Monitoring the Training Process in Women's Soccer (Football)

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CERTIFICATE OF AUTHORSHIP/ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Abstract

The basis of the present thesis was to assess the validity and reliability of practical monitoring and testing tools that could be used by coaches, sport scientists and players to assist with the development and delivery of individualised training and periodisation programs, with the aim of achieving optimal performance. The aim of this research was to determine the utility of the session-RPE as a tool for monitoring training load (TL) in women's soccer and establish the efficacy of a submaximal Yo-Yo intermittent recovery test to assess aerobic training adaptations.

A major problem for coaches is being able to implement training programs that simultaneously meet the physical and technical/ tactical objectives of both the team and individuals within the team. Therefore, to overcome the limitations associated with team-based training, it has been suggested that a simple system which monitors an individual's training load (TL), and their response to their individual stimulus is required. Furthermore it is possible that if a valid and reliable test that was sensitive to changes in aerobic fitness adaptations was developed and then combined with measures of internal TL, an individual player's response to training could be monitored and the training process improved.

The purpose of the first study was to examine whether the session-RPE method for quantifying internal TL is a valid tool that can be used in women soccer players. The session-RPE, heart rate and session duration were recorded for individual

training sessions and matches over a period of 16 weeks. Session-RPE was then validated by correlation analysis with three commonly used HR-based methods for assessing TL.

The second study examined whether measurements of blood lactate, RPE and HR responses to the 6 min submaximal Yo-Yo intermittent recovery test Level 1 (Yo-Yo $_{submax}$) are repeatable and valid methods of monitoring aerobic adaptations in women soccer players. Ten elite players completed the following laboratory and field tests: maximal oxygen uptake ($\dot{V}O_2max$), lactate threshold velocity (LTV), Multistage Fitness Test (MSFT) and Yo-Yo $_{submax}$. The test-retest reliability of a 6 min Yo-Yo $_{submax}$ was completed by fourteen elite women players.

The third study assessed the sensitivity of physiological and perceptual responses following the 6 min Yo-Yo $_{submax}$ test to markers of aerobic fitness. Nine elite women soccer players completed the MSFT before and after a 14 week early season soccer program. In addition, the players completed a Yo-Yo $_{submax}$ test every four to five weeks during this period. The amount of change (Δ) in the blood lactate concentration $[BLa^-]$, heart rate (HR) and rate of perceived exertion (RPE) responses from the Yo-Yo $_{submax}$ test from the pre to post test occasions were correlated with the amount of change (Δ) in blood lactate, HR and RPE response from maximal field and laboratory-based treadmill tests. Furthermore, the same variables were correlated with training loads (TL) recorded over the 14 weeks.

The main finding in the first study was that the session-RPE method for monitoring TL was valid in women soccer players. Significant correlations were observed across all training types and in particularly aerobic-based training sessions of a less-intermittent nature. In study two and three the validity, sensitivity and repeatability of a submaximal Yo-Yo intermittent recovery test was assessed for use with women soccer players. We found that the test had a moderate level of repeatability and that the physiological variables taken following the Yo-Yo $_{submax}$ related to Multi-Stage Fitness Test (MSFT) performance but not to Lactate Threshold Velocity (LTV). The Yo-Yo $_{submax}$ proved not to be a sensitive tool in assessing changes in aerobic capacity in elite women soccer players. Furthermore we found no correlation between Yo-Yo $_{submax}$ variables and TL.

In conclusion, the results of the present studies suggest session-RPE may be a valid method for assessing internal TL for soccer players. Furthermore, Yo-Yo $_{submax}$ may be a viable method for assessing aerobic capacities in soccer players. However, it is recommended that when this test is used to monitor soccer players, results are interpreted according to the test-retest coefficient of variation result provided in this study.

Keywords

Aerobic fitness

Blood lactate

Heart rate

Internal training load

Periodisation

Soccer training

Submaximal fitness test

Rating of Perceived Exertion

List of Abbreviations

1RM	One repetition max
$[BLa^-]$:RPE	Ratio of blood lactate to rating of perception of effort
CR 10	Category ratio scale
HR	Heart rate
HRmax	Maximal heart rate
HR:RPE	Ratio of heart rate to rating of perceived exertion
HR:$[BLa^-]$	Ratio of heart rate to blood lactate
LT	Lactate threshold
LTV	Lactate threshold velocity
LT_{zone}	Lactate threshold zone
LIST	Loughborough Intermittent Shuttle Test
MSFT	Multistage fitness test
OBLA	Onset of blood lactate accumulation
RPE	Rating of Perceived Exertion
TL	Training Load
TRIMP	Training Impulse
$\dot{V}O_2max$	Maximal oxygen consumption
Yo-Yo IR1	Yo-Yo intermittent recovery test level 1
Yo-Yo $_{submax}$	6min Yo-Yo intermittent recovery test level 1

Chapter 1

Introduction

Background

Optimal performance in high level soccer requires the concurrent development of tactical, technical and physical skills (Stølen, Chamari, Castagna, & Wisløff, 2005). A soccer match is characterised by high-intensity intermittent bouts with only limited recovery periods and taxes both the aerobic and the anaerobic energy systems (Reilly, 1997; Mohr, Krustrup, & Bangsbo, 2003b; Reilly, 2003; Krustrup, Mohr, Ellingsgaard, & Bangsbo, 2005). Due to the intermittent nature of soccer, successful players are required to have a high level of aerobic endurance, while also possessing a well-developed anaerobic capacity which is required to perform skills such as sprinting, jumping and kicking. In addition, high level soccer players also require well-developed technical and tactical abilities. Due to the diverse training demands of top level soccer players, it is imperative that coaches are able to monitor the training loads of individual players within a team so that performance can be optimised.

Training and Playing Demands of Soccer

During a 90 min game it has been reported that elite players cover distances between 10 and 13 km (Ekblom, 1986; Bangsbo, Nørregaard, & Thosøe, 1991; Bangsbo, 1994b; Mohr et al., 2003b; Krustrup et al., 2005; Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2006), with the average work intensity close to the lactate threshold, which is normally between 80-90% of HRmax (Reilly, 1997; Helgerud, Christian Engen, Wisløff, & Hoff, 2001; Reilly, 2003; Stroyer, Hansen, & Klausen, 2004; Impellizzeri, Marcora, Castagna, Reilly, Sassi, Iaia, & Rampinini, 2005a; Stølen et al., 2005). In addition to these aerobic demands, high level players usually perform 1000-1400 short activities, each changing every 4-6 s (Stølen et al., 2005). These short activities consist of between 10-20 brief sprints (< 4 s), high-intensity running approximately every 70 s and an estimated 15 tackles, 10 headings, 50 involvements with the ball and about 30 passes, as well as sustaining forceful contractions to maintain balance and control of the ball against defensive pressure and changing pace (Stølen et al., 2005). Collectively, these previous findings show that many well-developed physical capacities such as high aerobic fitness, speed, strength, power and agility are required for optimal soccer performance. The wide variety of physical demands require that training programs be constructed to develop each of these capacities for both the team and individual players within a team.

Due to the diversity of skills and abilities required during high level soccer, players are required to complete a wide variety of training methods. Previous studies have reported that between 12-20 h per week of training is required for semi-professional (Naessens, Chandler, Kibler, & Driessens, 2000) and professional (Filaire, Lac, & Pequignot, 2003) soccer players. Incorporated within these large training commitments, soccer players play at least one match per week during the competitive season.

A high level of physical and psychological stress is associated with competition (Bangsbo, 1994b; Reilly & Gilbourne, 2003). These training and competition demands place significant physical and psychological stress on players, which can lead to reduced performance or in severe cases illness, injury or even overtraining syndrome (Reilly & Gilbourne, 2003). Therefore, due to the amount of training undertaken by each player and also their individual response to training, each player needs to be carefully monitored by coaches to ensure that they are adapting to their training stimulus.

Monitoring Training

Due to the wide variety of physiological and skill requirements for a team sport such as soccer, physical training programs are difficult to implement. A major problem for coaches is being able to implement training programs that simultaneously meet the physical and technical/ tactical objectives of both the team and individuals within the team. Furthermore, another challenge for the coach is allowing for recovery between regular competitive games, whilst also maintaining the physical training stimulus that allows for fitness adaptations (Reilly, 2005; Reilly & Ekblom, 2005). Therefore, there is a need for a simple and reliable method for monitoring training and the individual training response in soccer players (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004; Impellizzeri, Rampinini, & Marcora, 2005c).

The nature of soccer training being conducted in a group environment means that it has the potential to lead to an increase in players not receiving specific training based on their own individual characteristics (Impellizzeri et al., 2005c). For example Hoff et al. (2002), demonstrated that when training in a team environment using small-sided games, players with superior fitness levels did not receive sufficient training stimulus to further increase their fitness. Alternatively, players with lower fitness levels may be overstressed during team–based training sessions leading to an increase in fatigue, injury and a reduction in performance. Impellizzeri et al. (2005c), recently reported that players who trained at a higher intensity during a seven week training period showed greater improvement in aerobic fitness measures, compared with players who trained at a lower intensity despite undertaking the same training program. Collectively, these findings show that some soccer players may not receive sufficient training stimulus when a team-based training approach is undertaken. Therefore, to overcome the limitations associated with team-based training, it has been suggested that a simple system which monitors an individual's training load (TL), and their response to their individual stimulus is required.

Methods for Monitoring Internal Training Load

The assessment of internal TL requires quantification of the intensity of the physiological stress imposed on the athlete and its duration (Foster, 1995). While the duration of a training session is easily measurable as time in mins, intensity can be determined with different methods, such as heart rate (HR) and ratings of perceived exertion (RPE) (Banister, 1985; Foster, 1995).

The use of HR to describe and determine exercise intensity is based on the well-known linear relationship between HR and $\dot{V}O_2$ over a wide range of steady-state submaximal workloads (Åstrand & Rodahl, 1986). This approach has been used to estimate the energy cost of soccer-specific exercises and matches (Bangsbo, 1994b; Rodríguez & Iglesias, 1998). There have been many HR-based methods developed and validated to assist with monitoring internal TL in athletes. One HR-based method for assessing internal TL is proposed by (Banister, 1991, Morton, et al., 1990). This method calculates the training impulse (TRIMP) by multiplying the training session duration by its average intensity weighted by a sex-specific co-efficient. Another HR-based method for assessing internal TL used HR measures in various zones, applied weighting factors to each of these zones and summed the results (Edwards, 1993; Lucía, Hoyos, Santalla, Earnest, & Chicharro, 2003). Although these methods for quantifying internal TLs may be effective for endurance-based sports, there has been limited research examining the validity of these methods in team sports.

There are several limitations associated with HR-based methods for quantifying internal TL. For example, the need for technical expertise to collect and collate the information, the time consuming process of collecting the HR data and the financial cost associated with purchasing and maintaining HR telemetric systems. Another limitation of using a HR-based method and depending on HR monitors is the chance of technical errors during a training session which will result in the loss of important information. Finally, another limitation of HR-based methods for quantifying internal TL in soccer is that it is a relatively poor method of evaluating very high intensity exercise such as weight training, high intensity interval training, and plyometric training (Coutts, 2001; Impellizzeri et al., 2004). For these reasons, the use of HR-based methods for quantifying TL may not be the most valid approach for measuring TL in the field.

Session-RPE method for Quantifying Internal Training Load

Foster (1995) proposed an alternative method for assessing internal TL utilizing Borg's Category Ratio 10-point (CR-10) scale as a measure of exercise intensity. Using this method, internal TL can be calculated by multiplying the training duration in minutes by the rate of perceived exertion (RPE) score to get a session-RPE measure. To ensure a mean is reported for the entire training session, it is recommended the RPE is taken 30-minutes after the completion of the session. The TL for each day of the week is then summed to provide a weekly TL. Whilst this method was originally proposed for endurance athletes, recently research has been conducted into it's validity for use in team sports and in particular soccer players (Impellizzeri et al., 2004).

One of the benefits of using Borg's CR-10 (Borg, Ljungren, & Ceci, 1985) is it gives a more holistic indication of 'global' exercise intensity as it is a measure of both psychological and physiological factors such as oxygen uptake, HR, ventilation, beta endorphins, circulating glucose concentration, and glycogen depletion (Morgan, 1994). Studies have also shown that through the RPE-method other information such as monotony and strain can also be derived (Foster & Lehmann, 1997; Foster, Helmann, Esten, Brice, & Porcari, 2001b; Delattre, Garcin, Mille-Hamard, & Billat, 2006). These measures have been reported to be useful in monitoring an athletes tolerance to training (Foster, 1998), and likelihood of illness, injury and overtraining (Foster, 1998; Andersen, Triplett-McBride, Foster, Doberstein, & Brice, 2003).

Although this method appears to be a viable practical method for assessing internal TL in team sport athletes the validity of this method is not yet well established. There has only been one published study that has examined its validity in soccer players (Impellizzeri et al., 2004) who reported a correlation between session-RPE and three commonly used HR-based methods and male soccer players. To date, no studies have investigated the validity of this approach in women soccer players.

The session-RPE method may provide valuable information in regards to monitoring TLs throughout the season and appears to be of great benefit for monitoring individual soccer players TLs. This simple tool may be part of a valuable monitoring system that assesses TLs, fatigue and fitness changes in soccer players. However, to gain useful information that can inform both the coach and the players about the effectiveness of the training process for an individual, tests that assess changes in aerobic adaptations should be incorporated into the training program of all players.

At present, the common tests for monitoring soccer player's aerobic adaptation through measurements such as lactate threshold (LT) (Edwards, Clark, & Macfadyen, 2003) and maximal oxygen uptake ($\dot{V}O_2max$) (Helgerud et al., 2001; Reilly, 2005) require expensive laboratory equipment, are maximal in nature, and are time consuming. Due to these limitations (with the exception of only a few top-level clubs), these tests are not practical for most players. Recent research has suggested that submaximal field tests may provide similar information to that which is obtained from maximal laboratory-based tests (Coutts, 2002; Impellizzeri, Mognoni, Sassi, & Rampinini, 2005b; A. Sassi, Marcora, Rampinini, Mognoni, & Impellizzeri, 2006). The advantages of submaximal tests are that they are of low cost, do not require expensive equipment, are easy to implement and most of all are a viable testing option for most clubs.

Krustrup et al. (2003), were the first to propose the submaximal version of the Yo-Yo intermittent recovery (Yo-Yo IR) test. The Yo-Yo intermittent endurance test is a specific endurance test consisting of a 20 m shuttle run which increases in speed interspersed by 5 s of active recovery, until exhaustion (Krustrup & Bangsbo, 2001; Krustrup et al., 2003; Mohr et al., 2003b; Krustrup et al., 2005; Metaxas, Koutlianos, Kouidi, & Deligiannis, 2005). The aim of the test is to continue until the player can no longer maintain the required speed. This test is designed to replicate the last part of a soccer match where the player is required to continue performing sprints after prolonged intermittent exercise. Their study examined the reproducibility and validity of the Yo-Yo IR test and evaluated the physiological responses during the test. Firstly, they found a significant correlation between Yo-Yo IR test performance and the amount of high intensity exercise during a game, which has been suggested to be a practical surrogate measure of physical performance during a match.

Another field-based test used to evaluate aerobic outcome is Mognoni's test (Sirtori, Lorenzelli, Peroni-Ranchet, Colombini, & Mognoni, 1993) which assesses [BLa$^-$] following 6 min of submaximal running. Previous research has reported a strong correlation between blood lactate at the end of a single 6 min run and speed at onset of blood lactate accumulation (OBLA) during a multi-stage running test on an outdoor running track (Sirtori et al., 1993). More recently, Impellizzeri et al. (2005b) assessed the validity of a submaximal treadmill based on Mognoni's test in soccer players and reported that blood lactate responses to a 6 min submaximal run were reflective of changes in LT during a soccer season. Additionally, the reproducibility of this test was shown further supporting its use as a surrogate measure for the more invasive and expensive laboratory-based measures. One of the benefits of using submaximal field tests is the ability to test a large number of players in a relatively short time. In addition athletes are not required to perform maximally during this test which may be quite fatiguing and can lead to overreaching. Taken together, these early research findings suggest that field-based, submaximal tests of aerobic capacity using blood lactate measures may be a practical tool for assessing changes in aerobic adaptations in soccer players. However, further research needs to be conducted into the validity of using this test for monitoring aerobic adaptations in soccer.

Summary

High level soccer is a demanding sport and requires athletes to train to improve aerobic capacity, anaerobic capacity, strength and power as well as technical and tactical abilities. Due to these high training and competition demands, soccer players are placed under significant physical and psychological stress which can lead to overreaching or in severe cases illness or injury. Additionally, it has recently been shown that individual soccer players respond differently to the same training stress. Since soccer players usually train in groups or as a team, rather than according to individual demands, coaches are challenged to find ways to ensure that each player within a team is adapting to training. Therefore, due to the amount of training undertaken by each player and also their individual response to training, each player needs to be carefully monitored by coaches to ensure that they are adapting to training.

Research Problem

The multidisciplinary nature of soccer training as well as the arduous competition structure of week to week matches makes it difficult to monitor training and adaptations in individual players. Combined, these factors create a significant challenge for coaches who are responsible for planning both team and individual player's training. In addition, since soccer players usually train as a team, individual players training doses are not often titrated according to each players needs, therefore increasing the possibility that the desired effect of training is not being achieved.

Accordingly, there is a need for a simple, valid and reliable monitoring system for coaches to quantify an individual's internal TL. If a valid and reliable monitoring system was developed, coaches may be able to better individualise training programs so that optimal benefits could be gained by each player within a team. It is suggested that for soccer, a system that accurately measures internal TL and aerobic fitness changes would be of great benefit for coaches and players.

The session-RPE has been reported to be a valuable and reliable tool for monitoring TL in athletes (Foster, Florhaug, Franklin, Gottschall, Hrovatin, Parker, Doleshal, & Dodge, 2001a). It has also been validated as a valuable method to be used specifically for elite male soccer players (Impellizzeri et al., 2004), but research in the area of team sports is still limited and no research currently exists in the area of women soccer players with regards to this method.

Finally, at present, there are few practical, valid and reliable tests that are available to monitor aerobic fitness adaptation in soccer players. Recently, submaximal field tests have been suggested to be a potential surrogate measure of aerobic fitness adaptations for field sport athletes. However, to date, no studies have examined the validity, reliability or sensitivity of these measures in the field. It is possible that if a valid and reliable test that was sensitive to changes in aerobic fitness adaptations was developed and then combined with measures of internal TL, an individual player's response to training could be monitored and the training process improved.

Aims of the Research

The aim of the research is to determine the utility of the session-RPE as a tool for monitoring TL in women's soccer and establish the efficacy of a submaximal Yo-Yo Intermittent Recovery level 1 (Yo-Yo IR1) shuttle running test to assess aerobic training adaptations.

Objectives

Study 1: The validity of the session-RPE based method for use with women soccer players.

- Examine whether the session-RPE method for quantifying internal training load (TL) is a valid tool that can be used with women soccer players.

Study 2: The validity and repeatability of blood lactate, RPE and heart rate responses during the submaximal Yo-Yo intermittent recovery test for use with women soccer players.

- Determine whether blood lactate, RPE and HR responses to the 6 min submaximal Yo-Yo intermittent recovery test level 1 (Yo-Yo $_{submax}$) are repeatable and valid methods of aerobic adaptations in women soccer players.

Study 3: The practical usefulness of a new submaximal test for monitoring the training process in women soccer players.

- Assess the sensitivity of physiological and perceptual responses following a 6 min Yo-Yo $_{Submax}$ test to markers of aerobic fitness in women soccer players.

- Furthermore, assess if aerobic fitness changes identified in the submaximal tests can be related to TLs.

Hypotheses

Study 1:

- The session-RPE method is a valid method which can be used to quantify an athlete's internal TL in relation to soccer training.

- The session-RPE method will correlate well with other HR-based methods across all training types.

Study 2:

- The submaximal version of the Yo-Yo intermittent recovery test level 1 is a repeatable tool and valid in testing aerobic adaptations in women soccer players.

Study 3:

- The sub maximal version of the Yo-Yo intermittent recovery test level1 will be a valid tool for testing aerobic adaptations in soccer players and aerobic fitness changes will relate to individual TL's.

Contribution to Theory and Practice

Study 1:

The first study will further determine the validity of the session-RPE as a tool to monitor TL. From a practical perspective for coaches it may provide a simple tool which is easy for both coaches and athletes to use independently of any specialised support and provide easy to understand practical information on an athletes response to training. The session-RPE method will also assist coaches and athletes in the development of periodisation programs and the ability to longitudinally monitor the effects of a training program. It may also prove to be a useful tool in the early detection of training fatigue and/or overtraining syndrome.

Theoretically the study may add to the body of knowledge further validating the session-RPE in team sports and in particular soccer. Since this method of internal TL quantification was first developed for endurance athletes, research in team sports remains limited. More specifically research conducted on the validity of the session-RPE to soccer players is even more limited. To date no research has been conducted on it's validity to women soccer players.

Study 2:

This study will determine the reliability of physiological responses to a submaximal Yo-Yo IR1 test. Practically this is a valuable tool for coaches, athletes and sport scientists alike being a simple and easy to administer test for both sport scientists and coaches. For athletes the same valuable information normally recorded using a maximal test can be achieved without completing maximal testing until exhaustion, thus making it easier to co-ordinate throughout the season around matches and competitions.

Theoretically, there have been papers that have reported on the physiological responses to a submaximal Yo-Yo IR test but none have examined reliability of the submaximal version of the Yo-Yo IR test.

Study 3:

To date, there have only been two papers published examining the validity of the physiological responses to a submaximal test to monitor aerobic changes in soccer players. The present study will be the first to validate the physiological responses to a submaximal Yo-Yo IR test in soccer players. The Yo-Yo IR test has been validated using women soccer players. However, this will be the first study to examine the validity of the submaximal test in women soccer players.

Collectively, the information from these three studies will contribute to the area of coaching and sport science by providing practical and reliable tools for monitoring systems to track the training adaptations in soccer players. Theoretically, it will further validate research already conducted and test the reliability and validity of hypotheses not yet tested.

Limitations and Assumptions

Subject compliance

Dietary

It was assumed that all players followed the dietary guidelines outlined to them prior to any testing and throughout the study.

Perceptual variables

It was assumed that when self reporting of RPE scores was necessary (study one and three) that players followed the procedure outlined for recording their RPE after a training session or match.

Recovery

Submaximal field tests (study 3) were conducted in the allocated recovery weeks throughout the 14 weeks of the study. Individual TLs were used to determine if an athlete was in a rested state, and testing was scheduled and conducted early in the day before any training. However, since these variables were not directly assessed we were not able to determine if the players we optimally recovered for each test.

Delimitations

Sample size

With all subjects being elite athletes and committed to various playing and training commitments, it was difficult to keep a consistent number of training sessions across all individuals. To limit any bias a large sample size of training and match sessions was collected in study one.

Subjects

Subjects participating in this study were all elite level players who train full time in the sport and play at the highest competition level within their country. Elite players were used to determine the real world validity of the proposed tools and tests.

References

Andersen, L., Triplett-McBride, T., Foster, C., Doberstein, S., & Brice, G. (2003). Impact of training patterns on incidence of illness and injury during a women's collegiate basketball season. Journal of Strength and Conditioning Research, 17(4), 734-738.

Åstrand, P. O., & Rodahl, K. (1986). Textbook of Work Physiology. New York: McGraw Hill.

Bangsbo, J. (1994b). The physiology of soccer with special reference to intense intermittent exercise. Acta Physiologica Scandinavica, 151(Supplement 619), 1-156.

Bangsbo, J., Nørregaard, L., & Thosøe, F. (1991). Activity profile of competition soccer. Canadian Journal of Sport Sciences, 16, 110-116.

Banister, E. W. (1991). Modeling elite athletic performance. In H. J. Green & J. D. McDougal & H. A. Wenger (Eds.), Physiological Testing of Elite Athletes (pp. 403-424). Champaign, Illinois: Human Kinetics.

Banister, E. W., Calvert, T. W., Savage, M. V., & Bach, T. (1975). A systems model of training for athletic performance. Australian Journal of Sports Medicine and Exercise Science, 7, 57-61.

Borg, G., Ljunggren, G., & Ceci, R. (1985). The increase of perceived exertion, aches and pain in the legs, heart rate and blood lactate during exercise on a bicycle ergometer. European Journal of Applied Physiology, 54(4), 343-349.

Coutts, A. J. (2001). Monitoring training in team sports. Sports Coach, 24(3), 19-23.

Coutts, A. J. (2002). Monitoring fatigue and recovery in team sport athletes. Unpublished Doctoral Thesis, Central Queensland University, Rockhampton.

Coutts, A. J., Reaburn , P. R. J., Murphy, A. J., Pine, M. J., & Impellizzeri, F. M. (2003). Validity of the session-RPE method for determining training load in team sport athletes. Journal of Science and Medicine in Sport, 6(4), 525.

Delattre, E., Garcin, M., Mille-Hamard, L., & Billat, V. (2006). Objective and subjective analysis of the training content in young cyclists. Applied Physiology, Nutrition, and Metabolism, 31(2), 118-125.

Edwards, A. M., Clark, N., & Macfadyen, A. M. (2003). Lactate and ventilatory thresholds reflect the training status of professional soccer players where maximum aerobic power is unchanged. Journal of Sports Science and Medicine, 2(1), 23-29.

Edwards, S. (1993). High performance training and racing. In S. Edwards (Ed.), The Heart Rate Monitor Book (8th ed., pp. 113-123). Sacramento, CA: Feet Fleet Press.

Ekblom, B. (1986). Applied physiology of soccer. Sports Medicine, 3, 50-60.

Filaire, E., Lac, G., & Pequignot, J. M. (2003). Biological, hormonal, and psychological parameters in professional soccer players throughout a competitive season. Perceptual and Motor Skills, 97(3 Pt 2), 1061-1072.

Foster, C. (1998). Monitoring training in athletes with reference to overtraining syndrome. Medicine and Science in Sports and Exercise, 30(7), 1164-1168.

Foster, C., Hector, L. L., Welsh, R., Schrager, M., Green, M. A., & Snyder, A. C. (1995). Effects of specific versus cross-training on running performance. European Journal of Applied Physiology, 70(4), 367-372.

Foster, C., Helmann, K. M., Esten, P. L., Brice, G., & Porcari, J. P. (2001b). Differences in perceptions of training by coaches and athletes. South African Journal of Sports Medicine, 8(1), 3-7.

Foster, C., & Lehmann, M. (1997). Overtraining syndrome. In N. Gnuten (Ed.), Running Injuries (pp. 173-188). Philadelphia: W.B. Saunders.

Helgerud, J., Christian Engen, L., Wisløff, U., & Hoff, J. (2001). Aerobic endurance training improves soccer performance. Medicine and Science in Sports and Exercise, 33(11), 1925-1931.

Hoff, J., Wisløff, U., Engen, L. C., Kemi, O. J., & Helgerud, J. (2002). Soccer specific aerobic endurance training. British Journal of Sports Medicine, 36(3), 218-221.

Impellizzeri, F. M., Marcora, S. M., Castagna, C., Reilly, T., Sassi, A., Iaia, F. M., & Rampinini, E. (2005a). Physiological and performance effects of generic versus specific aerobic training in soccer players. International Journal of Sports Medicine, DOI: 10.1055/s-2005-865839.

Impellizzeri, F. M., Mognoni, P., Sassi, A., & Rampinini, E. (2005b). Validity of a submaximal running test to evaluate aerobic fitness changes in soccer players. In T. Reilly & J. Cabri & D. Araujo (Eds.), Science and Football V (pp. 105-111). London, UK: Routledge.

Impellizzeri, F. M., Rampinini, E., Coutts, A. J., Sassi, A., & Marcora, S. M. (2004). The use of RPE-based training load in soccer. Medicine and Science in Sports and Exercise, 36(6), 1042-1047.

Impellizzeri, F. M., Rampinini, E., & Marcora, S. M. (2005c). Physiological assessment of aerobic training in soccer Journal of Sports Sciences, 23(6), 583-592.

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., Pedersen, P. K., & Bangsbo, J. (2003). The Yo-Yo Intermittent Recovery Test: Physiological response, reliability, and validity. Medicine and Science in Sports and Exercise, 35(4), 697-705.

Krustrup, P., Mohr, M., Ellingsgaard, H., & Bangsbo, J. (2005). Physical demands during an elite female soccer game: importance of training status. Medicine and Science in Sports and Exercise, 37(7), 1242-1248.

Lucía, A., Hoyos, J., Santalla, A., Earnest, C., & Chicharro, J. L. (2003). Tour de France versus Vuelta a Espana: which is harder? Medicine and Science in Sports and Exercise, 35(5), 872-878.

Mohr, M., Krustrup, P., & Bangsbo, J. (2003b). Match performance of high-standard soccer players with special reference to development of fatigue. Journal of Sports Sciences, 21(7), 519-528.

Morgan, W. P. (1994). Psychological components of effort sense. Medicine and Science in Sports and Exercise, 26(9), 1071-1077.

Morton, R. H., Fitz-Clarke, J. R., & Banister, E. W. (1990). Modeling human performance in running. Journal of Applied Physiology, 69(3), 1171-1177.

Naessens, G., Chandler, T. J., Kibler, W. B., & Driessens, M. (2000). Clinical useful of nocturnal urinary noradrenaline excretion patterns in the follow-up of training processes in high-level soccer players. Journal of Strength and Conditioning Research, 14(2), 125-131.

Rampinini, E., Coutts, A. J., Castagna, C., Sassi, R., & Impellizzeri, F. M. (2006). Analysis of top-level soccer match performance with particular reference to the opponents Journal of Science and Medicine in Sport, in review.

Reilly, T. (1997). Energetics of high-intensity exercise (soccer) with particular reference to fatigue. Journal of Sports Sciences, 15, 257-263.

Reilly, T. (2003). Motion analysis and physiological demands. In T. Reilly & A. M. Williams (Eds.), Science and Soccer (pp. 59-72). London: Routledge.

Reilly, T. (2005). An ergonomics model of the soccer training process. Journal of Sports Sciences, 23(6), 561-572.

Reilly, T., & Ekblom, B. (2005). The use of recovery methods post-exercise. Journal of Sports Sciences, 23(6), 619-627.

Reilly, T., & Gilbourne, D. (2003). Science and football: a review of applied research in the football codes. Journal of Sports Sciences, 21(9), 693-705.

Rodríguez, F. A., & Iglesias, X. (1998). The energy cost of soccer: Telemetric oxygen uptake measurements versus heart rate-VO_2 estimations. Journal of Sports Sciences, 16(5), 484-485.

Sassi, A., Marcora, S. M., Rampinini, E., Mognoni, P., & Impellizzeri, F. M. (2006). Prediction of time to exhaustion from blood lactate response during submaximal exercise in competitive cyclists. European Journal of Applied Physiology.

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: an update. Sports Medicine, 35(6), 501-536.

Stroyer, J., Hansen, L., & Klausen, K. (2004). Physiological profile and activity pattern of young soccer players during match play. Medicine and Science in Sports and Exercise, 36(1), 168-174.

Chapter 2

Literature Review

Introduction

Soccer is the most widely played game in the world and the soccer World Cup is the biggest global sporting event (Bangsbo, 1994b). Women's soccer is currently the fastest growing sport for women in the UK. Since the inaugural Women's World Cup held in China in 1991, its popularity and professionalism has increased remarkably. However, despite this growing popularity, there still is not a great deal of research into the science of women's soccer (Davis & Brewer, 1993; Krustrup, Mohr, Ellingsgaard, & Bangsbo, 2005; Stølen, Chamari, Castagna, & Wisløff, 2005). At present, there is little empirical data into the correct training approaches for women soccer players and viable methods for monitoring training progression and adaptations.

Soccer requires a wide range of tactical, technical and physical skills that are required to perform at the highest level (Bangsbo, 1994b; Stølen et al., 2005). A soccer match is characterised by high intensity intermittent bouts with only limited recovery periods and as a consequence energy provision is via both the aerobic and anaerobic sources (Bangsbo, 1994b; Reilly, 1997). Due to the intermittent nature of the work demands during match play, soccer players are required to possess a high level of aerobic endurance, while also having well developed anaerobic abilities (Bangsbo, 1994b; Mohr, Krustrup, & Bangsbo, 2005; Stølen et al., 2005)

In this literature review I will look at the characteristics associated with performance in soccer, and the training process associated with the development of those characteristics in soccer players. Additionally I will cover the importance of monitoring training load as well as monitoring and assessing training adaptations in soccer players. Finally I will highlight current methods and tests available in the field and identify limitations associated with them.

Characteristics Associated With Performance in Soccer

Many previous studies have analysed soccer match performance and isolated the factors that are crucial for success (Bangsbo, Nørregaard, & Thosøe, 1991; Bangsbo, 1994b; Reilly, 1997; Helgerud, Christian Engen, Wisløff, & Hoff, 2001; Hoff, Wisløff, Engen, Kemi, & Helgerud, 2002; Mohr, Krustrup, & Bangsbo, 2003b; Reilly, 2003; Hoff & Helgerud, 2004; Bangsbo, 2005; Mohr et al., 2005; Reilly, 2005; Stølen et al., 2005; Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2006). For example, Rampinini et al. (2006) have shown that aerobic capacity, endurance, strength and power are important factors for success in soccer. Although these factors have been widely examined in male soccer players, research in the women's game has been more limited. In particular, there is little empirical data that examines the training factors that influence match performance. Furthermore, to the authors' knowledge, there have been no published studies that examine appropriate methods to assess progression and predict performance in elite women soccer players.

During a 90 min match it has been reported that an elite male player would cover distances between 10 and 13 km (Ekblom, 1986; Bangsbo et al., 1991; Bangsbo, 1994b; Mohr et al., 2003b; Bangsbo, 2005; Krustrup et al., 2005; Rampinini et al., 2006). Similar distances were recorded in a study by Ekblom & Aiginger, (unpublished data in Davis and Brewer, (1993), where distance covered during a match by an elite Swedish women's National League squad was 8.5 ± 2.2 km. More recent research has reported that high level Danish women players cover an average of 10.3 ± 1.6 km during a match (Krustrup et al., 2005). In addition to these endurance demands, explosive activities such as jumping, kicking, tackling, turning and sprinting, are also required (Stølen et al., 2005). Ekblom & Aiginger, (unpublished data in Davis and Brewer, (1993) reported that elite women players completed 100 discrete sprints per game at an average distance of 14.9 ± 5.6m. Krustrup et al., (2005) reported an average change of activities approximately 1400 during a game.

The soccer player is mainly dependent on aerobic metabolism due to the duration of a match and the need to repeatedly use the aerobic energy sources to restore anaerobic energy sources for continuing high intensity bouts (Hoff & Helgerud, et al., 2004). It has been reported that the average work intensity during a match is close to the lactate threshold, normally between 80-90% of HRmax (Davis & Brewer, 1993; Bangsbo, 1994b; Helgerud et al., 2001; Mohr et al., 2003b; Reilly, 2003; Krustrup et al., 2005; Stølen et al., 2005; Impellizzeri, Marcora, Castagna, Reilly, Sassi, Iaia, & Rampinini, 2006). However, despite the reliance on aerobic energy provision during a match, the outcome of a game is highly dependent on high-intensity, anaerobic efforts, with 1-11% of match distance coming from sprinting. In a recent comprehensive review of the research, Stølen et al, (2005) reported that during a typical match each high level player would perform 1000-1400 short activities each changing every 4-6 s. These activities include 10-20 sprints, with high-intensity running approximately every 70 s and completing an estimated 15 tackles, 10 headers, 50 involvements with the ball and approximately 30 passes. These results demonstrate that a high level of skill, speed, strength and power are important factors for high level soccer players.

Most of these previous findings have been in elite male football players and there is a limited amount of research completed on women players. Additionally the majority of the previous studies have reported similar relationships between the characteristics, both individual and match specific, for both men and women (Helgerud et al., 2002,). There have been many studies conducted trying to identify the physiological characteristics of women soccer players with most of these demonstrating that women players have similar fitness characteristics to other team sport athletes (Jensen & Larsson, 1992; Rhodes & Mosher, 1992; Davis & Brewer, 1993; Tumilty, 1993) For example, Tumilty (1993) tested 20 players of the Australian women's soccer team and reported similar findings in regards to speed, aerobic capacity and strength characteristics to high level women athletes in both individual events and team sports but not male soccer players.

The most likely explanation for the differences between men and women soccer players are the sex-specific hormonal and physiological characteristics such as anabolic hormone levels and cardiac dimensions. In addition, the differences in the level of professionalism between men and women soccer may also contribute to these differences. Until recently, women's soccer was not a fully professional sport and as such the athletes were not able to train on a full-time basis like their male counterparts. Thus, women players did not train or compete at the same level as their male equivalents. Nonetheless, the relative magnitude of differences in strength and endurance parameters compared to sedentary counterparts of the same sex are similar for both male and women elite soccer players (Stølen et al., 2005).

The characteristics associated with elite level soccer players are varied in terms of types of skills needed for elite performance. Additionally the same characteristics seem to be consistently highlighted across studies. Although there is limited research conducted into the characteristics associated with women soccer players, the research that has been conducted to date highlights similar characteristics to men. Having so many variables associated with optimal performance means that the training process needs to be well planned, and the monitoring and assessment process relevant and specific.

The Training Process

Aerobic fitness, strength, flexibility and anaerobic fitness components such as jumping and acceleration have been shown to be important factors in soccer performance (Reilly, 1996). Therefore, all these factors have to be developed in each individual player with a comprehensive physical training program. A training program needs to meet the physical and technical/tactical objectives of both the team and individual within the team. The training program also needs to allow for recovery between regular competitive games, whilst also maintaining the physical stimulus that allows for fitness adaptations (Reilly & Ekblom, 2005)

Other aspects that need to be taken into account in a training program are the different physical demands in the form of the individual players training status, their playing positions and tactical roles (Bangsbo, et al. 2006). This adds to the complexity of planning a comprehensive training program. The training programs needed to achieve optimal performance are complex. Additionally there is a high training load experienced by players each week because of a comprehensive training schedule, a high competition load, and limited recovery periods from week to week. Thus the ability to monitor each players training load is vital. Therefore there is a need for a simple, reliable method for monitoring training and the individual player's training response in soccer.

Naessens et al., (2000) reported that between 12-20 hours per week of training is required for male professional soccer players. This training should focus on regular aerobic and anaerobic training (Bangsbo, 2005). In addition, strength and flexibility also need to be trained along with the technical and tactical aspects of the game. Bangsbo et al. (2006) noted that a typical week of training for a soccer team consisted of 6 training sessions within 5 days, one match day and one rest day. As an example, these sessions would consist of technical/tactical training, high intensity aerobic training, speed endurance training, strength training and speed training (Bangsbo, et al., 2006). Although this training model was based on elite male soccer players, previous research based on women soccer players has also recommended similar physical training programs to male soccer players (Bangsbo, 1994).

An additional barrier for high level women soccer players is that the women's game is not professional. Therefore, most female players need to combine their training with either work or study, leaving limited time to commit to training. Due to these increased commitments, there is limited time each week to allow women players to train. Therefore, it is essential that any available training time is used efficiently. Indeed, it has been suggested that the focus in training sessions for women's soccer should be based on the specific needs of the individual (Brewer and Davis, 1994).

Even though certain types of training and associated training intensities have been recommended for achieving adaptations in soccer players (Helgerud et al., 2001; Hoff et al., 2002; Bangsbo, Mohr, & Krustrup, 2006; Impellizzeri et al., 2006), individuals, within a team setting, may experience the training load (TL) differently (Impellizzeri, Rampinini, & Marcora, 2005c). For example, Hoff, et al., (2002) showed that a steady state exercise intensity of 91% of HR max was induced by interval playing in small-sided games in Norwegian women first-division players, though players with a $\dot{V}O_2max$ >60 mL/kg/min were not reaching that exercise intensity during small-sided games. Collectively, these studies show that there are many factors that can affect the training process in women's soccer and suggest that there is a need to monitor the training process to ensure an individual player's performance outcomes are optimised.

Monitoring Athletes Training Loads

The importance of monitoring training and training load

Previous studies have highlighted the importance that an athlete's physical capacity has on their performance during a match. For example, Krustrup et al., (2005), recently highlighted the differences in a players physical capacity and their physical match performance. Therefore being able to monitor training adaptations in soccer players may provide important information for coaches and scientists that will enable better control over the training process. According to Bannister's (1975; 1980; 1991) model for understanding an athletes performance and adaptation to training, coaches should accurately measure TLs along with fitness and fatigue changes.

$$\text{Performance} = \text{Fitness} - \text{Fatigue}$$

Banister et al (1975)

Previous studies have suggested that up to 48 hours may be required to recover from a heavy training session (Foster and Lehmann, 1997). Although fitness is gained after each session, it is not until the fatigue from the last session has decreased, that the fitness is gained. Consequently, athletes training at an elite level often do not have the opportunity to fully recover, which can place them at higher risk of fatigue (Coutts, Reaburn, Piva, & Rowsell, 2007b; Coutts, Slattery, & Wallace, 2007c), illness / injury (Andersen, Triplett-McBride, Foster, Doberstein, & Brice, 2003; Putlur, Foster, Miskowski, Kane, Burton, Scheet, & McGuigan, 2004), or overreaching (Halson & Jeukendrup, 2004). Therefore, it is recommended that TLs be monitored by coaches and athletes so that the balance between fitness and recovery is maintained to achieve optimal performance.

To be able to accurately measure and control an athlete's training load (TL) is an important ingredient of successful coaching. The ability to assess an athletes TLs has important implications for producing an effective training program (Coutts, Sirotic, Catterick, & Knowles, 2007). Viru & Viru, (2000), reported that it is not the external load but the relative physiological stress which is imposed on the athlete (i.e. the internal TL) which is the stimulus for training adaptation. Therefore a valid and reliable method to assess internal TL is needed.

Being able to assess an athlete's internal TL becomes even more important in a team sport, such as soccer due to the high use of various training methods that can focus on the development of tactical and technical skills, aerobic endurance, power, strength, agility, flexibility and speed (Bangsbo et al., 2006). To effectively train all of these aspects a variety of training sessions need to be incorporated into a weekly and monthly periodization plan. Therefore, methods to easily and reliably monitor TL's from a variety of training modes could prove an extremely important and valuable tool for both soccer coaches and players.

Heart rate-based methods for monitoring training load

Most methods used to assess TL are based on collecting heart rate (HR) information (Banister & Wenger, 1982; Banister, Good, Holman, & Hamilton, 1986; Banister, 1991; Flanagan & Merrick, 2001; Wood, Hayter, Rowbottom, & Stewart, 2005). HR information is considered important because it has been shown that it demonstrates an almost linear relationship with $\dot{V}O_2$ over a wide range of steady-state submaximal exercise intensities (Åstrand & Rodahl, 1986). Previous studies have shown that using HR is one of the best ways to quantify aerobic training intensity for endurance-based activities (Gilman, 1996; Achten & Jeukendrup, 2003) and in soccer HR has mostly been used as a determinant of exercise intensity (Bangsbo, 1994b; Helgerud et al., 2001; Hoff et al., 2002).

One HR-based method for assessing internal TL is the training impulse (TRIMP) method proposed by Banister (1986). The TRIMP is calculated by multiplying the training session duration by its mean intensity and then by a sex-specific co-efficient. This method allows for the quantification of internal TL represented by one score (TRIMP) and accounts both exercise duration and intensity. Another

HR-based method for assessing internal TL was proposed by Edwards (1993). This method consists of measuring the accumulation of five training zones, each zone having a coefficient and then multiplying each zone specifically and summating the total. For example from 50-60% of HRmax = 1 and 90-100% of HRmax = 5. An alternative method for quantify internal TL using HR data was proposed by Gilman (1996). This method involves the multiplication of time spent in three separate zones (easy, moderate and high). These zones are determined by HR values corresponding to LT and ventilatory threshold. However, this method gives an indication of the distribution of intensity within a session not so much the internal TL. Finally, Lucia et al., (2003) proposed another method for calculating internal TL. This involved multiplying the time spent in three different HR zones and then summating the results. The HR zones responded to zone 1 = below ventilatory threshold, zone 2 = between ventilatory threshold and respiratory compensation point and zone 3 = above the respiratory compensation point. Each zone is given a coefficient and the duration of the time spent in that shown is multiplied (zone 1 = 1, zone 2 = 2 and zone 3 = 3).

Although each of these methods have been validated and proven to be reliable tools in monitoring internal TL for endurance athletes, there are limiting factors associated with their use with soccer players (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). These limitations are the need for technical expertise to collect and collate the information, the time consuming process of collecting the HR data, and the financial cost associated with purchasing and maintaining HR telemetric systems. Moreover, since Federation of International Football

Associations (FIFA) rules prevent players from wearing a HR transmitter belt during a match, internal training experience during competition are unable to be collected using traditional HR-based methods. Another limitation is that HR is a comparatively poor method of evaluating very high-intensity exercise such as weight training, high-intensity interval training, and plyometric training (Foster, Florhaug, Franklin, Gottschall, Hrovatin, Parker, Doleshal, & Dodge, 2001a). Thus, even with the most optimal HR monitoring strategy, integration of the TRIMP does not translate well to very high-intensity exercise training (Foster et al., 2001a) or intermittent exercise (Rodríguez & Iglesias, 1998; Achten & Jeukendrup, 2003), both of which are common in soccer training.

As previously stated, it has been well established that HR and $\dot{V}O_2$ are linearly related (Åstrand and Rodahl, 1986). However, often this relationship is determined in a controlled laboratory setting. In this setting the environment can be controlled as well as the athlete being able to prepare for the laboratory test to their best ability (e.g.; sleep, fluids, and carbohydrates). In contrast, in the field, there are various physiological and environmental factors which can influence this relationship determined in the laboratory test (Achten and Jeukendrup, 2003). Other physiological factors such as hydration can affect the reliability of using HR to monitor exercise intensity. In a review article on HR monitoring Achten and Jeukendrup (2003) reported that HR can be increased by up to 7.5% when exercising in a dehydrated state without a raised core temperature which can significantly affect measures of HR-based TL. Environmental factors such as temperature can also have an influence on HR. In a cold environment HR will underestimate the intensity of exercise. During hot conditions, because the core temperature increases and heat loss mechanisms are less efficient, HR for the same exercise intensities will be higher.

There are still gaps in the knowledge about the changes to HR that occur during overtraining and overreaching. It has been previously shown that during maximal exercise HR decreases when individuals are overreached (Costill, 1998, Hedelin et al; 2000). Most findings have shown clear decreases in maximal HR although the findings are not as clear during submaximal exercise. However, because of the psychobiological nature of the RPE, it has been suggested that it can be a useful tool for preventing overreaching and monitoring training. Indeed, Martin and Anderson (2000) noted that during overreaching for a given HR, the reported RPE had increased. This suggests that RPE is more sensitive to recognising fatigue than HR. It is due to these factors, that RPE is considered a valuable tool for monitoring the training process in sports training.

Alternative method for monitoring training load

A proposed method of assessing internal TL to HR-based methods has been the RPE-based method. The session-RPE method for quantifying internal TL was firstly proposed by Foster et al., (1995) who developed this tool for quantifying TLs in speed skaters. This method provides a single value representing an athletes internal TL for a session and is calculated by multiplying the training duration in minutes by the rate of perceived exertion (RPE) using the category ratio scale (CR

10-scale) (Borg, Ljunggren, & Ceci, 1985) (Table 1). Previous studies have reported the session-RPE based method to be related to both HR and blood lactate markers of exercise intensity (Foster et al., 1995; Foster et al., 2001a; Impellizzeri et al., 2004; Coutts, Rampinini, Castagna, Marcora, & Impellizzeri, 2007a). More specifically, recent research has shown that the session-RPE-method provides a better indication of TL during small-sided soccer games than either HR or blood lactate markers alone (Coutts, Rampinini, Marcora, & Impellizzeri, 2006).

Table 1: The 10-point Rating of Perceived Exertion Scale (Borg et al., 1985).

Rating	Description
0	Rest
1	Very, Very Easy
2	Easy
3	Moderate
4	Somewhat Hard
5	Hard
6	
7	Very Hard
8	
9	
10	Maximal

There have been many studies focusing on quantifying TL in endurance sports (Banister et al., 1986; Morton, Fitz-Clarke, & Banister, 1990; Banister, 1991; Foster, Daines, Hector, Snyder, & Welsh, 1996; Foster & Lehmann, 1997; Morton, 1997; Foster, 1998; Delattre, Garcin, Mille-Hamard, & Billat, 2006). High correlations were found between the session-RPE and HR-based methods (Foster et al., 2001a). Also, moderate to strong correlations have been reported between session-RPE TLs and the various HR-based internal TL measures in steady-state endurance training (Foster et al., 1995), interval training (Foster et al., 2001a) and also soccer-specific exercise (Impellizzeri et al., 2004; Coutts et al., 2007a). However, to date this relationship between these measures has not been examined in female athletes.

The Practical Application of the Session-RPE-Method in Monitoring Training

The session-RPE method was initially proposed as a tool for monitoring internal TL in endurance athletes. However, its ability to provide a single value for each training session offers significant practical benefits for the coach of various team sports. Several recent studies have been conducted to validate the use of this method for quantifying TL in team sports such as basketball (Foster et al., 2001a) rugby league (Coutts, Reaburn, Murphy, Pine, & Impellizzeri, 2003) and soccer (Impellizzeri et al., 2004; Coutts et al., 2007a).

The application of the session-RPE method to soccer training offers significant potential to guide the coach in improving the training process for individual players. In particular, a change in perception of effort to a standard TL might be used to guide coaches in titrating future training for individual players. Research has shown the player's RPE could be influenced by the individual's current psychological state (Morgan, 1973). This is supported by previous research that has investigated overreaching (i.e. decreased performance) and reported that RPE increases in athletes suffering from an increased state of fatigue (Snyder, Jeukendrup, Hesselink, Kuipers, & Foster, 1993). Furthermore, recent studies have shown that between 30-50% of soccer players may suffer from these conditions during a season (Naessens, Chandler, Kibler, & Driessens, 2000; Filaire, Bernain, Sagnol, & Lac, 2001; Filaire, Lac, & Pequignot, 2003). Therefore, a practical measure to monitor the training process and the player's response to training may be a valuable tool for coaches of high level soccer teams.

Since Borg's RPE scale has been shown to monitor both psychological and biological factors (Borg, 1982) it may be a valuable tool for early identification and prevention of overreaching and overtraining in soccer players. This is supported by Martin and Anderson (2000) who examine the HR-RPE relationship throughout a period of high intensity training in male collegiate cyclists. They reported that perception of effort for a given HR increased at the end of the training compared to the beginning, therefore indicating that the HR-RPE relationship may be used to monitor the amount of 'overreaching'. On the basis of these findings, it is suggested that the RPE-method could serve as a valuable tool for monitoring the training process and the player's response to training. Therefore, these measures may be useful for monitoring impending overreaching in soccer players especially if used in conjunction with simple standardised performance tests.

Another advantage of being able to quantify internal TL is that it can provide information to guide future training planning. Periodisation of training is important to ensure that adequate physiological stimulus and also recovery are set to achieve optimal performance (Rowbottom, 2000). For example, the daily and weekly TL's calculated using the session-RPE technique can be monitored daily to ensure that training is being implemented according to how it has been intended (Foster, Helmann, Esten, Brice, & Porcari, 2001b; Impellizzeri et al., 2005c; Coutts et al., 2007). Additionally, if particular players are considered to have completed too much or too little training in comparison to their individual goals, their training program can be modified so that their TL's are optimised.

Although there have only been a few studies that have examined the session-RPE method in team sports, the available studies suggest that this method may be a valuable part of a system that can be used to monitor the training process in soccer players. Additionally, the literature also demonstrates that due to the multifactorial nature of training programs in soccer there is a need for a valid and reliable athlete monitoring system that assesses global fatigue and fitness states. The present thesis will add to the research already available monitoring the training process in soccer.

Aerobic and Anaerobic Fitness Qualities of Soccer Players

Previous research has shown that soccer match play demands that players possess well developed aerobic and anaerobic energy systems (Bangsbo, 1994b; Bangsbo et al., 2006; Bangsbo, Iaia, & Krustrup, 2007). In general, these previous studies have shown that the aerobic system plays the major role while it is the anaerobic system that is recruited in relation to the short sprints, jumps and tackles. Moreover, Stølen et al., (2005) reported that both women and men soccer players taxed the aerobic and anaerobic energy systems to a similar level.

In a recent review, Stølen et al., (2005) reported that physiological profiles of elite women soccer players usually have a moderate to high fitness levels with $\dot{V}O_2max$ reported between 38.6 - 57.6 $mL \cdot kg^{-1} \cdot min^{-1}$. However, earlier research reported that elite Czech women midfielders and forwards have $\dot{V}O_2max$ values greater than 60 $mL \cdot kg^{-1} \cdot min^{-1}$ (Bunc & Psotta, 2001). However, at present there is limited research that has described the physiological characteristics of women's soccer and more research is required before a full understanding of the physiological characteristics associated with performance is established. It is also well established that higher levels of aerobic fitness can facilitate recovery during high intensity intermittent exercise through improved lactate removal enhanced aerobic response and enhanced phosphocreatine (PCr) regeneration (Tomlin & Wenger, 2001). Therefore, it seems reasonable to suggest that women soccer players will benefit from increased aerobic fitness levels.

There have been many studies completed on elite male soccer players using both laboratory-based methods and match analysis to identify the characteristics associated with elite performance (Bangsbo, 1994b; Filaire et al., 2001; Krustrup, Mohr, Amstrup, Rysgaard, Johansen, Steensberg, Pedersen, & Bangsbo, 2003; Hoff, 2005; Mohr et al., 2005; Stølen et al., 2005; Krustrup, Mohr, Nybo, Jensen, Nielsen, & Bangsbo, 2006a; Krustrup, Mohr, Steensberg, Bencke, Kjaer, & Bangsbo, 2006b; Bangsbo et al., 2007; Di Salvo, Baron, Tschan, Calderon Montero, Bachl, & Pigozzi, 2007; Rampinini, Bishop, Marcora, Ferrari Bravo, Sassi, & Impellizzeri, 2007a; Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007b). Since there is relatively little literature available on women soccer players ,(Davis & Brewer, 1993; Mercer, Gleeson, & Wren, 2003; Mohr, Ellingsgaard, Andersson, Bangsbo, & Krustrup, 2003a; Krustrup et al., 2005; Andersson, Krustrup, & Mohr, 2007; Hewitt, Withers, & Lyons, 2007; Juric, Sporis, & Vatroslav, 2007; Scott & Drust, 2007; Vucetic, Sporis, & Jukic, 2007), there is a need to further explore the characteristics of elite women soccer players in relation to match performance. Such data will be useful for further comparison to sub-elite players, other team players and non-athletes, so that a full understanding of the physiological characteristics important for developing high level women soccer players can be achieved. Although the focus of this thesis is not on determining the characteristics prominent in elite women soccer players, data will be collected that will further describe the physiological characteristics associated with high level soccer performance in women.

Training for Aerobic Capacity in Soccer

Aerobic capacity is an important physiological factor associated with high level soccer performance (Stølen et al., 2005). Recently, there have been many investigations that describe various training methods for improving aerobic capacity in soccer players (Wisløff, Helgerud, & Hoff, 1998; Helgerud et al., 2001; Hoff et al., 2002; Hoff & Helgerud, 2004; Impellizzeri, Marcora, Castagna, Reilly, Sassi, Iaia, & Rampinini, 2005a; Reilly, 2005; Sassi, Reilly, & Impellizzeri, 2005).

Aerobic Endurance Training

The purpose of endurance training is usually to increase aerobic capacity. Previous research has suggested that endurance training and adaptations associated with it, improve recovery from high intermittent exercise (Thoden, 1991). Recovery from high intermittent exercise within a match is an important factor associated with performance and logically, this suggests that a high aerobic capacity is important for optimal performance in soccer players. The common measures of aerobic capacity are maximal oxygen uptake ($\dot{V}O_2max$) and lactate threshold. Recent research has shown that the optimal training methods for improving aerobic capacity in soccer training involves endurance interval training with short bouts of high intensity work (Bangsbo, 1994a, b; Helgerud et al., 2001; Impellizzeri et al., 2006). Furthermore, there is also good evidence to support the use of match-specific small-sided games training to improve aerobic capacity in soccer players (Hoff et al., 2002; Coutts & Sirotic, 2004; Sassi et al., 2005; Impellizzeri et al., 2006; Rampinini, Marcora, Castagna, Abt, Chamari, Sassi, & Impellizzeri, 2007c).

During a 90 min game it has been reported that an elite male player may cover distances between 10 to 13 km, with the majority of time being spent at submaximal intensities that allow for energy provision via aerobic sources (Ekblom, 1986; Reilly, 1996; Mohr et al., 2003a; Impellizzeri et al., 2006; Di Salvo et al., 2007; Rampinini et al., 2007a; Rampinini et al., 2007b). Similar distances have been recorded in women soccer players (Davis & Brewer, 1993; Krustrup et al., 2005). A notable characteristic of soccer is the highly intermittent nature of the work demands in which brief, maximal sprint efforts are interspersed with longer periods of lower intensity activity (Reilly, 2003). A consequence of this intermittent work profile in soccer is the need for a well developed aerobic energy system to restore the anaerobic and alactic energy sources used during high intensity bouts (Bangsbo, 2000).

Recent studies have shown that increases in aerobic fitness can transfer directly to match physical performance in soccer players (Helgerud et al., 2001; Impellizzeri et al., 2006). For example, Helgerud et al. (2001) reported that a 10.1% increase in $\dot{V}O_2max$ achieved through 8 weeks of high-intensity interval running in well-trained young male soccer players transferred to improved running performance during a match and during soccer specific tests. In addition, recent research has also demonstrated a positive correlation between maximal oxygen uptake and high intensity running during a game in both high-level women soccer (Krustrup et al., 2005) and elite male soccer players (Mohr et al., 2003a). Indeed, Mohr et al (2003a) suggested that aerobic power may be more important for the physical match performance in elite women players than their elite male counterparts. Collectively, the research clearly suggests that an increased aerobic capacity is associated with improved physical match performance. However, at present a significant challenge for sports scientists and coaches who work with soccer is to be able to accurately quantify changes in aerobic fitness in soccer players during the training year.

Methods for Testing Aerobic Capacity in Soccer Players

There are many physiological and physical factors required for high performance soccer (Bangsbo et al., 2006). Therefore, the ability to monitor these factors in the development of players is of great importance to coaches and sport scientists. In addition to the measurements that are commonly taken in the pre-season and mid-season, the ability to monitor progression in these factors at regular intervals throughout the season would provide valuable information to guide training programs during the entire training year. For most of these physiological and physical factors there are simple tests that can be used to assess them. For example, sprint tests over distances of 10 to 40-m are common in soccer to assess speed characteristics (Bangsbo et al., 1991; Hoff & Helgerud, 2004; Wisløff, Castagna, Helgerud, Jones, & Hoff, 2004), whilst leg strength if often assessed using 1- repetition max (1-RM) leg squat performance (Wisløff et al., 1998; Wisløff et al., 2004; Hoff, 2005). However, in contrast, there are few simple tests that can be used to monitor changes in aerobic fitness in soccer players.

Maximum oxygen uptake ($\dot{V}O_2max$) and lactate threshold (LT) are considered to be the most important element in determining aerobic endurance capacity (Edwards, Clark, & Macfadyen, 2003; Coyle, 1999). However, unfortunately there are several limitations with these laboratory-based tests which restrict its usefulness as a regular monitoring tool in soccer players. In particular, these tests are time consuming, expensive to undertake, require a high level of expertise to conduct, require a maximal effort from the players and are not always valid measures of changes in match performance in soccer players (Bangsbo, 1994b; Impellizzeri, Mognoni, Sassi, & Rampinini, 2005b). To overcome these limitations, several recent studies have highlighted the potential of using submaximal aerobic tests for tracking changes in aerobic fitness in soccer players (Krustrup et al., 2003; Impellizzeri et al., 2005b; Impellizzeri et al., 2005c). For example, Impellizzeri et al., (2005b), reported that some studies have shown training induced changes in the submaximal test results (i.e. lactate and HR changes) without concurrent changes in $\dot{V}O_2max$. Moreover, Bangsbo (1994b) also reported that $\dot{V}O_2max$ is not always sensitive to training-induced changes in aerobic fitness. This previous study tested $\dot{V}O_2max$ in 11 soccer players after 7 weeks of training before a Championship Cup match and did not find any improvements in $\dot{V}O_2max$ after the training period. However, despite this, significant changes were recorded in submaximal blood lactate concentrations ([BLa$^-$]) with a decrease being documented after the 7 week training period and remained throughout the rest of the season. Furthermore, Casajus (2001) also found no changes in $\dot{V}O_2max$ in a professional soccer team despite improvements in ventilatory threshold during an entire season in top level Spanish male soccer players. Both these previous studies demonstrate using submaximal tests could provide more thorough information on soccer player's aerobic fitness status than $\dot{V}O_2max$ alone. Taken together, the findings of these previous studies provide evidence to suggest that submaximal assessments of aerobic fitness may be more sensitive and practical than a maximal test for monitoring soccer players.

Tests Used to Evaluate and Monitor Adaptations in Football Players

It is important to have simple and accessible tests so that coaches and scientists are able to evaluate training and improvements in physical capacities of players. Although there are many tests that can be used to assess aerobic fitness, most of these tests are laboratory based requiring expensive equipment, expertise and time to conduct. Therefore only a few of the top-professional clubs with access to significant financial and personal resources are able to adopt this monitoring approach.

Another barrier to completing these tests with soccer players is that the maximal tests require the athlete to be tested to exhaustion which may result in residual fatigue and subsequently poor training and playing performances. These tests rely on high player motivation to complete and are not the preferred method for both athletes and coaches to test players before and during a season. For this reason submaximal field-based tests have been developed so that testing aerobic fitness variables is more efficient, practical and applicable for soccer players and coaches in the field.

Field-based Maximal Tests

Many field tests have been developed to assess soccer-specific performance (Leger & Lambert, 1982; Nicholas, Nuttall, & Williams, 2000; Wragg, Maxwell, & Doust, 2000; Krustrup et al., 2003; Krustrup et al., 2006a). Most of these tests require maximal effort but offer a large advantage in that many players can be tested at one time. This factor makes these tests more attractive than laboratory-based tests to coaches and sports scientists who work with soccer teams. For example, Leger and Lambert (1982) developed a multistage 20-m (MSFT) shuttle run test for this reason. The MSFT is a test to exhaustion involving a continuous incremental running protocol. A strong correlation was found between the running speed reached at the end of the MSFT and $\dot{V}O_2max$.

The Loughborough Intermittent Shuttle Test (LIST) is another performance test designed to assess soccer-specific running performance. The LIST is designed to stimulate the activity patterns experienced during a soccer game and consists of two components. The first part being of a fixed duration and consists of five 15 min protocols separated by 3 min recovery. The second part consists of an open-ended time period which is designed to bring participants to exhaustion within approximately 10 min. This test has been validated as a reliable test to assess the physiological responses to high-intensity exercise, and is able to simulate closely the match demands of soccer. Indeed, Nicholas et al., (2000) reported that distance covered, number of sprints, blood lactate and HR recorded during LIST were similar to those reported during a match. However, a limitation with both the MSFT and the LIST is that they both require maximal effort and motivation and can be time consuming. These qualities decrease the application to testing soccer players in the field.

The Yo-Yo fitness tests are a relatively new group of tests for assessing soccer-related fitness This battery of tests was first developed by famous Danish scientist and professional soccer player, Jens Bangsbo (1994a). They are available in three separate formats, each with two levels (i.e. the Yo-Yo Endurance Test, the Yo-Yo Intermittent Endurance Test and the Yo-Yo Intermittent Recovery Test). The Yo-Yo intermittent endurance test is a specific endurance test consisting of a 20 m shuttle run which increases in speed interspersed by 5 s of active recovery, until exhaustion (Krustrup & Bangsbo, 2001; Krustrup et al., 2003; Mohr et al., 2003b; Krustrup et al., 2005; Metaxas, Koutlianos, Kouidi, & Deligiannis, 2005). The aim of the test is to continue until the player can no longer maintain the required speed. This test is designed to replicate the last part of a soccer match where the player is required to continue performing sprints after prolonged intermittent exercise. There have been many studies which have examined the validity and reliability of the soccer specific field tests (Krustrup et al., 2003; Castagna, Impellizzeri, Belardinelli, Abt, Coutts, Chamari, & D'Ottavio, 2006; Krustrup et al., 2006a).

Another popular test is the Yo-Yo intermittent recovery test which has been designed to measure the player's ability to recover from intense exercise, which is an important aspect related to performance in football. The running speeds of this test are higher than those of the endurance test with a 10 s active recovery break in between. Krustrup et al., (2003) showed that performance in the Yo-Yo intermittent recovery test correlated well with the physical match performance of elite male soccer players. This test was also reported to have a high sensitivity which allowed it to be used for detailed analysis of differences between players and also the seasonal changes of a player's physical capacity. Furthermore, Krustrup and Bangsbo (2001) also showed a correlation with top class referees and match running performance and more recently demonstrated this test to be a good predictor of high-intensity running throughout competitive matches in women soccer players (Krustrup et al., 2005). However, it has also recently demonstrated only low to moderate correlations between the Yo-Yo endurance test (Metaxas et al., 2005), Yo-Yo intermittent endurance test (Metaxas et al., 2005) and Yo-Yo intermittent recovery test (Sirotic & Coutts, 2006) performance with $\dot{V}O_2max$. Taken collectively, these results suggest that Yo-Yo tests may not be a valid predictor of $\dot{V}O_2max$ for soccer players; however, these tests do appear to be valid and reliable tests for assessing match-specific running performance in soccer players. Finally, the limitations of these tests are that they require maximal effort and a high level of motivation which restricts its application for regular testing in high level soccer players.

Alternative Tests to Maximal Tests

Submaximal Field-based Tests

Another field-based test used to evaluate aerobic performance is Mognoni's test (Sirtori, Lorenzelli, Peroni-Ranchet, Colombini, & Mognoni, 1993) which assesses [BLa⁻] following 6 min of submaximal running. Previous research has reported a strong correlation between blood lactate at the end of a single 6 min run and speed at onset of blood lactate accumulation (OBLA) during a multi-stage running test on an outdoor running track (Sirtori et al., 1993). However, there has only been one other paper confirming the validity of this test for soccer players (Impellizzeri et al., 2005b). Impellizzeri et al., (2005b) recently reported a significant correlation between the changes in blood lactate accumulation at the end of a 6 min run and training induced changes in OBLA. On the basis of these results it was suggested Mognoni Test to be appropriate for an estimation of aerobic fitness changes within individual soccer players. However, a limitation of this submaximal test is that only one player can be assessed at any time which limits its application in a team sport environment such as soccer.

It has been suggested previously that a submaximal version of the Yo-Yo tests may be a useful tool for assessing aerobic fitness changes in soccer players (Krustrup et al., 2003; Impellizzeri et al., 2005b). In particular it has been suggested that an abbreviated 6 min test may be used to assess aerobic fitness changes by measuring the final HR or blood lactate accumulation at the end of the standard workload. Impellizzeri et al. (2005b) recently demonstrated that submaximal [BLa$^-$] may be useful for longitudinal assessment for changes in lactate threshold within individual soccer players. It was suggested that such measures may be a valuable tool in assessing an individual athlete's seasonal progression in relation to aerobic fitness changes within a team. They also suggested that since [BLa$^-$] could easily be influenced by previous hard training or an athlete being in an overreached state, that the ratio of blood lactate to perception of effort (La:RPE) ratio could also be calculated (Garcin, Fleury, & Billat, 2002). In their study Garcin et al (2002)., found that maximal and submaximal [BLa^-] had remained unchanged and that RPE had increased significantly after 8 weeks of intense training at the beginning of a season. A significant increase in RPE was recorded for some of the subjects, although the La: RPE ratio did not change, suggesting that subjects are likely to be overreached when the ratio decreases significantly.

The benefits of being able to gain valuable information from submaximal fitness tests are that many players can be tested in a short time, and athletes are not required to do a maximal test therefore planning for testing in relation to matches throughout the season becomes more feasible. The limitations of the test are that HR monitors are still needed and collection of blood lactate still requires an invasive procedure. To date there have been no studies assessing the reproducibility of the submaximal Yo-Yo test or validating the submaximal Yo-Yo intermittent recovery tests as a test on it's own. Moreover, to date, there has only been one test validating the Yo-Yo IR test in women soccer players (Krustrup et al., 2005).

The need to ensure an optimal training program encompassing all training components as well as optimal recovery time within a week to week competition cycle is of great importance to a coach and soccer player. To be able to achieve this there is a need to monitor and assess individual responses to training and competition. Our current project aims to identify valid, reliable and practical tools which can be used by sport scientists, coaches and players to support an individual training and monitoring approach to training programs of individual players in team sports.

Summary of Literature Review

Previous studies have identified aerobic capacity, endurance, speed, strength and power as important factors associated with high level performance in soccer. A training program needs to optimally develop the physical capacities and address the technical/tactical objectives of each individual player within a team. In addition to the training program, match preparation and competition as well as recovery need to also be considered. Therefore, developing an effective training program incorporating the right balance of training stimuli and recovery for an individual player can be complicated. A practical tool which monitors a player's response to the training stimuli provides coach, sport scientist and player with valuable information to ensure optimal performance. Many HR-based methods of monitoring an individual's internal TL have been validated but each have limitations. Using the session-RPE based method provides a simplistic and holistic approach to ensuring a players internal TL can be monitored and training programs adjusted to individual needs.

The importance of aerobic fitness in elite soccer players has been well documented. An ability to monitor aerobic adaptations throughout the season would ensure that players were developing their aerobic capacity to their potential. There are many laboratory and field-based maximal tests that are available to determine aerobic adaptations in soccer players. However, limitations are associated with them being maximal tests and the practical implications of administering these tests within a season. A submaximal soccer-specific field test would provide a valuable alternative to the maximal tests and be an important monitoring tool for coaches and sport scientists. The purpose of the current research is to determine the validity and reliability of both the session-RPE method and the submaximal Yo-Yo intermittent recovery test in elite women soccer players.

References

Achten, J., & Jeukendrup, A. E. (2003). Heart rate monitoring: Applications and limitations. Sports Medicine, 33(7), 517-538.

Andersen, L., Triplett-McBride, T., Foster, C., Doberstein, S., & Brice, G. (2003). Impact of training patterns on incidence of illness and injury during a women's collegiate basketball season. Journal of Strength and Conditioning Research, 17(4), 734-738.

Andersson, H., Krustrup, P., & Mohr, M. (2007). Differences in movement pattern, heart rate and fatigue development in international versus national league matches of Swedish & Danish elite female soccer players. Journal of Sports Science and Medicine 10(1 (Supp)), 138-140.

Åstrand, P. O., & Rodahl, K. (1986). Textbook of Work Physiology. New York: McGraw Hill.

Bangsbo, J. (1994a). Fitness training in football. Bagsværd: HO+Storm.

Bangsbo, J. (1994b). The physiology of soccer with special reference to intense intermittent exercise. Acta Physiologica Scandinavica, 151(Supplement 619), 1-156.

Bangsbo, J. (2000). Physiology of intermittent exercise. In W. E. Garrett & D. T. Kirkendall (Eds.), Exercise and Sport Science (pp. 53-65). Philadelphia: Lippincott, Williams & Wilkins.

Bangsbo, J. (2005). Variations in running speeds and recovery time after a sprint during top-class soccer matches. Medicine and Science in Sports and Exercise, 37(5), s87.

Bangsbo, J., Iaia, F. M., & Krustrup, P. (2007). Metabolic response and fatigue in soccer International Journal of Sports Performance and Physiology, 2(2), 111-127.

Bangsbo, J., Mohr, M., & Krustrup, P. (2006). Physical and metabolic demands of training and match-play in the elite football player. Journal of Sports Sciences, 24(7), 665-674.

Bangsbo, J., Nørregaard, L., & Thosøe, F. (1991). Activity profile of competition soccer. Canadian Journal of Sport Sciences, 16, 110-116.

Banister, E. W. (1991). Modeling elite athletic performance. In H. J. Green & J. D. McDougal & H. A. Wenger (Eds.), Physiological Testing of Elite Athletes (pp. 403-424). Champaign, Illinois: Human Kinetics.

Banister, E. W., & Calvert, T. W. (1980). Planning for future performance: Implications for long term training. Canadian Journal of Applied Sports Sciences, 5(3), 170-176.

Banister, E. W., Calvert, T. W., Savage, M. V., & Bach, T. (1975). A systems model of training for athletic performance. Australian Journal of Sports Medicine and Exercise Science, 7, 57-61.

Banister, E. W., Good, P., Holman, G., & Hamilton, C. L. (1986). Modelling the training response in athletes. In D. M. Landers (Ed.), Sport and Elite Performers (pp. 7-23). Champaign, Illinois: Human Kinetics.

Banister, E. W., & Wenger, H. A. (1982). Monitoring Training. In J. D. MacDougall & H. A. Wenger & H. J. Green (Eds.), Physiological Testing of the Elite Athlete. New York: Movement Publications.

Borg, G., Ljunggren, G., & Ceci, R. (1985). The increase of perceived exertion, aches and pain in the legs, heart rate and blood lactate during exercise on a bicycle ergometer. European Journal of Applied Physiology, 54(4), 343-349.

Bunc, V., & Psotta, R. (2001). Physiological profile of very young soccer players. Journal of Sports Medicine and Physical Fitness, 41(3), 337-341.

Casajus, J. A. (2001). Seasonal variation in fitness variables in professional soccer players. Journal of Sports Medicine and Physical Fitness, 41(4), 463-469.

Castagna, C., Impellizzeri, F. M., Belardinelli, R., Abt, G., Coutts, A. J., Chamari, K., & D'Ottavio, S. (2006). Cardiorespiratory responses to Yo-Yo Intermittent Endurance test in nonelite youth soccer players. Journal of Strength and Conditioning Research, 20(2), 326-330.

Coutts, A. J., Rampinini, E., Castagna, C., Marcora, S., & Impellizzeri, F. M. (2007a). Physiological correlates of perceived exertion during soccer-specific exercise. Journal of Science and Medicine in Sport, in review.

Coutts, A. J., Rampinini, E., Marcora, S., & Impellizzeri, F. M. (2006). Physiological correlates of perceived exertion during soccer-specific exercise. Scandinavian Journal of Medicine and Science in Sports, in review.

Coutts, A. J., Reaburn, P., Piva, T. J., & Rowsell, G. J. (2007b). Monitoring for overreaching in rugby league players. European Journal of Applied Physiology, 99(3), 313-324.

Coutts, A. J., Reaburn, P. R. J., Murphy, A. J., Pine, M. J., & Impellizzeri, F. M. (2003). Validity of the session-RPE method for determining training load in team sport athletes. Journal of Science and Medicine in Sport, 6(4), 525.

Coutts, A. J., & Sirotic, A. C. (2004). Increasing aerobic fitness improves match-specific running performance in team sport athletes. Paper presented at the 9th Annual Congress of the European College of Sport Science, Clermont-Ferrand, France. 243.

Coutts, A. J., Sirotic, A. C., Catterick, C., & Knowles, H. (2008). Monitoring Training Loads in Professional Rugby League. In T. Reilly & F. Korkusuz & E. Ergin (Eds.), Science and Football VI (pp. in press). London, UK: Routledge.

Coutts, A. J., Slattery, K. M., & Wallace, L. K. (2007c). Practical tests for monitoring fatigue and recovery in triathletes. Journal of Science and Medicine in Sports, doi:10.1016/j.jsams.2007.1002.1007

Coyle, E. F. (1999). Physiological determinants of endurance exercise performance. Journal of Science and Medicine in Sport, 2(3), 181-189.

Davis, J. A., & Brewer, J. (1993). Applied physiology of female soccer players. Sports Medicine, 16(3), 180-189.

Delattre, E., Garcin, M., Mille-Hamard, L., & Billat, V. (2006). Objective and subjective analysis of the training content in young cyclists. Applied Physiology, Nutrition, and Metabolism, 31(2), 118-125.

Di Salvo, V., Baron, R., Tschan, H., Calderon Montero, F. J., Bachl, N., & Pigozzi, F. (2007). Performance characteristics according to playing position in elite soccer. International Journal of Sports Medicine, 28(3), 222-227.

Edwards, A. M., Clark, N., & Macfadyen, A. M. (2003). Lactate and ventilatory thresholds reflect the training status of professional soccer players where maximum aerobic power is unchanged. Journal of Sports Science and Medicine, 2(1), 23-29.

Ekblom, B. (1986). Applied physiology of soccer. Sports Medicine, 3, 50-60.

Filaire, E., Bernain, X., Sagnol, M., & Lac, G. (2001). Preliminary results on mood state, salivary Testosterone:Cortisol ratio and team performance in a professional soccer team. European Journal of Applied Physiology, 86(2), 179-184.

Filaire, E., Lac, G., & Pequignot, J. M. (2003). Biological, hormonal, and psychological parameters in professional soccer players throughout a competitive season. Perceptual and Motor Skills, 97(3 Pt 2), 1061-1072.

Flanaghan, T., & Merrick, E. (2001). Quantifying the work-load of soccer players. In W. Spinks & T. Reilly & A. J. Murphy (Eds.), Science and Football IV (pp. 341-349). London: E & FN Spon.

Foster, C. (1998). Monitoring training in athletes with reference to overtraining syndrome. Medicine and Science in Sports and Exercise, 30(7), 1164-1168.

Foster, C., Daines, E., Hector, L., Snyder, A. C., & Welsh, R. (1996). Athletic performance in relation to training load. Wisconsin Medical Journal, 95, 370-374.

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., Doleshal, P., & Dodge, C. (2001a). A new approach to monitoring exercise training. Journal of Strength and Conditioning Research, 15(1), 109-115.

Foster, C., Hector, L. L., Welsh, R., Schrager, M., Green, M. A., & Snyder, A. C. (1995). Effects of specific versus cross-training on running performance. European Journal of Applied Physiology, 70(4), 367-372.

Foster, C., Helmann, K. M., Esten, P. L., Brice, G., & Porcari, J. P. (2001b). Differences in perceptions of training by coaches and athletes. South African Journal of Sports Medicine, 8(1), 3-7.

Foster, C., & Lehmann, M. (1997). Overtraining syndrome. In N. Gnuten (Ed.), Running Injuries (pp. 173-188). Philadelphia: W.B. Saunders.

Garcin, M., Fleury, A., & Billat, V. L. (2002). The ratio HLa:RPE as a tool to appreciate overreaching in young high-level middle-distance runners. International Journal of Sports Medicine, 23(1), 16-21.

Gilman, M. B. (1996). The use of heart rate to monitor the intensity of endurance training. Sports Medicine, 21(2), 73-79.

Halson, S. L., & Jeukendrup, A. E. (2004). Does overtraining exist? : an analysis of overreaching and overtraining research. Sports Medicine, 34(14), 967-981.

Helgerud, J., Christian Engen, L., Wisløff, U., & Hoff, J. (2001). Aerobic endurance training improves soccer performance. Medicine and Science in Sports and Exercise, 33(11), 1925-1931.

Hewitt, A., Withers, R., & Lyons, K. (2007). Match analyses of Australian international women soccer players using an athlete tracking device. Journal of Sports Science and Medicine, 10(1 (Suppl)), 138-140.

Hoare, D. G., & Warr, C. R. (2000). Talent identification and women's soccer: An Australian experience. Journal of Sports Sciences, 18(9), 751-758.

Hoff, J. (2005). Training and testing physical capacities for elite soccer players. Journal of Sports Sciences, 23(6), 573-582.
Hoff, J., & Helgerud, J. (2004). Endurance and strength training for soccer players. Sports Medicine, 34(3), 165-180.
Hoff, J., Wisløff, U., Engen, L. C., Kemi, O. J., & Helgerud, J. (2002). Soccer specific aerobic endurance training. British Journal of Sports Medicine, 36(3), 218-221.
Impellizzeri, F. M., Marcora, S. M., Castagna, C., Reilly, T., Sassi, A., Iaia, F. M., & Rampinini, E. (2005a). Physiological and performance effects of generic versus specific aerobic training in soccer players. International Journal of Sports Medicine, DOI: 10.1055/s-2005-865839.
Impellizzeri, F. M., Marcora, S. M., Castagna, C., Reilly, T., Sassi, A., Iaia, F. M., & Rampinini, E. (2006). Physiological and performance effects of generic versus specific aerobic training in soccer players. International Journal of Sports Medicine, 27(6), 483-492
Impellizzeri, F. M., Mognoni, P., Sassi, A., & Rampinini, E. (2005b). Validity of a submaximal running test to evaluate aerobic fitness changes in soccer players. In T. Reilly & J. Cabri & D. Araujo (Eds.), Science and Football V (pp. 105-111). London, UK: Routledge.
Impellizzeri, F. M., Rampinini, E., Coutts, A. J., Sassi, A., & Marcora, S. M. (2004). The use of RPE-based training load in soccer. Medicine and Science in Sports and Exercise, 36(6), 1042-1047.
Impellizzeri, F. M., Rampinini, E., & Marcora, S. M. (2005c). Physiological assessment of aerobic training in soccer Journal of Sports Sciences, 23(6), 583-592.
Jensen, K., & Larsson, B. (1992). Variations in physical capacity among the Danish national soccer team for women during a period of supplemental training. Journal of Sports Sciences, 10, 144-145.
Juric, I., Sporis, G., & Vatroslav, M. (2007). Analysis of morphological features and played team positions in elite female soccer players. Journal of Sports Science and Medicine, 10(1 (Suppl)), 138-140.
Krustrup, P., & Bangsbo, J. (2001). Physiological demands of top-class soccer refereeing in relation to physical capacity: effect of intense intermittent exercise training. Journal of Sports Sciences, 19(11), 881-891.
Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., Pedersen, P. K., & Bangsbo, J. (2003). The Yo-Yo Intermittent Recovery Test: Physiological response, reliability, and validity. Medicine and Science in Sports and Exercise, 35(4), 697-705.
Krustrup, P., Mohr, M., Ellingsgaard, H., & Bangsbo, J. (2005). Physical demands during an elite female soccer game: importance of training status. Medicine and Science in Sports and Exercise, 37(7), 1242-1248.
Krustrup, P., Mohr, M., Nybo, L., Jensen, J. M., Nielsen, J. J., & Bangsbo, J. (2006a). The Yo-Yo IR2 test: physiological response, reliability, and application to elite soccer. Medicine and Science in Sports Exercise, 38(9), 1666-1673.

Krustrup, P., Mohr, M., Steensberg, A., Bencke, J., Kjaer, M., & Bangsbo, J. (2006b). Muscle and blood metabolites during a soccer game: implications for sprint performance. Medicine and Science in Sports and Exercise, 38(6), 1165-1174.

Leger, L. A., & Lambert, J. (1982). A maximal multistage 20 m shuttle run test to predict $\dot{V}O_2max$. European Journal of Applied Physiology, 49, 1-5.

Lucía, A., Hoyos, J., Santalla, A., Earnest, C., & Chicharro, J. L. (2003). Tour de France versus Vuelta a Espana: which is harder? Medicine and Science in Sports and Exercise, 35(5), 872-878.

Martin, D. T., & Andersen, M. B. (2000). Heart rate-perceived exertion relationship during training and taper. Journal of Sports Medicine and Physical Fitness, 40, 201-208.

Mercer, T. H., Gleeson, N. P., & Wren, K. (2003). Influence of prolonged intermittent high-intensity exercise on knee flexor strength in male and female soccer players. European Journal of Applied Physiology, 89(5), 506-508.

Metaxas, T. I., Koutlianos, N. A., Kouidi, E. J., & Deligiannis, A. P. (2005). Comparative study of field and laboratory tests for the evaluation of aerobic capacity in soccer players. Journal of Strength and Conditioning Research, 19(1), 79-84.

Mohr, M., Ellingsgaard, H., Andersson, H., Bangsbo, J., & Krustrup, P. (2003a). Physical demands in high-level female soccer - application of fitness tests to evaluate match performance. Journal of Sports Sciences, 22(6), 552-553.

Mohr, M., Krustrup, P., & Bangsbo, J. (2003b). Match performance of high-standard soccer players with special reference to development of fatigue. Journal of Sports Sciences, 21(7), 519-528.

Mohr, M., Krustrup, P., & Bangsbo, J. (2005). Fatigue in soccer: A brief review Journal of Sports Sciences, 23(6), 593-599.

Morgan, W. P. (1973). Psychological factors influencing perceived exertion. Medicine and Science in Sports and Exercise, 5(2), 97-103.

Morton, R. H. (1997). Modelling training and overtraining. Journal of Sports Sciences, 15(3), 335-340.

Morton, R. H., Fitz-Clarke, J. R., & Banister, E. W. (1990). Modeling human performance in running. Journal of Applied Physiology, 69(3), 1171-1177.

Naessens, G., Chandler, T. J., Kibler, W. B., & Driessens, M. (2000). Clinical useful of nocturnal urinary noradrenaline excretion patterns in the follow-up of training processes in high-level soccer players. Journal of Strength and Conditioning Research, 14(2), 125-131.

Nicholas, C. W., Nuttall, F. E., & Williams, C. (2000). The Loughborough Intermittent Shuttle Test: A field test that simulates the activity pattern of soccer. Journal of Sports Sciences, 18, 97-104.

Putlur, P., Foster, C., Miskowski, J. A., Kane, M. K., Burton, S. E., Scheet, T. P., & McGuigan, M. R. (2004). Alteration of immune function in women collegiate soccer players and college students. Journal of Sports Science and Medicine, 3(4), 234-243.

Rampinini, E., Bishop, D., Marcora, S. M., Ferrari Bravo, D., Sassi, R., & Impellizzeri, F. M. (2007a). Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players. International Journal of Sports Medicine, 28(3), 228-235.

Rampinini, E., Coutts, A. J., Castagna, C., Sassi, R., & Impellizzeri, F. M. (2006). Analysis of top-level soccer match performance with particular reference to the opponents Journal of Science and Medicine in Sport, in review.

Rampinini, E., Coutts, A. J., Castagna, C., Sassi, R., & Impellizzeri, F. M. (2007b). Variation in top level soccer match performance. International Journal of Sports Medicine, in press.

Rampinini, E., Marcora, S., Castagna, C., Abt, G. A., Chamari, K., Sassi, A., & Impellizzeri, F. M. (2007c). Factors influencing physiological responses to small-sided soccer play. Journal of Sports Sciences, 25(6), 656-666.

Reilly, T. (1996). Motion analysis and physiological demands. In T. Reilly (Ed.), Science and Soccer (pp. 65-81). London: E & F.N. Spon.

Reilly, T. (1997). Energetics of high-intensity exercise (soccer) with particular reference to fatigue. Journal of Sports Sciences, 15, 257-263.

Reilly, T. (2003). Motion analysis and physiological demands. In T. Reilly & A. M. Williams (Eds.), Science and Soccer (pp. 59-72). London: Routledge.

Reilly, T. (2005). An ergonomics model of the soccer training process. Journal of Sports Sciences, 23(6), 561-572.

Rhodes, E. C., & Mosher, R. E. (1992). Aerobic and anaerobic characteristics of elite female university players. Journal of Sport Sciences, 10, 143-144.

Rodríguez, F. A., & Iglesias, X. (1998). The energy cost of soccer: Telemetric oxygen uptake measurements versus heart rate-VO_2 estimations. Journal of Sports Sciences, 16(5), 484-485.

Rowbottom, D. G. (2000). Periodization of training. In J. Garret, W.E. & D. T. Kirkendall (Eds.), Exercise and Sport Science (pp. 499-514). Philadelphia: Lippincott, Williams and Wilkins.

Sassi, R., Reilly, T., & Impellizzeri, F. (2005). A comparison of small-sided games and interval training in elite professional soccer players. In T. Reilly & J. Cabri & D. Araujo (Eds.), Science and Football V. The Proceedings of the Fifth World Congress on Science and Football (pp. 341-343). Abingdon, Oxon: Routledge.

Scott, D., & Drust, B. (2007). Work-rate analysis of elite female soccer players during match-play. Journal of Sports Science and Medicine, 10(1 (Suppl)), 138-140.

Sirotic, A. C., & Coutts, A. J. (2006). Predictors of prolonged high-intensity, intermittent running performance in team sport athletes. Journal of Strength and Conditioning Research, in press.

Sirtori, M. D., Lorenzelli, F., Peroni-Ranchet, F., Colombini, A., & Mognoni, P. (1993). A single blood lactate measure of OBLA running velocity in soccer players. Medicina dello Sport, 43, 281-286.

Snyder, A. C., Jeukendrup, A. E., Hesselink, M. K., Kuipers, H., & Foster, C. (1993). A physiological/psychological indicator of over-reaching during intensive training. International Journal of Sports Medicine, 14(1), 29-32.

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: an update. Sports Medicine, 35(6), 501-536.

Tumilty, D. (1993). Physiological characteristics of elite soccer players. Sports Medicine, 16(2), 80-96.

Viru, A., & Viru, M. (2000). Nature of training effects. In J. Garret, W.E. & D. T. Kirkendall (Eds.), Exercise and Sport Science (pp. 67-95). Philadelphia: Lippincott Williams and Wilkins.

Vucetic, V., Sporis, G., & Jukic, I. (2007). Muscle strength, kicking and sprinting performance parameters in elite female soccer players Journal of Sports Science and Medicine, 10(1 (Supp)), 138-140.

Wisløff, U., Castagna, C., Helgerud, J., Jones, R., & Hoff, J. (2004). Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. British Journal of Sports Medicine, 38(3), 285-288.

Wisløff, U., Helgerud, J., & Hoff, J. (1998). Strength and endurance of elite soccer players. Medicine and Science in Sports and Exercise, 30(3), 462-467.

Wood, R. E., Hayter, S., Rowbottom, D., & Stewart, I. (2005). Applying a mathematical model to training adaptation in a distance runner. European Journal of Applied Physiology, 94, 310-316.

Wragg, C. B., Maxwell, N. S., & Doust, J. H. (2000). Evaluation of the reliability and validity of a soccer-specific field test of repeated sprint ability. European Journal of Applied Physiology, 83, 77-83.

Chapter 3

Validity of the Session-RPE Method for Use with Women Soccer Players

Abstract

Purpose: The purpose of this study was to examine whether the session-RPE method for quantifying internal training load (TL) is a valid tool that can be used with women soccer players.

Methods: Fifteen elite women soccer players took part in the study (age 19.3 ± 2.0 y, $\dot{V}O_2max$ 50.8 ± 2.7 $mL \cdot kg^{-1} \cdot min^{-1}$). Session-RPE, heart rate and duration were recorded for 735 individual training sessions of different type (e.g., technical, weights, conditioning, speed) and matches over a period of 16 weeks. Session-RPE was validated using Pearson's product moment correlation with three commonly used HR-based methods for assessing TL. Differences between the mean TL for each exercise type were determined using a one-way ANOVA.

Results: The mean correlation across all training types between session-RPE with Banisters TRIMP, LT_{zone} TRIMP and Edwards TL were r = 0.81, 0.83 and 0.85 (all p<0.01), respectively. Correlations for session-RPE and three HR-based methods by session type were all significant (all p<0.05). The strongest correlations were reported for technical (r = 0.68 to 0.82), conditioning (r = 0.60 to 0.79) and speed sessions (r = 0.61 to 0.79)(all p<0.05).

Conclusion: The session-RPE is a valid method for assessing internal TL in women soccer players across all types of training commonly used in soccer. Stronger correlations were found with less-intermittent, aerobic-based training sessions as opposed to intermittent anaerobic-based sessions. The results support the hypothesis that session-RPE is a valid method for assessing internal TL in a variety of training modes in women soccer players.

Key Words: internal training load, heart rate, soccer training, periodisation.

Introduction

A major problem for soccer coaches is being able to implement training programs that simultaneously meet the physical and technical/ tactical objectives of both the team and individuals within the team. Furthermore, another challenge for the coach is allowing for recovery between regular competitive games, whilst also maintaining the physical training stimulus that allows for fitness adaptations (Reilly, 2005; Reilly & Ekblom, 2005). Therefore, there is a need for a simple and reliable method for monitoring training and the individual training response in soccer players (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004; Impellizzeri, Rampinini, & Marcora, 2005).

In order to optimise athletic performance, physical training should be prescribed to suit each athlete's individual characteristics. However, in soccer, training sessions are often conducted in a group which reduces the likelihood that players are receiving specific training based on their individual characteristics (Impellizzeri, Rampinini, & Marcora, 2005). For example Hoff et al., (2002) demonstrated that soccer players with superior fitness levels did not receive sufficient training stimulus to further increase their fitness when training in a team environment using small-sided games alone. It has also been suggested that players with inferior fitness levels may be overstressed during team–based training sessions leading to increased fatigue, injury and a reduction in performance. Collectively, these findings show that individuals within the same soccer team may not receive an appropriate level of training stimulus when a team-based training approach is undertaken. Therefore, to overcome the limitations associated with team-based training, it has been suggested that a simple system which quantifies an individual's internal TL (i.e. the relative physiological stress which is imposed on the athlete) is developed, so that coaches can monitor and titrate training according to individual players needs.

The assessment of internal TL requires quantification of the intensity and duration of the physiological stress imposed on the athlete (Foster, 1995). While the duration of the training session is easily measurable, intensity is more difficult to quantify. However, the most common methods used to measure exercise intensity in soccer are heart rate (HR) and ratings of perceived exertion (RPE) (Impellizzeri, Rampinini, & Marcora, 2005). The use of HR to measure exercise intensity is based on the well-known linear relationship between HR and $\dot{V}O_2$ over a wide range of steady-state submaximal workloads (Åstrand & Rodahl, 1986). However, there are several limitations associated with HR-based methods for quantifying internal TL. For example, a high level of technical expertise is required to collect and collate HR information from a whole team, collecting and analysing HR data for each player can be time consuming, there is a chance for technical errors with HR systems and the financial cost associated with purchasing and maintaining HR telemetric systems can be high. Finally another limitation of HR-based methods for quantifying internal TL in soccer is that it is a relatively poor method of evaluating very high intensity exercise such as weight training, high intensity interval training, and plyometric training (Coutts, 2001; Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). For these reasons the use of HR-based methods for quantifying TL may not be the most valid or practical approach for measuring TL in the field.

Foster (1995) proposed an alternative method for assessing internal TL utilizing Borg's Category Ratio–10 (CR-10) point scale as a measure of exercise intensity. Using this method internal TL can be calculated by multiplying the training duration by the rate of perceived exertion (RPE) score. Whilst this session-RPE method was originally proposed for endurance athletes, previous research has shown that these methods have a good level of agreement with HR-based methods for quantifying TL in team sports (Foster et al., 2001) and in particular soccer players (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). However, a limitation of these previous studies is that the majority of them have focused on endurance sports or one type of training mode (e.g., resistance training). Of the few studies that have focused on team sports and in particular soccer, the variety of training modes analysed has been limited to predominantly aerobic and technical/ tactical training sessions largely using small sided games. This study will assess the validity of the session-RPE method across all the training types typical of a soccer training program; therefore including both aerobic and technical/ tactical training, as well as anaerobic training and matches. This study will be the first to validate the session-RPE method for women soccer players.

The session-RPE method may provide valuable information in regards to monitoring TL throughout the season and appears to be of great benefit for monitoring individual soccer players' TL. As well as providing valuable information in regards to monitoring TL, the session-RPE method provides a practical alternative to using HR-based methods. However, the validity of this method has not been fully assessed across a range exercise types in women soccer players. Therefore, the purpose of this study is to examine whether the session-RPE method for quantifying internal training load (TL) is a valid tool that can be used with women soccer players.

Methods

Subjects

Fifteen elite women soccer players (age: 19.3 ± 2.0 y, height: 169 ± 5.1 cm, body mass: 64.8 ± 7.7 kg, $\dot{V}O_2$max: 50.8 ± 2.7 mL·kg^{-1}·min^{-1}) were recruited for this study. All were scholarship holders at the Football Association (FA) National Player Development Centre (Loughborough University, Loughborough, UK). Ten of the fifteen subjects were members of the England international age-group team at Under 17 y, Under 19 y, Under 21 y or open age level. Prior to the commencement of this study all subjects were given an information sheet outlining potential risks associated with involvement in this study. A written consent form was also obtained from each subject or their parent. Prior to any testing ethical approval was granted by the UTS Human Research Ethics Committee.

Approach to the Problem

The data for this study was collected from 15 high performance women soccer players over a 16 week soccer season. All subjects completed a $\dot{V}O_2$max test and a lactate threshold (LT) test at the beginning of the training year to determine the individual HR training zones. HR and session-RPE was monitored during each training session and match during the 16 week season. The relationship between the session-RPE TL and commonly used HR-based TL quantification methods were used to examine the criterion validity of the session-RPE. The strength of the relationship was reported within each individual player and also for each different training type completed during the season.

Training

Session-RPE and HR-based data was collected for 735 individual training sessions of different type (e.g., technical, weights, conditioning, speed) and matches. For the LT_{zone} method 623 of the total training samples and matches were used, because the remaining samples lacked speed lactate information. For each player a minimum of 20 sessions RPE and HR-based TL data were used to ensure adequate statistical power for the correlation analysis.

Monitoring Training Load

The TL for each session was calculated using the session-RPE method (Foster et al., 2001) for each player during the study period. This method involved multiplying the training duration in minutes by the mean training intensity (Foster et al., 2001). The training intensity was measured using a modified 10-point Rating of Perceived Exertion Scale (CR-10: RPE) (Borg et al.(1985) shown in Table 1. To ensure the subjects reported a mean RPE for the entire training session, the RPE was taken 30-minutes after the completion of the session. The TL for each day of the week was summed to provide a weekly TL.

Table 1. The 10-point Rating of Perceived Exertion scale (Borg, Hassmen, & Langerstrom, 1985).

Rating	Description
0	Rest
1	Very, Very Easy
2	Easy
3	Moderate
4	Somewhat Hard
5	Hard
6	
7	Very Hard
8	
9	
10	Maximal

Recording Training Intensity

Training intensity was recorded using Polar Individual HR monitors (Polar, OY, Finland) where HR was recorded every five seconds. To reduce HR recording error during training, all subjects were asked to check their HR monitors prior to each session and after each training set (~10 min). Following each training session, HR information was then downloaded to a computer using Polar Advantage Software (Polar, OY, Finland).

Criterion Measures of Internal TL

Several HR-based methods for quantifying TL were used as the criterion measure of internal TL in this investigation. The TRIMP method proposed by Banister et al. (1991) assumes each exercise bout elicits a training impulse. The expression of TL measured in TRIMP units is determined using the following formula:

$$TL = D(\Delta HR\ ratio)e^{b(\Delta HR\ ratio)}$$

Where: D = duration of training session, and b = 1.67 for females and 1.92 for males (Banister & Fitz-Clark, 1993; Morton, Fitz-Clarke, & Banister, 1990).

The HR-based method proposed by Edwards (1993) for determining internal TL was also used as a criterion measure of internal TL in this study. The Edwards (1993) HR-based method involves integrating the total volume of the training session with the total intensity of the exercise session relative to five intensity phases. An exercise score for each training bout is calculated by multiplying the accumulated duration in each HR zone by a multiplier allocated to each zone (50-60% HRmax = 1, 60-70% HRmax = 2, 70-80% HRmax = 3, 80-90% HRmax = 4 and 90-100% HRmax = 5) and then summating the results.

The final criterion measure of internal TL used in this study was the HR-based approach based on lactate thresholds (LT_{zone}). This approach has previously been used in a similar investigation (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). The main difference between Edward's and LT_{zone} methods for quantifying TL are that the HR zones determined in Edward's (1993) investigation are based on standardized predetermined zones, whereas LT_{zone} HR zones are based on individual parameters determined in the laboratory.

Physiological Tests

All subjects completed a maximal oxygen uptake test, and twelve of the fifteen subjects completed a lactate threshold test.

Lactate Threshold Test

Lactate threshold was measured using an incremental run on a motorised treadmill (RunRace, Technogym, Gambettola, Italy) at the Physiology Laboratory at The School of Sport and Exercise Sciences (Loughborough University, UK). The test began at between 8 km·hr^{-1} and 9 km·hr^{-1} dependant on the individual. Treadmill speed was increased every 4 minutes by 1 km·hr^{-1} up to a maximum speed of 12 km.hr^{-1}, and then 0.5 km·hr^{-1} for the final subsequent stages. Blood samples (25 µL) were taken at rest, along with two samples collected towards the end of each stage from the players thumb and analysed using a YSI 2300 STAT Plus Glucose and Lactate Analyser (Fleet, Hampshire, England). Lactate threshold was determined using the D_{max} method with the Lactate-E macro add-in (Higgins and Newell, 2005) within Microsoft Excel (Microsoft Corporation, USA).

Maximal Oxygen Uptake

The physiological tests were measured during an incremental run to exhaustion on a motorised treadmill (Run Race, Technogym, Gambettola, Italy) at the Physiology Laboratory at The School of Sport and Exercise Sciences (Loughborough University, UK). The test began with a five-minute warm-up at 8 km·hr^{-1}. The work protocol commenced and remained constant at a workload of between 8 km·hr^{-1} and 11 km·hr^{-1} throughout the test. The treadmill gradient was increased every 3 minutes by 2.5% until exhaustion (3.5, 6.0, 8.5, 11.0%) HR was recorded using portable HR monitors (Polar® NV HR monitor, OY, Finland).

Maximal oxygen uptake was measured using the conventional Douglas bag method. Expired gases were analysed using Servomex 1440 (Cowborough, Sussex, England) which was calibrated prior to each test with reference and calibration gases of known concentrations and a Harvard Dry Gas Meter (Edenbridge, Kent, UK).

Statistical Analyses

The relationship between session-RPE and previously used HR-based methods for monitoring (TL) and between training types were analysed using Pearson's product moment correlation. Relationships were determined between each of these methods for a) each session completed by each individual player and, b) each type of training completed by the players. Differences between the mean TL for each exercise type were determined using a one-way ANOVA with a Scheffe post hoc test. Statistical significance was set at $p<0.05$. SPSS statistical software package version 11.5 (SPSS Inc., Chicago, USA) was used for all statistical calculations.

Results

Individual correlations of session-RPE and all three HR-based TL methods are outlined in Table 2. All correlations were statistically significant ($p <0.01$) There were also significant correlations between the session-RPE and all the HR-based (TL) methods for each of the various training modalities (Table 3).

Table 2. Individual correlations between session-RPE (TL) and three HR-based methods. LT_{zone} TRIMP was not measured for subjects marked with N/A because lactate threshold measurements were not available.

Subject	N	Banister's TRIMP	LT_{zone} TRIMP	Edward's TL
1	20	0.75	0.88	0.50
2	115	0.76	0.82	0.74
3	20	0.92	0.85	0.93
4	60	0.91	0.63	0.93
5	26	0.76	N/A	0.85
6	80	0.88	0.93	0.95
7	39	0.74	0.56	0.78
8	20	0.95	0.66	0.91
9	20	0.94	0.97	0.96
10	58	0.81	0.88	0.91
11	80	0.91	0.94	0.93
12	42	0.67	N/A	0.72
13	39	0.87	0.90	0.90
14	44	0.89	N/A	0.89
15	72	0.90	0.94	0.92
Range		0.67 – 0.95	0.56 – 0.97	0.50 – 0.96
Mean ± SD		0.81 ± 0.09	0.83 ± 0.14	0.85 ± 0.12

Table 3. Correlation coefficients and p values for session-RPE (TL) and three HR-based methods separated by session type for the combined group of players.

	Bannister's Method			LT_{zone} Method			Edward's Method		
	R	N	p	R	N	p	R	N	p
Conditioning	0.74	139	<0.001	0.60	119	<0.001	0.79	139	<0.001
Matches	0.49	65	<0.001	0.49	56	<0.001	0.64	65	<0.001
Speed	0.61	59	<0.001	0.75	48	<0.001	0.79	59	<0.001
Technical	0.68	230	<0.001	0.69	200	<0.001	0.82	230	<0.001
Weights	0.25	242	<0.001	0.34	200	<0.001	0.52	242	<0.001

Figure 1 shows the mean (±SD) session TL for the session-RPE and HR-based methods for each of the common training modalities completed during the study periods. A one-way analysis of variance demonstrated that the TLs for each monitoring method (i.e., Banister's TRIMP, LT_{zone} and Edwards TRIMP) were not significantly different ($F = 0.15$, $df = 2$, $p = 0.86$). However within session-RPE and each monitoring method highly significant differences were detected based on training type ($p<0.001$). A post-hoc analysis Scheffe test showed that training load for matches were significantly greater than for weights, speed and conditioning, and that training load for weights were less than technical sessions.

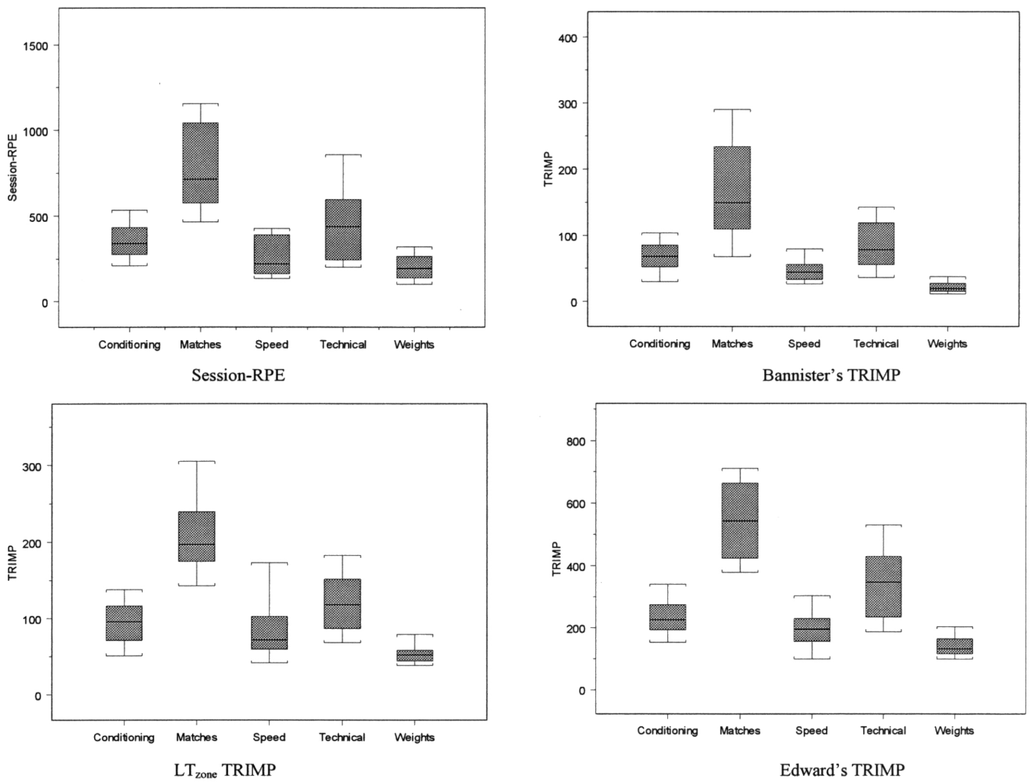

Figure 1. Box plots summarising the distribution of values for session-RPE and all three HR-based methods of measuring TL.

Discussion

This purpose of this study was to examine whether the session-RPE method for quantifying training load (TL) is a valid tool that can be used with women soccer players. The results showed that the session-RPE method had a significant positive correlation with three HR-based methods for quantifying TL within each of the 15 players examined. Moreover, we also found significant positive correlations were observed between session-RPE and the various HR methods across various training activities common to soccer. The present findings support previous studies reporting the session-RPE as valid tool for monitoring internal TL in training activities common to women's soccer.

In agreement with previous research (Foster 2001, Impellizzeri et al 2004), were observed moderate-to-strong relationships between session-RPE TL and HR-based TL methods (r = 0.50 to 0.85) within individual players. However, this study reported higher mean scores for individual correlations recorded in this study (0.81 - 0.85) than those reported in previous studies that examined soccer training (Impellizzeri et al., 2004). A possible explanation for the lower correlations recorded compared with other similar studies in sports other than soccer could be contributed to an increased anaerobic contribution during the intermittent activity which is synonymous with soccer training. In support of this, when we examined the relationships between the HR-based TRIMPS and the session-RPE method the lowest correlation was observed for the weights sessions (r = 0.25 to 0.52), which typically involve short high-intensity lifting efforts, followed by the matches (r = 0.49 to 0.64).

Previous studies have supported the validity of the session-RPE method as a tool for quantifying internal TL for resistance training using the percentage of one-repetition maximum (1-RM) as the criterion measure of training intensity (Foster et al., 2001, Day et al., 2004, Gearhart, 2001, Singh et al., 2007). In contrast to these previous studies, we compared the session-RPE method with HR-based methods. Since HR is considered a relatively poor method of evaluating very high intensity exercises such as weight training, high intensity interval training, and plyometric training it seems that using HR as the criterion measure of exercise intensity is a limitation. These types of exercises depend on a large contribution from anaerobic metabolism rather than aerobic mechanisms and therefore HR may not be an appropriate global measure of exercise intensity. It is possible that variables such as blood lactate measures taken during high-intensity exercises may better relate to RPE than HR measures.

Recent research has shown that RPE was more closely related to the combination of HR and blood lactate than either alone supporting the hypothesis that RPE is a valid global indication of exercise intensity (Coutts et al., 2007). Moreover, RPE has been suggested to be a more appropriate measure of exercise intensity than HR as it is thought to be representative of the combination of many factors affecting the internal load of exercise such as an athlete's psychological state (Morgan, 1973; Robertson & Noble, 1997), training status (Robertson & Noble, 1997; Martin, Andersen, & Gates, 2000) and the external TL (Impellizzeri, Rampinini, & Marcora, 2005). Furthermore, RPE has also demonstrated significant correlations with many physiological measures of exercise intensity such as $\dot{V}O_2$, ventilation, respiratory rate, [BLa⁻], HR and electromyographic activity during a variety of exercises (Chen, Fan, & Moe, 2002; Lagally et al., 2002; Robertson et al., 2004). Combined, these factors suggest that RPE may be a valid marker of internal training stress in athletes who undertake high-intensity, non-steady-state exercise such as soccer players.

To our best knowledge, no previous study has described the periodisation strategy used in top level women soccer players. These results show that competitive matches and technical sessions make up the majority of TL experienced by top level women soccer players in an average week and suggest that recovery practices should receive priority after these sessions. The simplicity and versatility of session-RPE makes it a valuable tool for athletes, coaches and sport scientists. Its low cost and lack of reliance on expertise make it a very user friendly and practical tool for monitoring TL in soccer. One of the benefits of using Borg's CR-10 scale (Borg, Ljunggren, & Ceci, 1985) is it's measure of both psychological and physiological factors, therefore giving a more holistic indication of the 'global' exercise intensity (Morgan, 1994). The present study also supports the benefits of using the session-RPE to support the development of effective individual periodisation plans for each player within a soccer team. Previous research has suggested that session-RPE could be used to report TL for a variety of session types including both aerobic and anaerobic training, as well as report TL in particular to soccer players (Foster et al., 1995, Foster et al., 2001a, Sweet et al., 2004, Gearhardt et al., 2001, Coutts, Reaburn, Murphy, Pine, & Impellizzeri, 2003, Impellizzeri et al., 2004; Coutts et al., 2007a).

Conclusion

The purpose of this study was to examine whether the session-RPE method is a valid tool for quantifying internal TL with women soccer players in a variety of different types of training modes. The results demonstrate that the session-RPE method has a strong relationship with various HR methods for quantifying TL for all individual players in this study and most of the different exercise modes routinely performed by top level women soccer players. These results support previous findings that session-RPE is a valid method for accessing internal TL for soccer players and in particular women soccer players.

References

Åstrand, P. O., & Rodahl, K. (1986). *Textbook of Work Physiology*. New York: McGraw Hill.

Banister, E. W. (1991). Modeling elite athletic performance. In H. J. Green, J. D. McDougal & H. A. Wenger (Eds.), *Physiological Testing of Elite Athletes* (pp. 403-424). Champaign, Illinois: Human Kinetics.

Banister, E. W., & Fitz-Clark, J. R. (1993). Plasticity of response to equal qualities of endurance training separated by non-training in humans. *Journal of Thermal Biology, 5*(6), 587-597.

Borg, G., Ljunggren, G., & Ceci, R. (1985). The increase of perceived exertion, aches and pain in the legs, heart rate and blood lactate during exercise on a bicycle ergometer. *European Journal of Applied Physiology, 54*(4), 343-349.

Borg, G. A. V., Hassmen, P., & Langerstrom, M. (1985). Perceived exertion in relation to heart rate and blood lactate during arm and leg exercise. *European Journal of Applied Physiology, 65*, 679-685.

Chen, M. J., Fan, X., & Moe, S. T. (2002). Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: a meta-analysis. *J Sports Sci, 20*(11), 873-899.

Coutts, A. J. (2001). Monitoring training in team sports. *Sports Coach, 24*(3), 19-23.

Edwards, S. (1993). High performance training and racing. In S. Edwards (Ed.), *The Heart Rate Monitor Book* (8th ed., pp. 113-123). Sacramento, CA: Feet Fleet Press.

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., et al. (2001). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research, 15*(1), 109-115.

Hoff, J., Wisløff, U., Engen, L. C., Kemi, O. J., & Helgerud, J. (2002). Soccer specific aerobic endurance training. *British Journal of Sports Medicine, 36*(3), 218-221.

Impellizzeri, F. M., Rampinini, E., Coutts, A. J., Sassi, A., & Marcora, S. M. (2004). The use of RPE-based training load in soccer. *Medicine and Science in Sports and Exercise, 36*(6), 1042-1047.

Impellizzeri, F. M., Rampinini, E., & Marcora, S. M. (2005). Physiological assessment of aerobic training in soccer *Journal of Sports Sciences, 23*(6), 583-592.

Lagally, K. M., Robertson, R. J., Gallagher, K. I., Goss, F. L., Jakicic, J. M., Lephart, S. M., et al. (2002). Perceived exertion, electromyography, and blood lactate during acute bouts of resistance exercise. *Med Sci Sports Exerc, 34*(3), 552-559; discussion 560.

Martin, D. T., Andersen, M. B., & Gates, W. (2000). Using profile of mood states (POMS) to monitor high-intensity training in cyclists: group versus case studies. *The Sport Psychologist, 14*, 138-156.

Morgan, W. P. (1973). Psychological factors influencing perceived exertion. *Medicine and Science in Sports and Exercise, 5*(2), 97-103.

Morgan, W. P. (1994). Psychological components of effort sense. *Medicine and Science in Sports and Exercise, 26*(9), 1071-1077.

Morton, R. H., Fitz-Clarke, J. R., & Banister, E. W. (1990). Modeling human performance in running. *Journal of Applied Physiology, 69*(3), 1171-1177.

Reilly, T. (2005). An ergonomics model of the soccer training process. *Journal of Sports Sciences, 23*(6), 561-572.

Reilly, T., & Ekblom, B. (2005). The use of recovery methods post-exercise. *Journal of Sports Sciences, 23*(6), 619-627.

Robertson, R. J., Goss, F. L., Dube, J., Rutkowski, J., Dupain, M., Brennan, C., et al. (2004). Validation of the adult OMNI scale of perceived exertion for cycle ergometer exercise. *Med Sci Sports Exerc, 36*(1), 102-108.

Robertson, R. J., & Noble, B. J. (1997). Perception of physical exertion: methods, mediators, and applications. *Exercise and Sport Sciences Reviews, 25*, 407-452.

Chapter 4

The Validity and Repeatability of Blood Lactate, RPE and Heart Rate Responses During the Sub-maximal Yo-Yo Intermittent Recovery Test for Use with Women Soccer Players

Abstract

Purpose: Submaximal field tests have recently been suggested to be a potential measure of aerobic fitness adaptations for field sport athletes. The purpose of this study is to determine whether blood lactate, RPE and HR responses to the 6 min submaximal Yo-Yo intermittent recovery test level 1 (Yo-Yo_{submax}) are repeatable and valid methods of aerobic adaptations in women soccer players.

Methods: Ten elite women soccer players (age: 19.3 ± 2.3 y, body mass: 66.0 ± 7.3 kg, height: 1.69 ± 0.05 m) completed the following laboratory and field based tests (maximal oxygen uptake ($\dot{V}O_2max$), Lactate threshold velocity (LTV), Multistage Fitness Test (MSFT) and Yo-Yo_{submax} in the first week of a season. The test-retest reliability of a 6 min Yo-Yo_{submax} was also completed by fourteen elite women soccer players.

Results: Significant correlations were detected for $\dot{V}O_2max$ with [BLa⁻] to RPE ratio (r = 0.51, p= 0.05) as well as HR to [BLa⁻] ratio (r = -0.62, p = 0.019) with the MSFT. Moderately significant correlations were detected for $\dot{V}O_2max$ with HR to RPE ratio (r = 0.62, p= 0.10) No significant association was detected between ratio measures and LTV (p>0.05). Furthermore there was no significance found for all independent measures. The coefficient of variation for [BLa⁻], HR and RPE was 20.7%, 4.0% and 13.1%, respectively.

Conclusion: These results show that the physiological variables taken following the Yo-Yo $_{submax}$ relate to MSFT performance but not LTV. Additionally, results showed only a moderate level of repeatability of these measures, which suggest that this submaximal test may not be suitable to detect changes in aerobic fitness during a soccer season.

Key Words: Yo-Yo IR, aerobic fitness, submaximal, HR, blood lactate, RPE.

Introduction

The multidisciplinary nature of soccer training combined with the arduous competition structure of week to week matches makes it difficult to monitor training and adaptations in players. At present, there are few practical and valid tests that are available to assess aerobic fitness adaptation in large groups of soccer players. Recently, submaximal field tests have been suggested to be a potential surrogate measure of aerobic fitness for field sport athletes (Krustrup, Mohr, Amstrup, Rysgaard, Johansen, Steensberg, Pedersen, & Bangsbo, 2003; Impellizzeri, Mognoni, Sassi, & Rampinini, 2005). However, to date, no studies have examined the validity of these tests as a measure of aerobic fitness with high level soccer players. It is possible that if a valid and reliable test that was sensitive to changes in aerobic fitness adaptations was developed it then could be used to monitor an individual player's response to training.

At present, the common tests for monitoring aerobic adaptation in soccer players, such as lactate threshold (LT) (Edwards, Clark, & Macfadyen, 2003) and maximal oxygen uptake ($\dot{V}O_2max$) (Helgerud, Christian Engen, Wisløff, & Hoff, 2001; Reilly, 2005) assessment, require expensive laboratory equipment, may demand maximal effort and are time consuming. Due to these limitations, with the exception of only a few top-level clubs, these tests are not practical for most players. Recent research has suggested that submaximal field tests may provide similar information as that which is obtained from maximal laboratory-based tests (Impellizzeri et al., 2005; Sassi, Marcora, Rampinini, Mognoni, & Impellizzeri, 2006; Coutts, Slattery, & Wallace, 2007). The advantages of submaximal tests are that they are of low cost, do not require expensive equipment, are easy to implement and are a viable option for most clubs.

Krustrup et al., (2003) were the first to propose the submaximal version of the Yo-Yo IR1 test. This previous study examined the reproducibility and validity of the Yo-Yo IR1 and evaluated the physiological responses during the test. It was reported that HR during the 6th min submaximal Yo-Yo IR1 correlated well with the physical match performance (i.e. HR obtained at both 6 and 9 min) were inversely correlated to Yo-Yo test performance, a significant correlation was reported between test performance and the amount of high-intensity exercise during a game of elite male soccer players. More recently, Krustrup et al., (2005) also reported that Yo-Yo IR1 test performance correlated to the amount of high-intensity running in a game in elite women soccer players. Unlike the previous study Krustrup et al., (2003) reported a positive correlation between high intensity running during a game and $\dot{V}O_2max$. Bangsbo, (2001) also showed a correlation with $\dot{V}O_2max$ and match running performance indicators in top class referees, however, there are only limited studies conducted to test and validate this method with elite women soccer players and no studies validating a submaximal version of the Yo-Yo IR1 test.

More recently, Impellizzeri et al. (2005) assessed the validity of a submaximal treadmill run in soccer players and reported that blood lactate responses to a 6 min submaximal run were reflective of changes in lactate threshold during a soccer season. Additionally, the coefficient of variation of this test was 9.6%, further supporting its use as a reliable surrogate measure for the more invasive and expensive laboratory-based measures. Taken together, these previous findings suggest that field-based, submaximal tests of aerobic capacity using blood lactate measures may be a practical tool for assessing changes in aerobic adaptations in soccer players. To date research investigating a valid submaximal test for monitoring aerobic adaptations in soccer players is limited, and no studies have investigated its efficacy as a test for measuring performance or aerobic fitness changes during the season. Therefore, the purpose of this study was to determine whether blood lactate, RPE and HR responses to the 6 min submaximal Yo-Yo intermittent recovery test level 1 (Yo-Yo$_{submax}$) are repeatable and valid methods of aerobic adaptations in women soccer players. An additional purpose of this study was to determine the test-retest reliability of this test in elite women soccer players.

Methods

Part A: Construct Validity of the Submaximal Yo-Yo Test Measures

Subjects

Fourteen elite female soccer players commenced the validity study and eight completed both laboratory and field based assessments (age: 19.3 ± 2.3 y, body mass: 66.0 ± 7.3 kg, height: 1.69 ± 0.05 m). All players were scholarship holders at the Football Association (FA) National Player Development Centre, based at Loughborough University, Loughborough, UK.

Physiological Tests

All subjects completed a $\dot{V}O_2max$ test, lactate threshold velocity, multistage fitness test (MSFT) and a 6 minute Yo-Yo IR1 submaximal test (Yo-Yo$_{submax}$).

Lactate Threshold Test

Lactate threshold (LT) was measured using an incremental run on a motorised treadmill (RunRace, Technogym, Gambettola, Italy) at the Physiology Laboratory at The School of Sport and Exercise Sciences (Loughborough University, UK). The test began at between 8 or 9 $km \cdot h^{-1}$ dependant on individual. Treadmill speed was increased every 4 minutes by 1 $km \cdot h^{-1}$ up to a maximum speed of 12 $km.h^{-1}$, and then 0.5 $km \cdot h^{-1}$ for the final stage, where the test was stopped at 12.5 $km \cdot h^{-1}$. Blood samples (25 µL) were taken at rest, along with two samples collected towards the end of each stage from the players thumb and analysed using a YSI 2300 STAT Plus Glucose and Lactate Analyser (Fleet, Hampshire, England). Lactate threshold was determined using the D_{max} method with the Lactate-E macro add-in (Higgins and Newell, 2005) for Microsoft Excel (Microsoft Corporation, USA).

Maximal Oxygen Uptake

The physiological tests were measured during an incremental run to exhaustion on a motorised treadmill (RunRace, Technogym, Gambettola, Italy) at the Physiology Laboratory at The School of Sport and Exercise Sciences (Loughborough University, UK). The test began with a five-minute warm-up at 8 $km \cdot h^{-1}$. The work protocol commenced and remained constant at a workload of between 8 $km \cdot h^{-1}$ and 11 $km \cdot h^{-1}$ throughout the test. The treadmill gradient was increased every 3 minutes by 2.5% until exhaustion (3.5, 6.0, 8.5, and 11.0%). Heart rate (HR) was recorded using portable HR monitors (Polar® NV HR monitor, OY, Finland). Maximal oxygen uptake was measured using the conventional Douglas bag method. Expired gases were analysed using Servomex 1440 (Cowborough, Sussex, England) which was calibrated prior to each test with reference and calibration gases of known concentrations and a Harvard Dry Gas Meter (Edenbridge, Kent, UK).

Field Tests

Multistage Fitness Test

The MSFT was used to determine maximal aerobic running performance (Leger & Lambert, 1982). For this test, the subjects were required to run back and forth on a measured 20 m indoor track, keeping in time with a series of audio signals from a compact disk (Australian Coaching Council, Belconnen, ACT). MSFT performance was taken as the stage and level of the test reached at volitional fatigue.

Sub-maximal Yo-Yo Intermittent Recovery Test

The Yo-Yo IR1 test is a specific endurance test consisting of a 20-m shuttle run which increases in speed and was interspersed by 10 s of active recovery, until exhaustion (Krustrup et al., 2003). The 6 min Yo-Yo IR, an abbreviated version of the maximal test, was completed on an indoor track under standard conditions. Players ran between two cones set 20-m apart maintaining an increased velocity by audio signal for 6-min. After every two 20-m runs a set active recovery time of 10 s was completed over 10-m. HR, RPE and Blood lactate measures were recorded as the primary physiological and perceptual measures. Polar HR monitors (Polar, OY, Finland) were worn by each subject and the average HR in the 6th min of the test was recorded and used for analysis. A single capillary blood lactate measure was taken from a thumb within the 1st minute of the completion of the test using a portable blood lactate analyser (Lactate Pro, Arkray, Japan). Subject RPE was recorded at the completion of the test using the 10-point Rating of Perceived Exertion scale (CR-10: RPE) (Borg, Ljunggren, & Ceci, 1985).

Part B: Reproducibility of the Submaximal Yo-Yo Test Measures

Subjects

The same fourteen elite women soccer players used in part A completed two, 6 minute Yo-Yo IR1 tests to determine the repeatability of the submaximal test. Each player completed two Yo-Yo$_{submax}$ tests which were conducted within a week of each other under standard conditions. Both tests were conducted on an indoor track and completed in the morning before any previous training was undertaken. All subjects were given information about and asked to standardise their food and fluid intake 24 h prior to each test. In particular clear guidelines were provided for carbohydrate and fluid intake as these have previously been shown to affect submaximal HR and blood lactate responses (Snyder, Jeukendrup, Hesselink, Kuipers, & Foster, 1993).

Statistical Analyses

A paired sample t-test was used on each dependent variable to determine if there were any significant differences in the session-to-session measures for HR, blood lactate concentration ([BLa$^-$]), and RPE for the Yo-Yo$_{submax}$. Pearson's Product Correlations were conducted to determine validity of test. Typical error as a coefficient of variation (%CV) was calculated to describe the session-to-session variability in the HR, [BLa$^-$], and RPE responses (Hopkins, 2000). Intraclass Correlation Coefficients (ICCs) were used to determine the strength of the association between the HR, [BLa$^-$] and RPE measures following each Yo-Yo$_{submax}$. Statistical significance was set at $p < 0.05$. SPSS statistical software package version 11.5 (SPSS Inc., Chicago, USA) was used for all statistical calculations.

Results

Part A: Construct Validity of the Submaximal Yo-Yo Test Measures

Results for all three tests are outlined in Table 1. A moderate correlation was detected for $\dot{V}O_2$max with HR-RPE ratio ($r = 0.62$, $p = 0.10$) and for [BLa$^-$]-RPE ratio ($r = 0.50$, $p = 0.07$). A significant correlation was found for HR-[BLa$^-$] ratio ($r = -0.62$, $p = 0.019$) measures taken at the end of the submaximal Yo-Yo IR1. There was no significant relationship between any ratio measures and LTV. There was a marginally significant correlation between $\dot{V}O_2$max and the MSFT ($r = 0.65$, $p = 0.08$).

Table 1: Correlation coefficients of submaximal test variables with $\dot{V}O_2$max, MSFT and LTV.

	HR	**RPE**	**[BLa$^-$]**	**HR-RPE ratio**	**[BLa$^-$]-RPE ratio**	**HR-[BLa$^-$] ratio**
$\dot{V}O_2$max (mL/kg/min)	0.15	0.48	0.03	0.62	0.39	0.04
MSFT (m)	-0.06	0.44	0.58	0.44	-0.51	-0.62*
LTV (km/h)	0.22	0.48	0.65	-0.43	-0.19	-0.30

*Significant at $p<0.05$

Part B Reproducibility of the Submaximal Yo-Yo Test Measures

Subjects

A paired sample t-test demonstrated that there were no significant differences detected (RPE, $p = 0.51$; HR, $p = 0.39$; [BLa$^-$], $p = 0.16$). The test-retest coefficient of variation (%CV) for the HR, [BLa$^-$] and RPE values obtained at the end of the submaximal 6 min Yo-Yo IR1 test was 4.0%, 20.7% and 13.1%, respectively. Test-retest %CV was lowest for HR-RPE ratio (13.6%), whilst the variability for the other two measurements was only moderately higher (HR-[BLa$^-$] ratio = 19.0%; [BLa$^-$]-RPE ratio = 26.0%).

Discussion

The purpose of this study was to determine whether blood lactate, RPE and HR responses to the 6 min submaximal Yo-Yo intermittent recovery test level 1 (Yo-Yo $_{submax}$) are repeatable and valid methods of aerobic adaptations in women soccer players. We detected a significant correlation between MSFT performance and HR-[BLa$^-$] but not with LTV or $\dot{V}O_2max$ in elite women soccer players. We also found that physiological responses to the Yo-Yo $_{submax}$ have an acceptable level of reproducibility. Together, these results suggest that the min Yo-Yo $_{submax}$ test may be a viable tool for monitoring performance changes, but not aerobic adaptations to soccer training.

The present study observed a moderate correlation between $\dot{V}O_2max$ and HR-RPE ratio ($r = 0.62$) and also between the MSFT and both [BLa$^-$]-RPE ($r = 0.50$) and HR [BLa$^-$] ($r = -0.62$). Impellizzeri et al., (2005) reported a significant correlation between laboratory-based LTs and submaximal field-based lactate as well as between training induced changes of lactate field and training induced changes of velocity at lactate thresholds. In contrast, we did not find a significant relationship between any of the physiological or perceptual variables taken following the Yo-Yo_{submax} and LT. This could be attributed to the intermittent nature of the Yo-Yo IR test and may suggest that the continuous Yo-Yo endurance test may be more suitable for measuring aerobic adaptations. Metaxas et al., (2005) in their comparative study of two field and two laboratory based tests found that blood lactate levels for both laboratory and field based intermittent protocols were higher than those recorded for the two continuous protocols used. The intermittent nature of the Yo-Yo test employed in the current study may explain the differences in the findings from this study and previous research.

The moderate correlation between the [BLa^-]-RPE and HR-[BLa^-] ratios and MSFT performance suggests the Yo-Yo_{submax} may offer some benefit as a non-fatiguing, surrogate measure for the maximal field-test. In particular, a lower [BLa^-] compared to RPE may be used to indicate increased performance adaptation to training and it could also be used as an early indicator of impending overreaching. Furthermore a higher HR for the same [BLa^-] may also be related to improved MSFT performance. These results suggest that this submaximal test could be used for detailed analysis of differences between players and also of the seasonal changes of a player's physical capacity (Krustrup et al., 2003; Metaxas, Koutlianos, Kouidi, & Deligiannis, 2005; Krustrup, Mohr, Nybo, Jensen, Nielsen, & Bangsbo, 2006). In agreement, Krustrup et al, (2003) reported an inverse relationship between Yo-Yo test performance and percentage of maximal HR (%HR_{max}) reached after 6 min and suggested that this may be a useful test for monitoring adaptations to soccer training. However, in order to achieve this, we suggest that the results from this test be interpreted according to the test-retest coefficient of variation reported in this study.

For a test to be practically useful for monitoring responses to training it needs not only to be valid but have an acceptable level of reliability. In this study there were no significant differences between any of the perceptual or physiological measures recorded following the Yo-Yo_{submax}. Moreover, the level of reproducibility test HR measures and ratios are similar to those reported from similar studies (Krustrup et al., 2003; Impellizzeri et al., 2005). For example, Impellizzeri et al., (2005) reported a moderate reliability with a CV of 9.6%. In addition, Krustrup et al., (2003) reported a CV of 4.9% for the maximal version of the Yo-Yo IR1 test. In this study, the coefficient of variation was the lowest for both HR ratio measures HR-RPE (TEM% = 13.6) and HR-[BLa] (TEM% = 19.0) and very low for HR individually (TEM% = 4.0). The lower variability recorded for HR measures in our findings may suggest that the sensitivity of test in relation to HR measures may be adequate for monitoring physical adaptations.

In summary, the present results suggest that the Yo-Yo $_{submax}$ may be a viable method for assessing aerobic capacities in soccer players. The advantages of this test are that it provides the ability to assess a large number of players in a relatively short time as well as overcome logistical difficulties with administering maximal test during a season. Other potential benefits of this test are that players are not required to perform maximal tests which may cause unnecessary fatigue. However, we recommend that when this test is used to monitor soccer players, results are interpreted according to the test-retest coefficient of variation result provided in this study.

References

Borg, G., Ljunggren, G., & Ceci, R. (1985). The increase of perceived exertion, aches and pain in the legs, heart rate and blood lactate during exercise on a bicycle ergometer. European Journal of Applied Physiology, 54(4), 343-349.

Coutts, A. J., Slattery, K. M., & Wallace, L. K. (2007). Practical tests for monitoring fatigue and recovery in triathletes. Journal of Science and Medicine in Sports, doi:10.1016/j.jsams.2007.1002.1007

Edwards, A. M., Clark, N., & Macfadyen, A. M. (2003). Lactate and ventilatory thresholds reflect the training status of professional soccer players where maximum aerobic power is unchanged. Journal of Sports Science and Medicine, 2(1), 23-29.

Helgerud, J., Christian Engen, L., Wisløff, U., & Hoff, J. (2001). Aerobic endurance training improves soccer performance. Medicine and Science in Sports and Exercise, 33(11), 1925-1931.

Hopkins, W. G. (2000). Measures of reliability in sports medicine and science. Sports Medicine, 30(1), 1-15.

Impellizzeri, F. M., Mognoni, P., Sassi, A., & Rampinini, E. (2005). Validity of a submaximal running test to evaluate aerobic fitness changes in soccer players. In T. Reilly & J. Cabri & D. Araujo (Eds.), Science and Football V (pp. 105-111). London, UK: Routledge.

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., Pedersen, P. K., & Bangsbo, J. (2003). The Yo-Yo Intermittent Recovery Test: Physiological response, reliability, and validity. Medicine and Science in Sports and Exercise, 35(4), 697-705.

Krustrup, P., Mohr, M., Ellingsgaard, H., & Bangsbo, J. (2005). Physical demands during an elite female soccer game: importance of training status. Medicine and Science in Sports and Exercise, 37(7), 1242-1248.

Krustrup, P., Mohr, M., Nybo, L., Jensen, J. M., Nielsen, J. J., & Bangsbo, J. (2006). The Yo-Yo IR2 test: physiological response, reliability, and application to elite soccer. Medicine and Science in Sports Exercise, 38(9), 1666-1673.

Leger, L. A., & Lambert, J. (1982). A maximal multistage 20 m shuttle run test to predict $\dot{V}O_2max$. European Journal of Applied Physiology, 49, 1-5.

Metaxas, T. I., Koutlianos, N. A., Kouidi, E. J., & Deligiannis, A. P. (2005). Comparative study of field and laboratory tests for the evaluation of aerobic capacity in soccer players. Journal of Strength and Conditioning Research, 19(1), 79-84.

Reilly, T. (2005). An ergonomics model of the soccer training process. Journal of Sports Sciences, 23(6), 561-572.

Sassi, A., Marcora, S. M., Rampinini, E., Mognoni, P., & Impellizzeri, F. M. (2006). Prediction of time to exhaustion from blood lactate response during submaximal exercise in competitive cyclists. European Journal of Applied Physiology.

Snyder, A. C., Jeukendrup, A. E., Hesselink, M. K., Kuipers, H., & Foster, C. (1993). A physiological/psychological indicator of over-reaching during intensive training. International Journal of Sports Medicine, 14(1), 29-32.

Chapter 5

The Practical Usefulness of a New Submaximal Test for Monitoring the Training Process in Women Soccer Players

Abstract

Purpose: The purpose of this study was to assess the sensitivity of physiological and perceptual responses following a 6 min submaximal Yo-Yo intermittent recovery level 1 test (Yo-Yo_{submax}) to markers of aerobic fitness in women soccer players. A further purpose of this study was to assess if aerobic fitness changes identified in the submaximal tests can be related to TLs.

Methods: Eleven elite women soccer players (age 19.0 ± 2.3 y, height 170 ± 5 cm, body mass 67.5 ± 7.6 kg) completed the multistage fitness test (MSFT) pre and post a 14 week early season soccer training program. In addition, the players completed a Yo-Yo_{submax} test every four to five weeks during this period. The amount of change (Δ) in the blood lactate concentration [BLa] , heart rate (HR) and rate of perceived exertion (RPE) responses from the Yo-Yo_{submax} test from the pre to post test occasions were correlated with the amount of change (Δ) in blood lactate, HR and RPE response from maximal field and laboratory-based treadmill tests. Furthermore, the same variables were correlated with training loads (TL) recorded over the 14 weeks.

Results: No significant difference was found between pre and post study in either $\dot{V}O_2max$ (P=0.55) or MSFT (P=0. 56). Additionally, there were no correlation between the change in the Yo-Yo_{submax} responses and the changes in either laboratory test or MSFT test performance during the testing period.

Conclusion: No significant changes were detected when testing either $\dot{V}O_2max$ or MSFT performance with 14 weeks training in high level soccer players. Additionally, we also found no significant change in the physiological and perceptual responses to the Yo-Yo_{submax} test during the training period.

Thus, the results suggest that the Yo-Yo_{submax} cannot be used to detect changes in aerobic capacities in elite level women soccer players.

Key Words: Yo-Yo IR1, aerobic fitness, submaximal exercise test, heart rate, blood lactate, RPE

Introduction

High level soccer is a demanding sport and requires athletes to train to improve aerobic capacity, anaerobic capacity, strength and power as well as technical and tactical abilities (Bangsbo et al., 2006). Due to these high training and competition demands, soccer players may be placed under significant physical and psychological stress which can lead to overreaching, illness, injury or overtraining syndrome (Filaire et al., 2001, Filaire et al., 2003, Naessens et al., 2000). Additionally, it has recently been shown that individual soccer players respond differently to the same training (Impellizzeri et al., 2005a) Since soccer players usually training in groups or as a team, rather than according to individual demands, coaches are often challenged to find ways to ensure that each player within a team is reaching their optimal potential. Due to individual responses to training, each player needs to be carefully monitored by coaches to assess how they are responding to the training stimuli. Indeed, it is possible that a player's response to training could be monitored and their training improved if a valid and reliable test that was sensitive to changes in aerobic fitness adaptations was developed and then combined with measures of training load (TL) (Impellizzeri et al., 2005a).

Several investigators have attempted to produce a simple test for assessing aerobic fitness in soccer players. For example, Krustrup et al., (2003, 2001) reported a high sensitivity for the Yo-Yo Intermittent Recovery test (level 1) (Yo-Yo IR1) in allowing for analysis of physical capacity of soccer players and top level referees in regards to seasonal changes in match running performance. These investigators suggested that the Yo-Yo IR1 test could be a more sensitive tool to use than the $\dot{V}O_2max$ for assessing performance changes in soccer players and referees. In contrast, Castagna et al. (2006) did not find a significant correlation with the Yo-Yo Intermittent Recovery test (level 1) (Yo-Yo IR2) and $\dot{V}O_2max$, but did report a significant correlation between vertical jump performance and Yo-Yo IR2 test, further supporting the specificity of the test to soccer. They suggested the Yo-Yo Endurance level 2 test (YYE2) to be an aerobic fitness related field test which could be used during pre season preparation, whereas the Yo-Yo Endurance level 1 test (YYIR1) might be regarded as an aerobic/ anaerobic soccer specific field test which can be used throughout the season as a monitoring tool.

The use of the Yo-Yo IR1 test as a soccer specific aerobic/ anaerobic test to assess physical adaptations has been previously supported. Although a practical tool to use, there are still limitations associated with it due to its being a maximal test. Regular maximal testing has its limitations as it can reduce player motivation, and it may even cause excessive fatigue in players. Therefore, it may be difficult to implement regularly in a training week during a competitive season. Recently, short duration, submaximal fitness tests have been suggested as a possible alternative option to these maximal aerobic fitness tests.

Krustrup et al., (2003) were the first to propose a submaximal version of the Yo-Yo IR1. Their study examined the reproducibility and validity of the Yo-Yo IR1 and evaluated the physiological responses during the test. It was reported that HR recorded in the 6^{th} min of the Yo-Yo IR1 correlated well with physical match performance. To date however, no studies have examined the efficacy of using the physiological and perceptual responses to a submaximal Yo-Yo IR1 test and if they can be used to monitor changes in aerobic fitness in soccer players. Therefore, the purpose of this study was to assess the sensitivity of physiological and perceptual responses following a 6 min submaximal Yo-Yo intermittent recovery level 1 test (Yo-Yo_{submax}) to markers of aerobic fitness in women soccer players. A further purpose of this study was to assess if aerobic fitness changes identified in the submaximal tests can be related to TLs.

Methods

Approach to the Problem

Changes in aerobic fitness and performance measures with both maximal tests and a new submaximal 6 min Yo-Yo test (Yo-Yo_{submax}) and session-RPE TLs were collected throughout a 14-week period (September to December) in 11 elite level women soccer players. The relationship between TLs and aerobic fitness changes was then established. The construct validity of the Yo-Yo_{submax} was determined by comparing the results of this test conducted before and after a 14-week training period to the 'gold standard' maximal oxygen uptake measurement ($\dot{V}O_2max$) as well as the multistage fitness test performance (MSFT). To assess the sensitivity of this test, the amount of change (Δ) in the blood lactate concentration ($[BLa^-]$), heart rate (HR) and rating of perceived exertion (RPE) responses from the Yo-Yo_{submax} from the pre- to post-test occasions were correlated with the amount of change (Δ) in the $[BLa^-]$, HR and RPE responses from the laboratory-based treadmill tests.

Subjects:

Eleven elite women soccer players in total were recruited for this study. All of the players train and study full time at the National Player Development Centre, Loughborough, UK, from Monday to Friday and play for their clubs in the National Women's Premiership competition in weekly fixtures as well as occasionally attend their club training sessions. Nine of the eleven subjects are members of the England international team at U17's, U19's, U21's or senior squad.

Prior to the commencement of this study all subjects were given an information sheet outlining potential risks associated with involvement in this study. A written consent form was also obtained from each subject or their parent. Prior to any testing ethical approval was granted by the University of Technology, Sydney Human Research Ethics Committee.

Subject Characteristics

At the start of the season, each player's age, height, body mass, and $\dot{V}O_2max$ were measured. The physical characteristics of the subjects are presented in Table 1.

Table 1: Physical characteristics of subjects.

	Age (yr)	Height (cm)	Body Mass (kg)	$\dot{V}O_2max$ ($mL \cdot kg^{-1} \cdot min^{-1}$)
Mean ± SD	19.0 ± 2.3	170 ± 5	67.5 ± 7.6	51.0 ± 4.7
Range	17 - 23	163 - 179	59.2 - 80.2	42.1 – 57.7

Experimental Protocol

All players completed a $\dot{V}O_2max$ test at the beginning of the study, however due to injury or competition only five were able to complete all four submaximal Yo-Yo IR field tests as well as a post-study $\dot{V}O_2max$ test. Furthermore nine of the eleven subjects completed a pre and post study MSFT. Four Yo-Yo_{submax} tests were conducted (September, October, November and December) at standard times four to five weeks apart during a 14-week training period (see Figure 1). These were conducted under standardised conditions on an indoor track and completed in the morning before any previous training was undertaken. All four tests were conducted in allocated recovery training weeks where lower TLs were completed. The TL data was recorded using the session-RPE method (Foster et al., 2001) for every training session.

Training

Players completed up to eight training and recovery sessions a week, including a match. A typical training week consisted of three technical/ tactical sessions which included aerobic based outcomes, two weights sessions, one aerobic conditioning session, one core stability session, one pool recovery session as well as one match. The TL for each session and match was calculated using the session-RPE method (Foster et al., 2001) for each player during the study period. This method involved multiplying the training duration in minutes by the mean training intensity (Foster et al., 2001). Training intensity was measured using a modified 10-point Rating of Perceived Exertion Scale (CR-10: RPE) (Borg et al. 1985b). To ensure the subjects reported a mean RPE for the entire training session or match, the RPE was taken 30-minutes after the completion of the session and match. The TL for each week was calculated to determine a weekly TL. TLs and testing periods are shown in Figure 1.

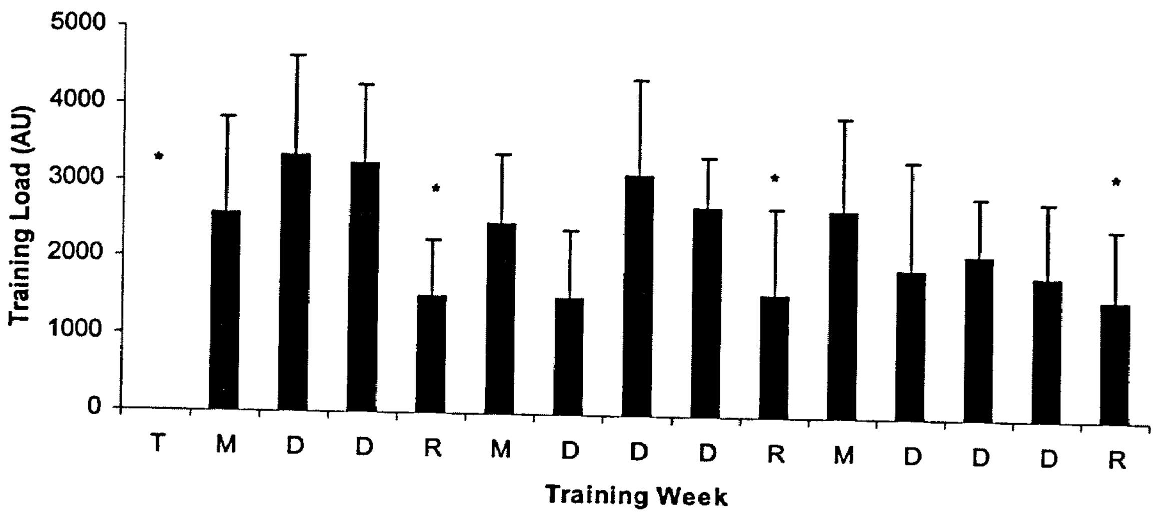

Figure 1: Mean (±SD) weekly training loads. Training weeks are identified as T, testing, M, maintenance, D, development, R, regeneration. * denotes submaximal Yo-Yo IR1 testing

Physiological Tests

Maximal Oxygen Uptake

Maximal oxygen uptake ($\dot{V}O_2max$) was measured during an incremental run to exhaustion on a motorised treadmill (RunRace, Technogym, Gambettola, Italy) at the Physiology Laboratory at The School of Sport and Exercise Sciences (Loughborough University, UK). The test began with a five-minute warm-up at 8 $km{\cdot}h^{-1}$. The work protocol commenced and remained constant at a workload of between 8 $km{\cdot}h^{-1}$ and 11 $km{\cdot}h^{-1}$ throughout the test. The treadmill gradient was increased every 3 minutes by 2.5% until exhaustion (3.5, 6.0, 8.5 and 11.0 $km{\cdot}h^{-1}$). HR was recorded using portable heart rate monitors (Polar® NV HR monitor, OY, Finland). Maximal oxygen uptake was measured using the conventional Douglas bag method. Expired gases were analysed using Servomex 1440 (Cowborough, Sussex, England) which was calibrated prior to each test with reference and calibration gases of known concentrations and a Harvard Dry Gas Meter (Edenbridge, Kent, UK).

Field Tests

Multistage Fitness Test

The multistage fitness test (MSFT) was used to determine maximal aerobic running performance (Leger and Lambert, 1982). For this test, the subjects were required to run back and forth on a measured 20 m indoor track, keeping in time with a series of audio signals from a compact disk (Australian Coaching Council, Belconnen, ACT). MSFT performance was taken as the distance travelled at volitional fatigue. The test-retest coefficient of variation (%CV) for this test was 6.4%.

Sub-maximal Yo-Yo Intermittent Recovery Test

The Yo-Yo IR1 test is a specific endurance test consisting of a 20-m shuttle run which increases in speed interspersed by 10 s of active recovery, until exhaustion (Krustrup et al., 2003). The Yo-Yo$_{submax}$, is an abbreviated version of the maximal test. The test was completed on an indoor track. Players ran between two cones set 20-m apart maintaining an increasing velocity set by audio signal for 6-min. After every two 20-m runs a set active recovery time of 10 s was completed over 10-m. HR, RPE and [BLa$^-$] measures were recorded as the key physiological and perceptual measures. Polar individual HR monitors (Polar, OY, Finland) were worn by each subject and the average HR in the 6th min of the test was recorded and used for data analysis. A single capillary blood lactate sample (5 μL) was taken from a thumb within the 1st

minute of completion of the test using a portable blood lactate analyser (Lactate Pro, Arkray, Japan). Subject RPE was recorded at the completion of the test using the 10-point Rating of Perceived Exertion scale (CR-10: RPE) (Borg et al., 1985a).

Statistical Analyses

A paired sample t-test was conducted between pre and post study for the $\dot{V}O_2max$ values and the MSFT performance measures to determine any changes in test scores over the study period. To describe the time-course change in aerobic fitness measures, HR, ([BLa^-] and RPE with the 6 min submaximal Yo-Yo IR test, a one-way analysis of variance (ANOVA) was used. Pearson's product correlation was used to analyse the relationship between TLs and aerobic fitness measures. Statistical significance was set at $p < 0.05$. SPSS statistical software package version 11.5 (SPSS Inc., Chicago, USA) was used for all statistical calculations.

Results

A paired sample t-test showed no significant difference between pre and post study $\dot{V}O_2max$ test scores ($t = 0.653$, $p = 0.55$) as well as for pre and post MSFT ($t = 0.607$, $p = 0.56$). A one way ANOVA demonstrated that there were no significant differences between [BLa^-], HR and RPE measures taken at 0, 4, 9 and 14 weeks of soccer training.

No change was detected over time in any of the aerobic fitness measures, or their ratios, for the duration of the study period (one way ANOVA, p = 0.47 – 0.84).

A significant correlation was detected for [BLa⁻] and [BLa⁻]-RPE for testing period between T2 and T3 (Table 2).

Table 2: Correlation matrix of TL with changes over time in three separate physiological and perceptual variables and their ratios. T1-T2 corresponds to training weeks 1- 5, T2-T3 corresponds with training weeks 6-10, T3-T4 corresponds with training weeks 11-14.

	RPE	HR	[BLa⁻]	HR-RPE ratio	[BLa⁻]-RPE ratio	HR-[BLa⁻] ratio
T1-T2	0.037	0.110	0.409	-0.076	0.349	-0.559
T2-T3	-0.067	-0.171	**-0.678***	-0.177	**-0.725***	0.520
T3-T4	0.257	0.279	0.300	-0.003	0.124	0.115

* Significant at $p<0.05$

Discussion

The purpose of this study was to assess the sensitivity of physiological and perceptual responses following a 6 min submaximal Yo-Yo intermittent recovery level 1 test (Yo-Yo_{submax}) to markers of aerobic fitness in women soccer. To assess this, we examined if changes in the physiological and perceptual responses to a submaximal tests could be related to TLs and also laboratory measures of aerobic fitness and performance during 14 weeks of soccer training. The present results demonstrated that there were no significant changes testing either $\dot{V}O_2max$ or MSFT performance with 14 weeks training in high level soccer players. Additionally, no significant change in the physiological and perceptual responses to the Yo-Yo $_{submax}$ test during the training period. Significant correlations were observed for two variables, [BLa⁻] and [BLa⁻]-RPE and TLs. This was observed between Yo-Yo $_{submax}$ test two and three.

Although there have been no previous studies that have examined changes in the 6 min Yo-Yo $_{submax}$ test with soccer training Impellizzeri et al. (2005) reported that there was a significant decrease in the lactate response to a 6 min submaximal running test during pre competition training period in soccer players. Moreover, although there were no differences in the lactate response to a 6 min submaximal running test during season, all values recorded in season were significantly lower (20%) than the preseason values suggesting an increase in aerobic fitness. The lack of change in the [BLa⁻] response to the Yo-Yo $IR1_{submax}$ in this study are surprising as several studies have noted considerable changes (8-15%) in aerobic fitness measures during the preseason training period in soccer players (Helgerud et al., 2001, Edwards et al., 2003, McMillan et al., 2005, Impellizzeri et al., 2005b, Impellizzeri et al., 2006).

Other studies have reported that submaximal HR responses may be useful for monitoring changes in team sport athletes (, Krustrup et al., 2003, Lamberts et al., 2004, Krustrup et al., 2005, Impellizzeri et al., 2005b). For example, Impellizzeri et al., (2005) reported significantly lower HR during the season compared to preseason as well as changes detected in field-based submaximal lactate test suggesting that the submaximal test they used could be used to monitor aerobic fitness changes. This was in agreement with Krustrup et al., (2005) who suggested that the 6^{th} min HR taken from their maximal Yo-Yo IR1 test was 5% lower during the season compared to pre season. However, we found no significant differences in any of the submaximal measures collected. In support of our findings, Krustrup et al., (2003) reported that the average HR for the maximal Yo-Yo IR1 test remained unchanged during the season. However, these previous investigators reported a large variation in individual values and suggested that these may have reflected the sensitivity of the Yo-Yo IR1 test and its use to focus on an individual player.

It is widely acknowledged that HR at a standard submaximal intensity should decrease as aerobic fitness increases (Wilmore et al., 2004). In the present study we found no significant changes in the HR measures obtained in either the field or laboratory-based tests. The lack of change in these measures suggests that there were no alterations in aerobic fitness during the pre-season preparation period and the commencement of the in-season training period. However, the lack of significant change in HR measures may also be explained by other factors such as the time of the season the testing occurred, the between time testing or the recovery undertaken by the players. Indeed, previous studies have shown that submaximal HR can decrease with both improvements in fitness (Krustrup et al., 2003, Krustrup et al., 2005) but also maladaptive training (Coutts et al., 2005). Therefore, to overcome this limitation, the ratio between HR and RPE or [BLa^-] and RPE have been suggested to be useful for monitoring training (Foster et al., 1999a, Foster et al., 1999b).

The present results suggest no change in physiological and perceptual variable ratios over the 14 week period. This finding is perhaps not surprising as it has been suggested elsewhere that changes may not be detected even though an improved performance has been observed (Foster et al., 1999b). In their study the same variables were monitored throughout the training season in elite competitive ice skaters. Although an increase in performance was observed, no changes were observed in the HR-[BLa⁻] and RPE-[BLa⁻] ratios suggesting that these measures may remain stable throughout a training year despite changes in performance.

The most obvious explanation for the lack of change in the test results of the submaximal test in the present study is that there were no changes in aerobic fitness measures during the study period. In support, there were no changes in $\dot{V}O_2max$ or MSFT performance during the study period. These results are surprising considering the high TLs being conducted in this study. Although this is the first study to describe the training of elite level women soccer players, the TLs are similar to those reported in professional soccer players from Italy and Tunisia as well as professional rugby league players in Australia (Coutts et al., 2008a, Coutts et al., 2008b). It is also possible that the players had developed their aerobic fitness levels to a level that appreciable changes in fitness are not common. Indeed, previous studies have shown that most changes in aerobic fitness occurs during the initial stages of the preseason in footballers (Helgerud et al., 2001, Impellizzeri et al., 2006). This may explain why no changes were observed in the submaximal test results in the current study.

In the present study no significant changes were detected between pre and post-training maximal oxygen uptake or the MSFT performance. Likewise no changes were detected in any variables or ratios between the four Yo-Yo $_{submax}$ tests. There are several factors that may have contributed to these findings. Firstly, the testing period did not incorporate pre season, secondly the short period of time between each submaximal test, finally the small sample size may have led to no significant changes being identified. Possible further studies could incorporate both pre season and early season training to monitor the changes over separate training phases. Further studies could incorporate higher prescribed sessions therefore TLs with sub elite players as a greater change in aerobic capacities would be expected. Finally, a Yo-Yo IR1 completed pre and post study period may provide a valuable marker to compare against. Our study suggests that the Yo-Yo $_{submax}$ cannot be used to detect changes in aerobic capacities in elite level women soccer players. Furthermore, changes in physiological and perceptual variables showed no relationship to TL.

References

Bangsbo, J., Mohr, M. & Krustrup, P. (2006) Physical and metabolic demands of training and match-play in the elite football player. *Journal of Sports Sciences,* **24,** 665-74.

Borg, G., Ljunggren, G. & Ceci, R. (1985a) The increase of perceived exertion, aches and pain in the legs, heart rate and blood lactate during exercise on a bicycle ergometer. *European Journal of Applied Physiology,* **54,** 343-9.

Borg, G. A. V., Hassmen, P. & Langerstrom, M. (1985b) Perceived exertion in relation to heart rate and blood lactate during arm and leg exercise. *European Journal of Applied Physiology,* **65,** 679-685.

Coutts, A. J., Chamari, K., Impellizzeri, F. M. & Rampinini, E. (2008a) Monitoring Training in Soccer: Measuring and Periodising Training. In *Fitness Training in Soccer.* (edited by pp. in press).

Coutts, A. J., Sirotic, A. C., Catterick, C. & Knowles, H. (2008b) Monitoring Training Loads in Professional Rugby League. In *Science and Football VI.* (edited by Reilly, T., Korkusuz, F. & Ergin, E.), pp. in press. London, UK, Routledge.

Coutts, A. J., Reaburn, P. R. J., Piva, T., Rowsell, G. & Murphy, A. J. (2005) Predictors of changes in $\dot{V}O_2max$ during periods of intense training in rugby league players. In *Science and Football V.* (edited by Reilly, T., Araújo, D. & Cabri, J.), pp. 387-394. London, UK, Routledge.

Edwards, A. M., Clark, N. & Macfadyen, A. M. (2003) Lactate and ventilatory thresholds reflect the training status of professional soccer players where maximum aerobic power is unchanged. *Journal of Sports Science and Medicine,* **2,** 23-29.

Filaire, E., Lac, G. & Pequignot, J. M. (2003) Biological, hormonal, and psychological parameters in professional soccer players throughout a competitive season. *Perceptual and Motor Skills,* **97,** 1061-1072.

Filaire, E., Bernain, X., Sagnol, M. & Lac, G. (2001) Preliminary results on mood state, salivary Testosterone:Cortisol ratio and team performance in a professional soccer team. *European Journal of Applied Physiology,* **86,** 179-184.

Foster, C., Snyder, A. & Welsh, R. (1999a) Monitoring of training, warm up, and performance in athletes. In *Overload, Performance Incompetence and Regeneration in Sport.* (edited by Lehmann, M., Foster, C., Gastmann, U., Keizer, H. & Steinacker, J. M.), pp. 43-52. New York, Kluwer Academic / Plenum Publishers.

Foster, C., Fitzgerald, D. J. & Spatz, P. (1999b) Stability of the blood lactate-heart rate relationship in competitive athletes. *Medicine and Science in Sports and Exercise,* **31,** 578-582.

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., Doleshal, P. & Dodge, C. (2001) A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research,* **15,** 109-115.

Helgerud, J., Christian Engen, L., Wisløff, U. & Hoff, J. (2001) Aerobic endurance training improves soccer performance. *Medicine and Science in Sports and Exercise,* **33,** 1925-1931.

Impellizzeri, F. M., Rampinini, E. & Marcora, S. M. (2005a) Physiological assessment of aerobic training in soccer *Journal of Sports Sciences,* **23,** 583-592.

Impellizzeri, F. M., Mognoni, P., Sassi, A. & Rampinini, E. (2005b) Validity of a submaximal running test to evaluate aerobic fitness changes in soccer players. In *Science and Football V.* (edited by Reilly, T., Cabri, J. & Araujo, D.), pp. 105-111. London, UK, Routledge.

Impellizzeri, F. M., Marcora, S. M., Castagna, C., Reilly, T., Sassi, A., laia, F. M. & Rampinini, E. (2006) Physiological and performance effects of generic versus specific aerobic training in soccer players. *International Journal of Sports Medicine,* **27,** 483-492

Krustrup, P., Mohr, M., Ellingsgaard, H. & Bangsbo, J. (2005) Physical demands during an elite female soccer game: importance of training status. *Medicine and Science in Sports and Exercise,* **37,** 1242-1248.

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., Pedersen, P. K. & Bangsbo, J. (2003) The Yo-Yo Intermittent Recovery Test: Physiological response, reliability, and validity. *Medicine and Science in Sports and Exercise,* **35,** 697-705.

Lamberts, R. P., Lemmink, K. A. P. M., Durandt, J. J. & Lambert, M. I. (2004) Variation in heart rate during submaximal exercise: implications for monitoring training. *Journal of Strength and Conditioning Research,* **18,** 641-645.

Leger, L. A. & Lambert, J. (1982) A maximal multistage 20 m shuttle run test to predict $\dot{V}O_2max$. *European Journal of Applied Physiology,* **49,** 1-5.

McMillan, K., Helgerud, J., Grant, S. J., Newell, J., Wilson, J., Macdonald, R. & Hoff, J. (2005) Lactate threshold responses to a season of professional British youth soccer. *British Journal of Sports Medicine,* **39,** 432-6.

Naessens, G., Chandler, T. J., Kibler, W. B. & Driessens, M. (2000) Clinical useful of nocturnal urinary noradrenaline excretion patterns in the follow-up of training processes in high-level soccer players. *Journal of Strength and Conditioning Research,* **14,** 125-131.

Chapter 6

General Discussion, Conclusion, Recommendations and Future Research Suggestions

General Discussion

The aim of this research was to determine the utility of the session-RPE as a tool for monitoring training load (TL) in women's soccer and establish the efficacy of a submaximal Yo-Yo intermittent recovery test to assess aerobic training adaptations. Our objectives were outlined in three separate, but inter-related studies. Our objectives were to:

- Examine whether the session-RPE method for quantifying internal training load (TL) is a valid tool that can be used with women soccer players.
- Determine whether blood lactate, RPE and HR responses to the 6 min submaximal Yo-Yo intermittent recovery test level 1 (Yo-Yo_{submax}) are repeatable and valid methods of aerobic adaptations in women soccer players.
- Assess the sensitivity of physiological and perceptual responses following a 6 min Yo-Yo_{submax} test to markers of aerobic fitness in women soccer players.
- Furthermore, assess if aerobic fitness changes identified in the submaximal tests can be related to TLs.

Prior to the commencement of the series of studies the hypotheses were:

- The session-RPE method is a valid method which can be used to quantify an athlete's internal TL in relation to soccer training.

- The session-RPE method will correlate well with other HR-based methods across all training types.

- The submaximal version of the Yo-Yo intermittent recovery test level 1 to be a repeatable tool and valid in testing aerobic adaptations in women soccer players.

- The sub maximal version of the Yo-Yo intermittent recovery test level1 will be a valid tool for testing aerobic adaptations in soccer players and aerobic fitness changes will relate to individual TL's.

The basis of our research was to assess the validity and reliability of practical monitoring and testing tools that could be used by coaches, sport scientists and players to assist with the development and delivery of individualised training and periodisation programs, in the endeavour for achieving optimal performance. We also sought to add to the limited literature available on women soccer players. The limitations associated with laboratory-based measures and maximal field tests currently available have already been established. There are a variety of simple, field tests available to assess physiological measures such as speed, strength and power, but the majority of tests available for assessing aerobic adaptations, even though field based, are of a maximal nature. Additionally, the demands placed on elite soccer players in regards to both competition and training commitments leaves limited room for error when delivering a training program aimed at balancing a sufficient training stimulus with adequate recovery. An ability to monitor an individual's response to training and competition within a team ensures an optimal balance is achieved.

Our main finding in our first study was that the session-RPE method for monitoring TL was valid in women soccer players. Significant correlations were observed across all training types and in particularly aerobic based training sessions of a less-intermittent nature. Although there have been previous studies focusing on anaerobic based training or aerobic based training, the benefit of this study was that it validated the session-RPE method over a training period which included all training elements found in a typical soccer program as well as competition, therefore adding to the practicality of this tool for use during a season.

In our second and third study we wanted to assess the validity, sensitivity and repeatability of a submaximal Yo-Yo intermittent recovery test for use with women soccer players. We found that the test had a moderate level of repeatability and that the physiological variables taken following the Yo-Yo_{submax} related to MSFT performance but not to LTV. Furthermore the Yo-Yo_{submax} proved not to be a sensitive tool in assessing changes in aerobic capacity in elite women soccer players. Furthermore we found no consistent correlation between Yo-Yo $_{submax}$ variables and TL.

Conclusion

This study has important theoretical and practical implications for sport scientists, coaches and players. Practically, we have established that the session-RPE method for monitoring internal TL is a valid tool which can be used with team sports and in particular elite women soccer players across all training modes typically experienced in a soccer training program. Furthermore, the use of this tool can support the development of optimal periodisation programs implementing a right balance of both training stimuli and recovery. Theoretically, although this research does not look into the performance characteristics of elite women soccer players it adds further knowledge to the area of monitoring the training process for women soccer players.

The results of study two and three suggest that the physiological variables taken following the Yo-Yo$_{submax}$ relate to MSFT performance but not LTV. Additionally, results showed only a moderate level of repeatability of these measures which suggest that this submaximal test may not be suitable to detect changes in aerobic fitness during a soccer season. Furthermore, study three showed that there were no significant changes in variables recorded post Yo-Yo $_{submax}$ at four separate times throughout the season and compared to maximal laboratory and field based test results, therefore suggesting the Yo-Yo$_{submax}$ to not be a sensitive tool in monitoring changes in aerobic adaptations.

Recommendations

Recommendations from this study are:

- The session-RPE is a valid method for monitoring internal TL in elite women soccer players.

- The Yo-Yo$_{submax}$ may be a viable method for assessing aerobic capacities in soccer players. However, we suggest that when this test is used to monitor soccer players, results are interpreted according to the test-retest coefficient of variation result provided in this study. The test-retest coefficient of variation (%CV) for the HR, [BLa$^-$] and RPE values were 4.0%, 20.7% and 13.1%, respectively. Test-retest %CV for HR-RPE, HR-[BLa$^-$] and [BLa$^-$]-RPE were 13.6%, 19.0% and 26.0%, respectively.

Suggestions for Future Research

Future research suggestions are to:

- Further investigate the use of session-RPE method as a tool for monitoring anaerobic based training modes with elite women soccer players,

- Examine different training strategies for improving aerobic fitness in elite women soccer players,

- Examine the relationship between measures of aerobic fitness and match performance in elite women soccer players; and,

- Develop optimal training models for optimising fitness and physical performance during the in-season period for elite women soccer players.