep the night before all testing. Where applicable, the normal use of prescription medications should be followed as recommended by your doctor.

Nutrition

In the 24 hours preceding a test, avoid drinking any alcohol. On the day of testing, avoid caffeine containing substances, like tea, coffee, chocolate and cola drinks. No substances should be taken in an attempt to enhance physical performance. You should be well hydrated throughout the day of testing and the day prior to testing by drinking sufficient fluid. Good quality nutrition is essential. Ensure that meals on the days prior to and days of testing are nutritionally balanced and familiar. Avoid any unaccustomed food during the period of the study. The last meal before testing should be around 3 hours before exercise testing. Thereafter, only take water if desired.

ANNEXURE 5: DATA RECORDING FORM

WELL-BEING QUESTIONNAIRE (ADAPTED FROM THE MULTI-COMPONENT TRAINING DISTRESS SCALE SCORE)

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Co-supervisor
Mr J. Clark
Department of Physiology
University of Pretoria
Tel: 012 420 6932
Email: jimmy.clark@up.ac.za

ATHLETE CODE: ___________________________________

DATE: ____

Test observation: _______________________________

Physical Performance Tests

Body mass (kgs):		10m sprint 1 (s):		5-0-5 L 2 (s):	
Stature (cm):		10 m sprint 2 (s):		5-0-5 R 2 (s):	
Standing reach height (cm):		40 m sprint 1 (s):		YO-YO Level (m):	
Jumping reach height 1 (cm):		40 m sprint 2 (s):		YO-YO distance (m):	
Jumping reach height 2 (cm):		5-0-5 L 1 (s):			
Jump height 1 (cm):		5-0-5 R 1 (s):			
Jump height 2 (cm):					