The Validity of Differential Ratings of Perceived Exertion to Monitor Training Load in Elite Youth Football

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Contents

Abstract

The internal and external measures of Training Load (TL) are readily monitored within team sports. This is essential as the tactical periodisation protocol means training days are based on different physical fitness components. One popular method to monitor internal TL is the Rating of Perceived Exertion (RPE). Although overall RPE will have discrepancies between two sessions it does not explain underlying psychophysiological differences important in understanding and prescribing training actions. Differential RPE can provide sport scientists and coaches with a better explanation of the mechanisms that determine subjective ratings. The aim of this study is therefore to determine the validity of differential RPE as a measure of internal training load.

Twenty-one development squad players from an elite Scottish Premier League Club took part in the study during the 2017/18 in season. Subjects were a mean 18.4 ± 0.9 years of age, mean height 180.4 ± 5 cm and weight 76 ± 7 kg. After each training session, players then responded to two simple questions, "How did the training session feel on your heart and lungs?" and "How did the training session feel on your legs?". Global Positioning Systems (GPS) were used to collect external load measure. This occurred for each available training session.

The greatest total distance covered occurs on match day (MD) minus three days (-3), (7017.4 ± 112.8 m). There is then a significant taper towards the match. Intensity of training was greatest on MD-3, with significantly greater high speed running (21 – 24 km/hr) and sprint distance (>24 km/hr) covered compared to all other training days (249.8 ± 47.5 and 49.6 ± 47.5, respectively, $p < 0.05$). High accelerations (3-4 $m.s^{-2}$) were found to be significantly greater on MD -2 (7.6 ± 5.7) compared to other training days (MD-4: 4.3± 3.2, MD-25.6 ± 3.6, MD-1: 2.6 ± 2.1). This changes to MD-3 (16.9 ± 5.9) for greatest decelerations (3-4 $m.s^{-2}$). Overall ratings of perceived exertion are comparable for MD-4 and MD–3 (5 ± 0.6, 5 ± 0.2). There is then a significant fall in RPE over the next two training sessions. Respiratory and lower limb muscular RPE were greatest on MD-3, decreasing towards the match. A typical four-day lead in shows a clear training load pattern, with significant differences between respiratory and lower limb RPE for both MD-4 and MD-3. Lower limb RPE was greater than respiratory RPE (4 ± 0.3, 3.00 ± 0.00, $P < 0.05$) on MD-4. Respiratory RPE was significantly greater on MD-3 (6 ± 0.2 5 ± 0.2, $p = 0.003$). The highest training load measures were observed on MD-3.

Significant positive correlations were found between respiratory RPE and high speed running distance for MD-3 ($r = 0.229$ $p = 0.014$). A positive correlation was also found with lower limb RPE however not significantly ($r = 0.181$). Similar results were seen for sprint distance and respiratory RPE ($r = 0.360$ $p = 0.013$) and lower limb RPE ($r = 0.278$ $p = 0.058$). Differential RPE can be sensitive to different microcycles. When MD-2 was investigated in sperate microcycles, lower limb RPE was perceived to be significantly greater for the speed session found within the two day lead in, in comparison to the four day lead in. Overall and respiratory RPE showed no significant differences between the two conditions. There were however certain GPS outputs including; High Speed Running, Sprint Distance and Accelerations which were found to be significantly greater for speed day within the four-day lead in.

Main findings of the present study were that firstly, the four main training days in the lead up to a match display significant objective differences across a given microcycle. Furthermore, the subjective ratings of perceived exertion differ significantly across the training days. It was also found that certain days relate more to either central or peripheral ratings of perceived exertion, depending on the specificity of the training session. This provides training load data for the team as a whole and on an individual basis, offering important information on the psychophysiological state of the athlete, their training status and predicting performance and/or injury.

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Author's Declaration

I declare, expect where explicit reference is made to the contributions of others, that this thesis is the result of my own work and has not been submitted for any other degree to the University of Glasgow or at any other institution.

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1. Introduction

1.2 Overview of Football

Football is characterised as a high intensity intermittent team sport in which players cover a large distance at moderate intensity interspersed with bouts of high intensity activity. Intense periods of activity include sprints, repeated high-speed running, jumps and tackles (Bangsbo, et al., 1991). This is combined with periods of low intensity involving mainly walking and jogging. A football match involves two competing teams with the full game lasting a total of 90 minutes, not including injury time. This is comprised of two 45 minute halves. The pitch dimensions range from 45-90 m in width and 90-120 m in length (FIFA, Laws of the Game 2015/16). Most teams are scheduled to play 1 game per week, however, teams now often compete in biweekly matches. The structure of weekly training programmes are therefore centred around optimising players' performance for upcoming matches and ensuring they receive adequate recovery. The training schedule is a complex construct which must incorporate several aspects to ensure players can succeed at a high level. Training must therefore be monitored effectively in order for athletes to receive the anticipated training effects with minimised risk of injury.

When a team has one match per week the players may have up to 5 training sessions in the lead up to the match, with bi-weekly matches the number of training and recovery sessions become limited. Player response to training will therefore be affected by preceding activities, one of the primary concerns of the current research. Monitoring athletes via both internal and external measures is important when understanding the training load applied during activity and how the athlete responds to that prescribed session and other key factors (Halson, 2014).

1.3 Characteristics of Football

The two teams consist of 11 players, 1 goalkeeper and 10 outfield players, separated into defenders, attackers and midfield positions. The players have positional specific demands, they are involved in different aspects of the game and so may produce different energy expenditures. The typical distance covered by an elite level player is said to be 10-13 Km (Bangsbo, et al., 1991; Mohr, et al., 2003; Krustrup et al., 2005), with central midfield players covering the greatest distance and central defenders covering the least (DiSalvo, 2007). Although football players cover large distances these are mainly covered at moderate to low intensities, placing demands on the aerobic energy system. According to Bangsbo, (1994), 90% of the total energy used in a match is said to be aerobic. However, the anaerobic metabolism contributes to crucial aspects of the game such as sharp turns, sprints and tackles. It has been suggested that such actions from the anaerobic system may be crucial to the outcome of the match (Faude, et al., 2012). It has been noted that wide midfield players undertake the greatest amount of high intensity running (DiSalvo, 2007). The intermittent nature of football leads to irregular changes in movement patterns (Bangsbo, 1994) including accelerations, decelerations, turns, jumps, sprinting as well as other football specific actions. These actions can place high demands on the body and lead to complex changes in the body's response. These characteristics become important when measuring the different aspects of training load as the body will respond in different ways to various activities. A reason for different objective measures and how this combines with the athletes own perception becomes important.

Consequently, performance analysis has become a key aspect of the training programme (Thorpe, et al., 2017). This has led to increased awareness in the sports science field, with this area having the potential to have positive effects on individual athletes and team performances. Due to the emerging technology, practitioners can now receive a large amount of information based on one training session. Information on training sessions must be analysed effectively and presented to managers and coaching staff in a way that is easily understood. Information can then begin to play a part in team selection and therefore must be accurate and well defined (Robertson, et al., 2017). It can also be used as a way of opening up conversations with players as contact between players and coaching staff is a key part of the training process.

1.4 Role of Training Load in Football

The construct of the training session is essential when it comes to the reasoning behind measuring training load. The goal of training is to prepare athletes to perform at their optimal level (Reilly, 2007). This takes place via systematic planning of training structures. Stimulating the development of different physiological, technical, tactical, physical and mental aspects of the game. There are several factors which can be manipulated when altering the structure of training to suit the time point in the microcycle. Such factors include; volume, intensity and duration, known together as training load (TL) (Malone, et al., 2015; Halson, 2014; Gabbett, 2016). Therefore, the variation of TL is through the manipulation of several variables such as total distance covered, high speed running, accelerations and decelerations. TL can be divided into two separate subdivisions; internal TL and external TL. The external TL is the training prescribed by coaches and so objective measures of work performed (Bourdon, et al., 2017), while internal load represents the physiological response to the specific workload performed. For athletes to achieve physiological adaption, the training programme must be adjusted, considering both training and competition demands.

The planning and systemic variation of training is known as periodisation. This is the division of the annual training plan into smaller training units through the variation in prescribed training loads (Morgans, et al., 2014). Training intensity must be accurately monitored as an insufficient training stimulus can lead to under training and consequently no training adaption taking place. Undertraining has also been related to increased injury risk due to athletes being underprepared (Gabbett, 2016). Such training adaption may be in the form of physiological markers or biochemical stressors ensuring that players are in peak condition for competition (Silva, et al., 2014). Excessive training may lead to overtraining, putting the athlete at a higher risk of obtaining injuries (Gabbett, 2016). Therefore, there must be a compromise of training loads between the competition demands and the developmental needs and physiological adaptions of the athlete (Bomba & Haff, 2009). The recovery process in training is also very important, this can be in the form of light training, which can lead the body's energy stores to return to baseline. Training following that can lead to a supercompensation effect, as the capacity of the player increases beyond baseline level (Brink, et al., 2014). The supercompensation effect is not only a physiological response but also psychological, and in order for adaptions to take place there must be an application of a new training stress (Gambetta, 2007; Merrier et al., 2017). However, if training variables are not tailored correctly with the appropriate balance of stress and recovery, the athlete may also experience symptoms of non-functional overreach (Matos, et al., 2011). Our knowledge of training load will help us understand how and why certain individuals respond to particular modes of training.

1.5 Periodisation in Football

The annual training plan in football is generally divided into the three phases; pre-season, in-season and off-season. Each phase can be further divided into smaller blocks, termed microcycles, which usually last 3-7 days in duration (Bompa, 2015; Malone, et al., 2015). In recent years there has been a change in the design of the appropriate weekly training plan. The concept of tactical periodisation is the idea of maintaining a regular and fixed weekly training pattern, keeping in mind the training and recovery demands (Mendez-Villanueva, 2012). This means that throughout the week, training is altered in account of the last game and the next one. Within the training days the physical component will alternate, by prioritising mainly strength, endurance or speed. Therefore, no two days within a given week will demand the same physical fitness components. This concept means that the body has time to recover from the physical components that were stressed the previous day. Recovery occurs when the dominant physical fitness components are switched throughout the week, across training days rather than within the same training session. Therefore, each training session may elicit different physiological responses. As well as fitness variables the complexity of training varies. This means the training intensity will differ; however, it will remain relative to the players recovery and readiness to train (Mendez-Villanueva, 2012).

The application of this periodisation protocol can be difficult due to external factors such as fixture scheduling and weather conditions. Meaning, the usual four day lead in to a match may become a three or even a two day lead. This will also be dependent on the starting team, who will need more recovery time than those who did not play the full game or those who did not play at all. During a congested fixture period the components of training focus mainly on recovery. The concept of the tactical periodisation protocol therefore changes with the different stages of the season and can be influenced by various external factors.

1.6 Objective Measures of Training Load

It is paramount to monitor athletes' fatigue, fitness and performance response to various training sessions. Quantification is based on internal (oxygen uptake, heart rate, blood lactate) and external measures (distance covered, power output, number of repetitions) of exercise intensity (Buchheit, 2014). When measuring fatigue, a number of tools can be used such as monitoring saliva and specific blood variables (Heisterberg, et al., 2013). A more direct indicator of muscle damage is to measure serum Creatine Kinase (CK) levels (Howatson & Malik, 2009). This has been shown to relate moderately to acceleration based player load in team sport training (Young, et al., 2012). Measuring maximum oxygen uptake (VO_2max) and changes in blood lactate levels may be used to track changes in fitness (Hoppe, et al., 2013; Beneke, et al., 2011). However, these methods can be invasive and time consuming.

Therefore, when it comes to measuring training load, heart rate (HR) monitors have become commonplace in most sports as an effective tool to quantify physiological response to training. The monitors are used to quantify the cardiovascular strain placed on the individual in response to a given external training load (Drust, et al., 2007). HR response can therefore provide valuable feedback on the physiological response to a certain training stimulus. A common method is to determine the percentage of heart rate max (Helgerud, et al., 2001) as this can allow coaches and sports scientists to regulate training intensity based on the amount of time spent above a certain percentage of the athlete's maximum heart rate. During certain training sessions it may be used as a tool to improved cardiovascular fitness or ensure only light intensities occur during recovery periods. Although HR is a good indicator of physiological load it does not provide important information on external loads. Where there is a high anaerobic component within drills HR may underestimate the intensity of the drill (Little & Williams, 2007). To gain a more complete picture of the training effects, researchers and practitioners began to use other tools to quantify external load, which used along with internal load will provide a clearer picture of the athlete's response to exercise. Individual players will show a different response to a given stimulus, therefore, measures should be based on individual calculations.

Global Positioning Systems (GPS) and time motion analysis have become the most popular methods of performance analysis within team sports (Aughey, 2011). GPS has advanced the understanding and research of physical performance analysis. The devices are used to quantify player movement. The device receives signals transmitted from at least 24 satellites orbiting the earth, which determine location, direction and speed of the receiver (Maddison & Ni Murchu, 2009). GPS units used for sporting analysis normally have sampling frequencies of 1Hz-15Hz. Several studies (Barbero-Alvarez, et al., 2010; Jennings, et al., 2010; Varley, et al., 2012), have shown that as sampling frequency increases reliability also increases. Modern GPS devices have sampling frequencies between 5-10Hz due to validity and reliability factors. Johnston, et al., (2014), investigated the validity and reliability of various sampling frequencies when measuring team sport movements via a sports stimulated circuit. This circuit included movements from a walk to a sprint, accelerations, decelerations and an agility section. Overall results found that the 10Hz sampling frequency provided lower levels of error for all movements compared to 5Hz and 15Hz. However, it had been noted by Johnston, et al., with all sampling frequencies there is reduced levels of inter-unit validity and reliability at high speeds (>20km/h). Additionally, only 10Hz GPS provides acceptable accuracy for high metabolic power (4.5%) compared to 5Hz GPS (Rampinini, et al., 2001). Practitioners have used such measures to monitor internal and external activity with an objective framework for evidence based decisions.

1.7 Subjective Measures of Training Load

Although the external load is the main determinant of the overall training load, other factors such as psychological stressors, environmental factors, general wellbeing and mood can have an effect on training load (Thronton, et al., 2019). The physiological stress imposed via external load can also differ between individuals. Therefore, a subjective rating of training in addition to objective measures becomes a useful tool. When monitoring and controlling the training process it is important to have a valid measure of individual training load, especially in team sports, as many of the training drills involve group exercises such as small sided games. Therefore, a popular method to determine internal load is measuring what is known as Rating of Perceived Exertion (RPE), as it is a simple, inexpensive and effective tool. This method involves individuals determining the rating of their perceived exertion based on a simple ratio scale.

The concept of perceived exertion was introduced by Borg and Dahlstrom in 1950 (Borg, 1970), with the meaning derived from experiences such as effort, fatigue, breathlessness and feelings from the working muscles. Such feelings were subject to force, arousal and exercise intensity. Perceived exertion is closely related to exercise intensity (Borg, 1998) and was therefore described as the feeling of how strenuous a task was. Exercise intensity can be defined by physiological measures such as oxygen uptake in absolute terms or relative terms via heart rate, also through physical terms such as work rate. Additionally, it can be evaluated by subjective measures perceived by the athlete (Borg, 1998). This provides a direct individual measure of exercise intensity. When an individual performs a muscular task, sensory cues are sent from the active muscles and joints, cardiovascular, respiratory system and other bodily organs (Hutchinson, 2006). Emotional and motivational state of an individual during exercise as well as physiological cues can also influence how the exercise was perceived.

The overall rating of perceived exertion integrates several signals form the working muscles and joints as well as signals from the cardiorespiratory and central nervous system, thus, providing a global measure of training stress (Impellizzeri, et al., 2004). This subjective rating of an athlete's perceived exertion is based on a simple ratio scale, developed originally by Borg (1970). This was a 15 point scale ranging from 6-20 anchored by simple verbal cues for easy interpretation. In broad terms this original scale follows the assumption that physiological strain increases with exercise intensity, and perception of effort follows that order. This is a debatable assumption but gives the scale a metric property and makes it easy to follow (Borg, 1998). Results may also integrate factors from the physiological continuum, this includes many variables such a ventilatory threshold, blood and muscle lactate and heart rate. According to Borg (1982), the numbers can be used to signify heart rates ranging from 60-200 beats.min^{-1}. Although stated as a close relationship, it is not a valid measure of heart rate. The scale was then adapted to include a simple number range, 0-10, where 0 infers no exertion and 10 is a strong feeling (Borg, 1982).

Borg CR-10 scale was modified by Foster (1995) by slightly adapting the verbal cues for easier understanding by the average lay person. Fosters 0-10 scale can also be used to calculate session RPE by multiplying the numerical rating by the duration of the training session (Foster, 2001). This makes the quantification relative to each individual training session by providing an arbitrary unit representing overall training load. Despite the differences in number range and wording, the scales are used in the same way, to measure the psychosomatic response of an individual to exercise. In the case of football, the RPE rating will refer to the internal response to the external stimuli, the drills set out by coaches at every training session. Research by Impellizzeri, et al., (2004) and Alexiou and Coutts (2008), showed significant correlations between the use of session RPE to monitor training load, and published methods based on heart rate response. Authors conclude that RPE based methods to quantify TL is a good indicator of internal load in football. In addition to this, oxygen uptake during exercise (VO2) and its expression as percentage of the maximal volume of oxygen uptake (%VO2max) were both strongly correlated to the session-RPE method for males and females practicing interval training (Herman, et al., 2016).

Borg conceptualised perceived exertion with a gestalt framework (Hutchinson, et al., 2006) which involve sensations from peripheral muscles, pulmonary system, cardiovascular system and other sensory organs. Therefore, the commonly used overall RPE consists of two main factors; central and peripheral. However, this overall rating may lack sensitivity and may be insufficient when measuring signals from a range of various external loads, for example; sprinting, accelerations, decelerations and jumps. An average weekly training will include an aerobic session, based on large training spaces with increased area per player which can lead to a greater total distance covered by players. Alternatively, it will also include a session based on speed and or strength, focused on smaller training spaces, causing more strain on muscles and tendons due to greater number of accelerations and decelerations. Both sessions are likely to induce different neuromuscular, metabolic and cardiovascular response (Little & Williams, 2007). Although overall RPE will have discrepancies between two sessions it does not explain underlying psychophysiological differences important in understanding and prescribing training actions.

In order to gain additional information from training sessions the overall RPE can be differentiated to encompass individual ratings, both central, the feelings from the respiratory and cardiovascular system and peripheral, feelings from working muscles and joints. Differential RPE will therefore provide sport scientists and coaches with a better explanation of the mechanisms that determine subjective ratings due to type of physical work taking place.

1.8 Research Proposal

As mentioned above there is a great importance when it comes to monitoring training load in team sports, integrating both objective and subjective measures. A commonly used subjective measure to quantify internal training load is the rating of perceived exertion. Distinguishing between the main factors involved in RPE measures may provide additional insight into training sessions and consequently the design and structure of training. It may help to answer several questions, for example, why an athlete has reduced activity compared to teammates. They may be affected by physiological aspects such as muscular fatigue or breathlessness, perhaps the training prescription or the athlete lacks motivation. At the football club where the research is taking place, there is a specific periodisation strategy. This involves different physical elements (speed, strength and endurance), therefore, physiological aspects of training will differ. Also, the varying microcycles of the tactical periodisation protocol within the club will affect preceding activities, consequentially affecting training response. Therefore, it becomes important to understand the psychophysiological differences in training actions. This research will focus on analysing differential RPE and objective measures to see how they work together to provide a holistic and integrated approach to understanding training load.

The limited current literature available (Malone, et al., 2014; McLaren, et al., 2016a, 2016b, 2018; Los Acros, et al., 2014, 2017) has demonstrated some advantages, however, it is not a transferable approach due to situational differences. This study can add to the current literature and look at how differential RPE can be used in the applied football setting and investigate the potential to supplement the current training load monitoring process used at the club. The aim of this study is therefore to determine if differential RPE is a valid and reliable measure of internal training load, this is how the body responds to the physiological stress imposed on the player (Booth & Thomason, 1991; Viru & Viru, 2000). Investigating the weekly training fluctuations of central, respiratory RPE and peripheral, lower limb muscular RPE and how they are incorporated into the tactical periodisation protocol, through validating respiratory RPE and lower limb RPE with objective GPS measures. We hypothesise that the central RPE and peripheral RPE would differentiate during different training days within the tactical periodisation protocol, with lower limb RPE perceived to be greater for strength based training sessions and respiratory RPE greater for aerobic based training sessions. Differential RPE will therefore correlate with specific GPS parameters, such as total distance covered, high speed running, accelerations and heart rate measures on those training day

2. Literature Review

Team sports, especially football involve irregular changes in exercise patterns (Bangsbo, 1994) this can lead to complex physiological changes and adaptions (Morgans, et al., 2014). Monitoring these physiological changes is crucial during the training process to ensure athletes are exposed to sufficient training stimuli in order for them to perform at their optimal levels during competition (Thornton, et al., 2019). The training structure is therefore periodised appropriately to ensure demands are being met. The periodisation framework is the planned and systematic variation of training parameters with the goal of optimising training adaptions (Gamble, 2016). Weekly trainings are multidimensional as training sessions are required to develop a number of energy systems as well as specific muscles, leading to multiple types of training sessions throughout a typical training week (Morgans, et al., 2014). Athlete monitoring is important as it provides useful information as to whether athletes are responding appropriately to imposed training demands (Thorpe, et al., 2017). Measuring workloads is done through monitoring both internal and external training loads (Bourdon, et al., 2017). Collecting and understanding this data is imperative to successful athlete monitoring systems (Buchheit, 2017).

The use of ratings of perceived exertion has become an extremely popular method in determining internal training load. This subjective RPE in accordance with other measures of physiological strain can begin to produce an overall picture of how an athlete responds to a certain training session (Vanrenterghem, et al., 2017). For example, an elevated RPE may signify a risk factor for overtraining for certain individuals. However, temporary alterations in mood may provide unfitting training response (Bourdon, et al., 2017). Although RPE alone cannot be used directly as a measure of 'dangerous strain' it can be integrated with other risk factors such as blood lactate levels, hormonal secretion and heart rate (Borg, 1982). An RPE that remains constant or begins to decrease for a certain type of training session may mean that adaptions are taking place and fitness levels are improving. In recent years RPE has been used alongside objective GPS measures, which provides data on external loads. This provides additional information on the context of training sessions and how the relationship is affected throughout various microcycles.

When overall ratings of perceived exertion were originally introduced, the concept involved two major components, one being, sensation of fatigue and strain from the muscles, tendons and joints engaged in the activity. The other coming from feelings of exertion from the chest, originating from the cardiorespiratory system (Pandolf, et al., 1984). Therefore, the aim of this study will incorporate the use of differential RPE, including muscular, respiratory and overall RPE measures. This will help improve the current literature on how ratings of perceived exertion may be used to aid the quantification of training load in team sports. Although ratings of perceived exertion had developed over the years, there has been little in further development in more recent years. When it comes to the concept of differential RPE there is a gap in the research, this study will provide more insight into the use of differential RPE within the applied football setting. The aim of the research is therefore, not only to determine how overall internal load is affected by the tactical periodisation protocol but also to determine the validity of differentiating ratings over the main training days. This research will aim to provide coaching staff with a more specific understanding of how their training sessions affected the athlete and if the training produced its desired outcome.

The following literature review examines previously published research into the use of rating of perceived exertion as a tool for monitoring internal training load. It will go on to review the available research on differential ratings of perceived exertion and how this is affected by the weekly training load protocol, specifically, in the lead up to a match. It will also review the in season periodisation within professional football, as this is important in understanding the range of training content and how it is manipulated in order to optimise performance.

2.1 Ratings of Perceived Exertion

When monitoring internal load, the majority of research examined used the 0-10 point Borg's (1998) category scale modified by Foster, et al., (1995). This is consistent with the RPE scales used in our study. One paper analysed, used ratings based on the CR100 scale as they suggested it provides a more precise measure of ratings of perceived exertion compared to the traditional CR10 scale (McLaren, et al., 2016a). When examining the validity and reliability of RPE based methods to monitor training load many studies make use of Fosters Session RPE (2001), which takes into account both intensity and duration of training.

Previous research has deemed PRE based methods of monitoring training load in team sports, specifically football, as a good indicator of global internal training load. When monitoring Fosters' RPE based methods, Impellizzeri, et al., (2004) found significant correlations between this method and other published methods (Edwards' TL, Banister's TRIMP and Lucia's TRIMP) based on heart rate response to exercise.

Other studies found RPE methods are significantly related to indicators of external physical load. Casamicha, et al. (2013), found very large associations between session RPE and the external measure of Total Distance Covered and Player Load. Players external load was monitored via GPS devices (Catapult) with a sampling frequency of 10Hz incorporating a 100Hz triaxial accelerometer. The majority the of research used GPS devices from one of two main supplier; Catapult and GPSports with the sampling frequency cited as 10Hz. This is consistent with GPS devices used within our study. In addition to this Scott, et al., (2013), found significant correlations between other important external measures, such as, high speed running (>14.4 km/h) and very high speed running (>19.8 km/h) and RPE based measures of internal load. The study compared various measures of external load during in season field based training for a professional soccer team competing in the Australian A-League. The use of RPE has therefore been proposed to be a valid and reliable method used to quantify internal load in team sports.

Depending on which muscles are activated due to certain activities, physiological response and ratings of perceived exertion may differ. This especially can be demonstrated between upper and lower body exercises as feelings of strain may be related to aerobic and anaerobic expenditure. Pandolf, et al., (1984), compared three differentiated ratings of perceived exertion; local, central and overall, while subjects completed arm crank and cycle exercises. Significant differences were found between; central, local and overall RPE between arm crank and cycle exercises at similar absolute exercise intensity. This study demonstrates the difference various exercises can have on response to perceived exertion.

2.2 Main Findings

Within elite football the weekly training structure is periodised to incorporate different training sessions that elicit different physiological responses to enhance player adaption. This demonstrates the importance of understanding the training load effects and outcomes for each training across a given week. The concept of tactical periodisation has become extremely popular in recent years, especially within sports science departments who readily monitor teams and individuals over this period. Studies have shown how this tactical periodisation protocol has been implemented within professional football and how it can be altered to suit different teams and their needs.

Impellizzeri, et al., (2004) found mean weekly RPE based training load differed throughout the week, generally decreasing in the three days that lead into a match to allow for adequate recovery. The various types of training days usually occur in accordance to match days ensuring optimum performance. Malone, et al., (2015) were one of the first authors to provide a report on the seasonal training load quantification in elite football. They investigated loading patterns within separate training units. Training data were analysed in regard to number of days prior to a match. Their training periodisation protocol was found to be different to the one used in the current study, with a day off in between MD-5 and MD-3. They found MD-1 displayed significantly lower external training load values than MD-2 for all performance variables with the exception of high speed distance (distance covered >5.5 m/s). All performance values for MD-1 were also significantly lower than that of MD-3. Similar results were seen for subjective RPE measures in the lead up to the match. With MD-1 displaying significantly lower values than previous training days. Los Acros, et al., (2017) investigated a five day lead, beginning with MD-6. They used session RPE as a measure of training load, using Fosters 0-10 scale. A progressive increase in TL to MD-3 followed by subsequent decreases were seen. These findings clearly suggest that there is an obvious training load pattern observed across training days in the lead up to a match.

Researchers have further investigated this TL pattern by discriminating between discrete sensory inputs, namely, central and peripheral exertion signals. McLaren, et al., (2016a) investigated the sensitivity of using differential ratings of perceived exertion to monitor internal load. They found moderate to large between protocol differences in RPE for breathlessness and RPE for leg muscle exertion when participants performed two maximal incremental – exercise protocols; cycle ergometer and treadmill protocols. It is noted that the exercise protocol affects differential RPE as it represents different dimensions of effort, discriminating between central and peripheral perceptions of effort. This study, however, was under controlled, experimental conditions and does not represent sport specific actions, namely in the professional football setting.

Los Acros (2014), investigated respiratory and muscular RPE over the competitive in season phase of a professional soccer team. The team followed a four-day training schedule in the lead up to a competitive match. Between training days significant differences were seen between respiratory and muscular RPE. However, on any given training day, they found no significant differences between respiratory and muscular RPE scores. The study, however, did not provide objective external measures for each training session. Although they state that the heaviest aerobic training session is usually conducted four days prior to the match and speed development three days prior, there is no external GPS data to back that up. To validate respiratory and muscular RPE, heart rate response to training over three heart rate zones (<70%, 70-90% and >90% HRmax) were recorded. Although HR monitoring is widely used in team sports, it is still not accepted as a gold standard measure (Buchheit, 2014) and makes it hard to understand the multifactorial nature and specificity of trainings. Similar results were seen by Los Acros, (2017), who noted differences between session respiratory and muscular TL scores were trivial. However, similar to the previous Los Acros, (2014) study, there were no objective measures used to aid the monitoring of training load.

As stated by McLaren, et al. (2016b), the recorded differential RPE measure is dependent upon training mode. Their study investigated the application of differential RPE during professional rugby training. As well as measuring ratings for breathlessness and leg muscle exertion, they also examined upper body muscle exertion and cognitive / technical demands. Sessions were represented based on their training typologies. Within session comparisons found RPE measures for leg exertion, to have large positive correlation with high intensity interval training. Additionally, RPE measures for breathlessness presented very large correlation with repeated high intensity effort based training and large correlation with skilled based conditioning training modes. Although the main exercises / drills were identified and represented as one of the main training typologies, there are no individual objective measures to identify such training days.

The findings from this study support others conducted in team sports, showing significant differences in differential RPE between training days. However, it contradicts findings from other studies which have shown no within session differences. Due to different teams having their own specific training plan, direct comparisons with studies cannot be made. Studies suggest that there is potential to differentiate between feelings of breathlessness and feelings of muscular fatigue. The inconsistency in results demonstrates how subjective such measures can be when using ratings of perceived exertion to monitor training load. Additionally, teams employ their own specific training plan, the validity of differential RPE is therefore affected under such circumstances, in the context of the team and their periodised training protocol.

It is evident that there is little knowledge on the validity of differential RPE, how it is affected by the periodised training plan and how it is used within an applied team sports setting. The literature has shown inconsistencies in the usefulness of differential RPE to aid the training load monitoring process within team sports. This review shows that further research is needed to clarify the validity and application when using differential RPE in football during the highly important periodised training schedule.

2.3 Aim

This study is will interpret the underlying psychophysiological disparities important in understanding differences in training sessions through the aiding tool of differential RPE. This will provide coaching staff with the information needed when monitoring and prescribing trainings activities. The aim of this study is therefore to determine if differential RPE is a valid and reliable measure of internal training load by investigating the weekly training fluctuations of central, respiratory RPE and peripheral, lower limb muscular RPE by validating these measures with objective GPS measures.

3 Methods

3.1 Participants

Twenty-one development squad players from an elite Scottish Premier League Club took part in the study during the 17/18 in season. Players included were all from outfield positions (Defence, Wide Midfield, Central Midfield, Attacker) with Goalkeeper data excluded. Subjects were a mean 18.4 ± 0.9 years of age, a mean height 180.4 ± 5 cm and weight 76 ± 7 kg. Data collection took place during the in-season period between January and April 2018 at the club's training ground on their 3g astro turf training pitch. Differential RPE as well as GPS data were available from 25 training sessions and from each athlete taking part in training during this time. Due to restriction of work in the applied setting there were a number of training sessions in which differential RPE was unable to be collected. Participants who did not participate in full training sessions were excluded from study for that training day. Data was collected as part of the normal training process for the club, contracts ask players to consent to data collection and analysis for revision of testing and monitoring protocols. The audited data was anonymised for use in the current study.

3.2 RPE Collection

Using the modified Borg scale (Foster et al., 2001), players were asked for an overall rating of perceived exertion after each training. The scale was then adapted (Figure 1 & 2) to differentiate between central, respiratory feelings of exertion (respiratory RPE) and local, muscular ratings of perceived exertion (lower limb RPE). Players responded to two simple questions, "How did the training session feel on your heart and lungs?" and "How did the training session feel on your legs?" in that order. Questions were asked 15 minutes after each training session to ensure elements towards the end of training did not influence results. The original methods recommend that RPE measures should be taken approximately 30 minutes following exercises to avoid the temporal latency effect (Foster, 2001). However, this delay was impractical in the current non-experimental setting. A novel study by Uchida, et al., (2014), who investigated the effect of timing on session RPE measurements after a training session for boxers, found session-RPE measures were not statistically different when obtained 10 or 30 minutes after training sessions of the same intensity. Therefore, the timing questions was selected 15 minutes post training. Players were asked the questions on an individual basis, without the presence of other players. All players were familiarised with the scales and questions to differentiate ratings in the weeks leading up to official data collection. Players had been previously trained in the use of the modified Borg 10 point RPE scale via explanation and meaning behind the scale. Despite the differences in number range and wording, the scales are used in the same way, to measure the psychosomatic response of an individual to exercise. In the case of football, the RPE rating will refer to the internal response to the external stimuli, the drills set out by coaches at every training session.

0	Rest
1	Very, Very Slight
2	Very Slight
3	Moderate
4	Somewhat Severe
5	Severe
6	
7	Very Severe
8	
9	
10	Maximal

Figure 1: Modified Borg Scale (Adapted from Foster, et., al 2001) to assess central ratings of perceived exertion (heart / lungs / breathing)

0	Rest
1	Very, Very Light
2	Very Light
3	Moderate
4	Somewhat Heavy
5	Heavy
6	
7	Very Heavy
8	
9	
10	Maximal Strain

Figure 2: Modified Borg Scale (Adapted from Foster, et., al 2001) to assess local ratings of perceived exertion (legs)

3.3 External Load

Global Positioning Systems (GPS) were used to collect external load measures via 10Hz GPS devices (GPSport, Canberra, Australia). The device was worn in a specially designed vest located on the back, placed in the upper thoracic region of the spine. All units were assigned to one specific player, meaning each player wore the same GPS unit for all trainings and matches, to minimise the risk of inter-unit variability. The GPS units (74mm x 42mm x 16mm, 67g) have 3-axis accelerometer, gyroscope and magnetometer sampling frequencies of 10Hz. Units had been worn during previous seasons; therefore, participants were familiar with the devices. All devices were switched on and activated 30 minutes prior to the beginning of training sessions, to ensure connection to satellites. During each training session players also wore a portable heart rate sensor, which was attached to the GPS vest (Polar Electro Oy, Kempele, Finland).

The available parameters chosen for analysis include:

- Total distance covered (m)
- Distance per minute (m/min)
- High speed running (21 – 24 km/hr)
- Sprint distance (> 24 km/hr)
- High accelerations (3 – 4 $m.s^{-2}$)
- High decelerations (3 – 4 $m.s^{-2}$)
- High Intensity time (HR > 85% max)

These specific objective parameters were selected based on current literature around validity and reliability of GPS. Speed thresholds (high speed running of 21-24 km/hr and sprint distance at >24 km/hr) are those commonly used for movement analysis for football training and match play and based on previously reported literature (Bangsbo, et al., 1991 and Rampinini, et al., 2007). Acceleration and deceleration thresholds are based on research by Russell, et al., (2016), who suggests that high intensity acceleration and deceleration thresholds reach $4m.s^{-2}$ during elite match play.

3.4 Training Procedure Overview

On a week with only one scheduled match (Figure 3), training took place as a four day lead up to a match (Table 1). This training structure began two days after the match. Match day plus 1 is an off day for recovery, match day plus 2 is the second day recovery (R2) which takes place in the gym. Due to being indoors and the low impact recovery, any data obtained for recovery sessions were not included in the study. Periods of fixture congestion lead to bi-weekly matches (Figure 4), which included one day off after the first match for recovery, followed by R2 and/ or MD-2. Players who played 60 minutes or more took part in R2 session while those who did not play 60 minutes or were not included in the match took part in a typical MD-2 training session. This is a similar scenario after the second match of the week, with first day recovery (R1) as a lighter session than R2 due to number of days post match.

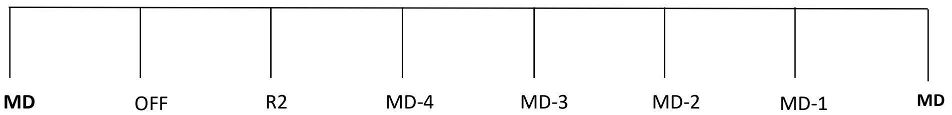


Figure 3: In season MD minus training schedule for typical microcycle showing four-day lead in to match

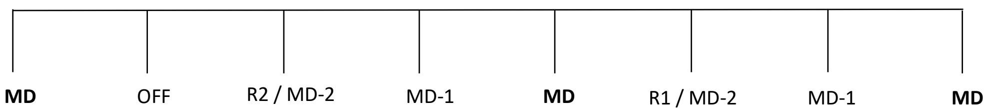


Figure 4: In season MD minus training schedule showing typical two-day lead in to match during fixture congestion period

Training Days

Training Day	***Descriptor***	***Training Aim***
MD – 4	Anaerobic	Small Spaces Fewer Numbers Mores accelerations/ decelerations
MD -3	Aerobic	Large Spaces Large total distance covered
MD – 2	Speed	Small Spaces Speed of movement / play Speed of thought
MD – 1	Reaction	Technical / tactical areas
MD	Match	

Table 1: Training days and descriptions

The duration of training varied depending on the training day, however on average, training lasted between 70 and 90 minutes. The training programme was designed and implemeted by the club's coaching and support staff. Training began with a standardised warm up, involving a pitch run and stretches for a period of 10 minutes. This was followed by an element of conditioning, which again varied depending on the training day. The main section of training involved several football specific drills, intended to enhance both physical and tactical abilities. All players trained together within the session.

Four days prior to a match (MD–4) is known as a 'strength day' day and is centred around more anaerobic components (Table 1). This involves smaller spaces and fewer numbers, therefore, leading to more accelerations and decelerations. This leads to more strain on the muscles, tendons and ligaments. Also enhancing game adaption skills through sharp movements. The following training (MD–3) is known as a 'resistance day'. This is an aerobically based training, in which spaces open, leading to a greater overall distance covered. The first two days within the four-day lead in are of a high volume and intensity, with the following two days tapering towards the match. MD–2 is a 'speed day'; this day focuses on speed of movement and play. The area per player becomes smaller, aiming to enhance speed of thought and decision making. One day prior to the match (MD-1) is a recovery day, to ensure optimal readiness for the upcoming match. This is known as a 'reaction day' and is of a low volume and intensity, with the main focus on technical and tactical areas. This framework involves both physiological and football specific training.

Although this is the tactical periodisation template, certain constraints within the time frame means that this is not always the case. The same weekly training programme is repeated in the lead up to matches. However, the components within the training sessions differ, with no two training sessions the same. The training days are categorised according to the specific focus of training, aiming to adapt and maintain certain areas (Wrigley, 2012). The overall aim was to ensure peak conditions are obtained for the upcoming match. Diet and lifestyles were not controlled during the course of the study.

3.5 Data Analysis

Raw data was downloaded from the GPS unit using the supplied USB device. Using the GPS software, the data was ‘cropped’ to include only data that was found within the official start and end time of training. The raw data CSV file was created with selected parameters and exported into a Microsoft Excel database along with ratings RPE for analysis. The inclusion criterion for training data was that athletes had to complete the whole training session.

Statistical analyses were conducted in “SPSS Version 22.0 for Windows (SPSS Inc, Chicago, IL, USA). All data were checked for normality distribution according to the Shapiro-Wilk’s test. Objective GPS and HR data were presented as mean ± standard deviation (SD). Subjective RPE data were presented as median ± standard error (SE) of median due to the categorical nature of RPE values.

One-Way ANOVA and Tukey Post Hoc Tests were used to compare all individual GPS and HR outputs over the four training days. Rank based non-parametric, Kruskal-Wallis tests were used to compare median RPE measurements. Spearman rank-order correlation coefficients were used to understand the relationship between differential RPE and the GPS outputs over the training days, scatterplots along with trendlines were produced to provide a visualisation of relationships.

In section 4.4 Two-Sample T-Tests compared external loads and Mann-Whitney U Test compared RPE measures over two speed days for statistical analysis, presented in bar charts. Primary axis allowed for visualisation of overall and differential RPE while secondary axis displays scatter plot of external loads.

For each player analysed in Section 4.5, Box Plots have been produced to visualise the inter-individual differences for differential RPE over each training day.

4. Results

The results of the training load monitoring study will be displayed in five sub-sections. The first section of results will describe the mean and median external and internal load to determine if training days are physically different with regard to the prescribed session and how this is perceived by the athletes. Secondly, the results will focus on a typical microcycle, to further analyse differential RPE over the four main training days. Finally, sub-sections three, four and five will provide the main focus of the results with the aim to investigate the validity, sensitivity and specificity of differential RPE and how it is affected by the tactical periodisation protocol.

4.1 Training Load Monitoring

A One-Way ANOVA was used to analyse the physical output produced via GPS measures over each training day. A total of 25 training sessions were recorded (MD-4 n=4, MD-3 n=5, MD-2 n=9, MD-1 n=7), with a total of 228 participant measurements. The data for each of the four training days in respect to number of days prior to a competitive match are shown in the following tables. The average training load data from all 25 training sessions via GPS and HR devices are shown in Table 2, represented as mean ± standard deviation. Table 3 presents the internal load, represented as median ± standard error of median for all training sessions.

Objective Measurements of Training Load for all Trainings

Training Load Variable	MD -4	MD - 3	MD - 2	MD – 1
Duration (min)	92.1 ± 3.0	94 ± 5.9	88.3 ± 14	75.1 ± 19.
Total Distance (m)	5633.4 ± 481.0	7017.4 ± 112.80*	5361.9 ± 630.8	2553.2 ± 540.2 ‡
Distance / Min (m/min)	62.5 ± 6.6	72.3 ± 10.6*	58.7 ± 7.8	34.6 ± 9.3 ‡
High Speed Running (21–24km/hr) (m)	21.6 ± 5.3	249.8 ± 47.5*	75.9 ± 19.3 †	6.9 ± 0.7
Sprint Distance (>24km/hr) (m)	2.50 ± 5.3	49.6 ± 47.5*	9.8 ± 19.3	2.4 ± 0.7
High Accelerations (3 -4m.s^{-2})	4.3 ± 3.2	5.6 ± 3.6	7.6 ± 5.7 †	2.6 ± 2.1 $
High Decelerations (3 -4m.s^{-2})	10.6 ± 3.7	16.9 ± 5.9*	11.3 ± 6.9	1.9 ± 2.1 ‡
High Intensity time (minutes >85% HR Max)	21.9 ± 13.2	23.0 ± 16.3	14.0 ± 9.9	2.2 ±3.1 ‡

Table 2: Mean data four main training sessions, represented as mean ± SD. * Denotes significant difference between MD-3 and MD-4, MD-2, MD-1. † denotes significant difference between MD-2 and MD-4, MD-3, MD -1. ‡ denotes significant difference between MD-1 and MD-4, MD-3, MD-2. $ denotes significant difference between MD-1 and MD-2 only. For all tests the significance level was set at $P \leq 0.05$.

Subjective Measurements of Training Load for all Trainings

Training Load Variable	MD -4	MD - 3	MD - 2	MD – 1
Overall RPE	5 ± 0.6	5 ± 0.2	4 ± 0.1 *	2 ± 0.1 ‡
Respiratory RPE	3 ± 0.6	4 ± 0.3	3 ± 0.1 †	1 ± 0.1 ‡
Lower Limb RPE	4 ± 0.7	5 ± 0.2	4 ± 0.2 *	2 ± 0.1 ‡

Table 3: Median data for ratings of perceived exertion from all four main training sessions, represented as median ± SE of median. * denotes significant difference between MD-2 and MD-4, MD-3, MD -1. † denotes significant difference between MD-2 and MD-3, MD-1. ‡ denotes significant difference between MD-1 and MD-4, MD-3, MD-2. For all tests the significance level was set at $P \leq 0.05$.

4.1.1 Duration

No significant differences were found for the duration between each of the main training sessions. The mean durations across all training days were very similar with the exception of MD-1, which had a mean duration of 75.18±19.21 minutes.

4.1.2 Volume

As presented in Table 2, the greatest total distance covered occurs on MD-3 (7017.4 ± 112.8m), this increased from MD-4 (5633.4 ± 481.0m), but the difference just failed to reach statistical significance (P=0.051). There is then a taper towards the match with significant differences for MD-3 vs MD-2 (5361±630.8m, p=0.03) and MD-1 (2553 ± 540.17m, p<0.01).

4.1.3 Intensity

The intensity of training was found to be greatest on MD-3, in reference to significantly greater high speed running (distance covered between 21–24 km/hr) and sprint distance (>24 km/hr) covered compared to all other training days (249.8 ± 47.5m and 49.6 ± 47.5m, respectively, p<0.05). Focusing on high speed running distance covered, there was a significant decrease for MD-2 compared to MD-3, followed by MD-4 and MD-1 (75.9 ± 19.3m, 21.6 ± 5.2m and 6.9 ± 0.7, respectively). A similar trend is observed for sprint distance. Continuing to focus on intensity of training, high accelerations (3-4 $m.s^{-2}$) were found to be significantly greater on MD-2 (7.6 ± 5.7$m.s^{-2}$) compared to all other training days. This changes to MD-3 predominating (16.9 ± 5.9$m.s^{-2}$) for decelerations. Decelerations are found to be greater than accelerations for all days except MD-1; Two-Sample T-Test found this to be at a significant level.

4.1.4 Internal Load

When comparing physiological differences gained from heart rate data, results showed time spent at high intensities (minutes > 85% HR max) is similar for MD-4 and MD-3 (21.92 ± 13.15 minutes and 22.98 ± 16.31 minutes, respectively, p=0.976). There is then a decrease across the remaining training days, with MD-1 having a significantly lower high intensity time (2.16 ± 3.06 minutes) than all other days.

The median overall and differential ratings of perceived exertion (± Standard Error of Median) presented in Table 3 are illustrated in the graph below (Figure 5). This includes all available measurements from all recorded training days. The overall ratings of perceived exertion are comparable for MD-4 and MD–3 (5 ± 0.6, 5 ± 0.2). There is then a fall in RPE in anticipation of the match, with the last two days being significantly lower and MD-1 having the lowest RPE (2 ± 0.1).

Respiratory RPE follows a similar trend, with MD-3 (4 ± 0.3) as the highest followed by a significant decrease to MD-2 (3 ± 0.1) and MD–1 (1 ± 0.1). Lower limb RPE was also found to be highest on MD-3 compared to all other training days. This is followed by a significant gradually decreased throughout the week towards the match. There is a statistical differentiation between respiratory RPE and lower limb RPE on MD–4 (Figure 5). Lower limb RPE was found to be statistically greater than respiratory RPE on this day. No other training day provides statistical differences between differential ratings of perceived exertion.

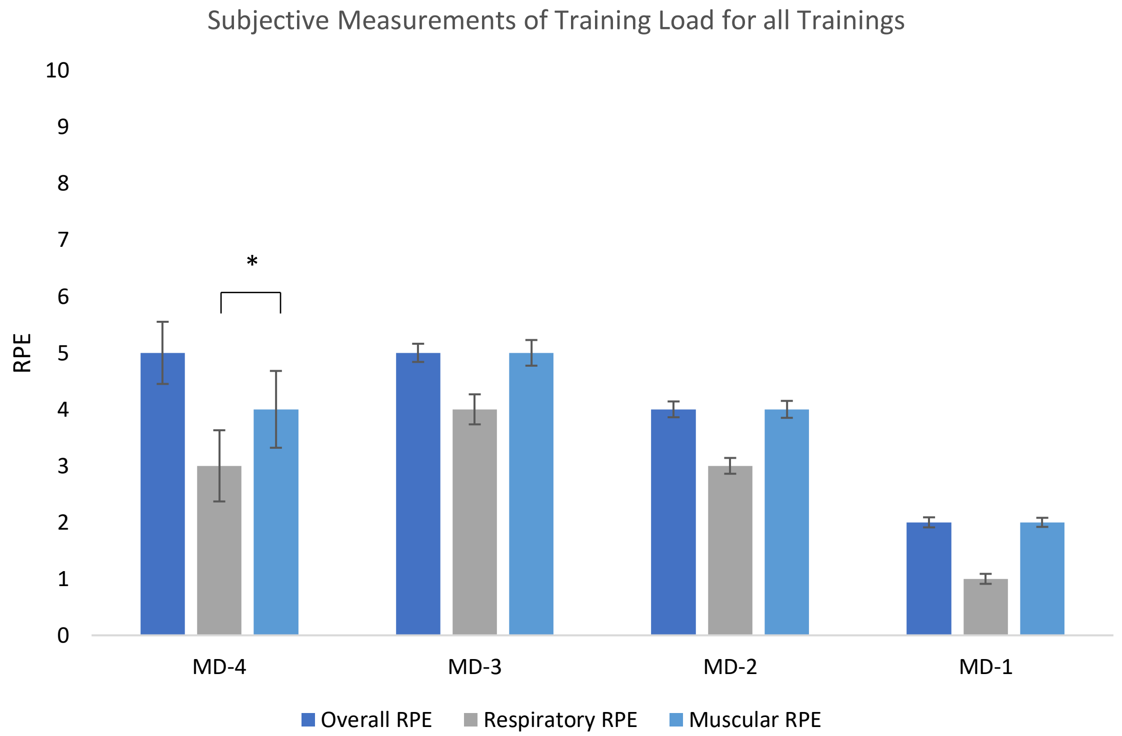


Figure 5: Graph displaying the median including standard error of median bars for overall RPE and differential RPE provided in table 2, from all available measures collected from all training session (MD-4, MD-3, MD-2, MD-1) throughout the study. * denotes significant difference between respiratory and lower limb ratings of perceived exertion. For all tests the significance level was set at $P \leq 0.05$.

4.2 Four-Day Lead In

Table 4 and 5 include data from one microcycle which is representative of a typical four day lead in. A total of 4 training sessions are included (MD-4 n=1, MD-3 n=1, MD-2 n=1, MD-1 n=1). Participants ranged from minimum thirteen to maximum sixteen for each training session.

Objective Measurements of Training Load for One Representative Four Day Lead In

Training Load Variable	MD - 4	MD - 3	MD - 2	MD – 1
Duration (min)	94	100	97	91
Total Distance (m)	5520.1 ± 269.8	7535.3 ±897.1*	5672 ±239.2	2152.6 ±279.1‡
Distance / min (m/min)	58.9 ± 3.0	66.4 ± 5.6*	58.3 ± 3	23.7 ± 3.1‡
High Speed Running (21–24km/hr)	18.4 ± 13.3	293 ± 66.5*	171.2 ± 55.4†	1.1 ± 2.1
Sprint Distance (>24km/hr)	2.4 ±3.6	75.6 ± 41.9*	18.6 ± 19	0.0 ± 0.0
High Accelerations (3 -4 m.s)	2.7 ± 1.3	6.2 ±4.1	16.1 ± 4.7†	2.1 ± 1.9
High Decelerations (3 -4 m.s)	9.7 ± 3.2#	18.5 ± 4.9	19.0 ±6.4	1.0 ± 1.1‡
High Intensity time (minutes >85% HR Max)	13 ± 8	13 ±12	9 ± 7	0.5 ± 0.6¥

Table 4: Internal and external training load data for each of the main training sessions during the four day lead in microcycle, represented as mean ± SD. * Denotes significant difference between MD-3 and MD-4, MD-2, MD-1. † denotes significant difference between MD-2 and MD-4, MD-3, MD -1. ‡ denotes significant difference between MD-1 and MD-4, MD-3, MD-2. # denotes significant difference between MD-4 and MD-3, MD-2, MD-1. ¥ denotes significant difference between MD-1 and MD-3, MD-4 only. For all tests the significance level was set at $P \leq 0.05$.

Subjective Measurements of Training Load for One Representative Four Day Lead In

Training Load Variable	MD -4	MD - 3	MD - 2	MD – 1
Overall RPE	4 ± 0.2	6 ± 0.3 †	4 ± 0.2	1 ± 0.2 $
Respiratory RPE	3 ± 0.0	6 ± 0.2 †	3 ± 0.3	1 ± 0.2 $
Lower Limb RPE	4 ± 0.3	5 ± 0.2 †	3 ± 0.4	1 ± 0.2 $

Table 5: Median data for ratings of perceived exertion from four main training sessions in microcycle, represented as median ± SE of median. † denotes significant difference between MD-3 and MD-4, MD-2, MD-1. $ denotes significant difference between MD-1 and MD-4, MD-3, MD-2. For all tests the significance level was set at $P \leq 0.05$.

Figure 6 displays the breakdown of internal loads for each training day during a representative weekly microcycle. This four day lead in shows a clear training load pattern. Within session comparisons found statistical differences between respiratory and lower limb RPE for both MD-4 and MD-3. Lower limb RPE was greater than respiratory RPE (4 ± 0.3, 3 ± 0.0, P = 0.00) on MD-4. Whereas MD-3 found participants perceived feelings within the respiratory and cardiovascular system to be statistically greater than feelings perceived within the lower limb system (6 ± 0.2, 5 ± 0.2, p = 0.003). No significant differences were found between lower limb and respiratory RPE for MD-2 or MD-1.

Overall, the highest perceived training load measures were observed on MD-3, all ratings increased from MD-4, at significant level. All measures then show a significant decrease towards the match, with the lowest found on MD-1.

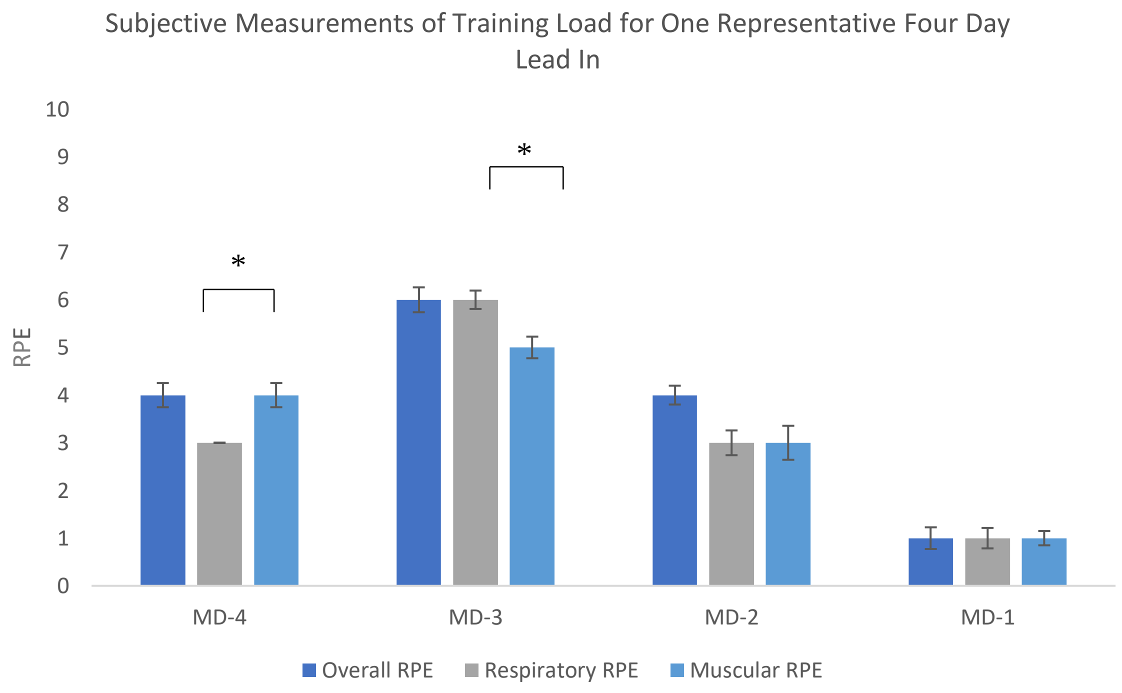


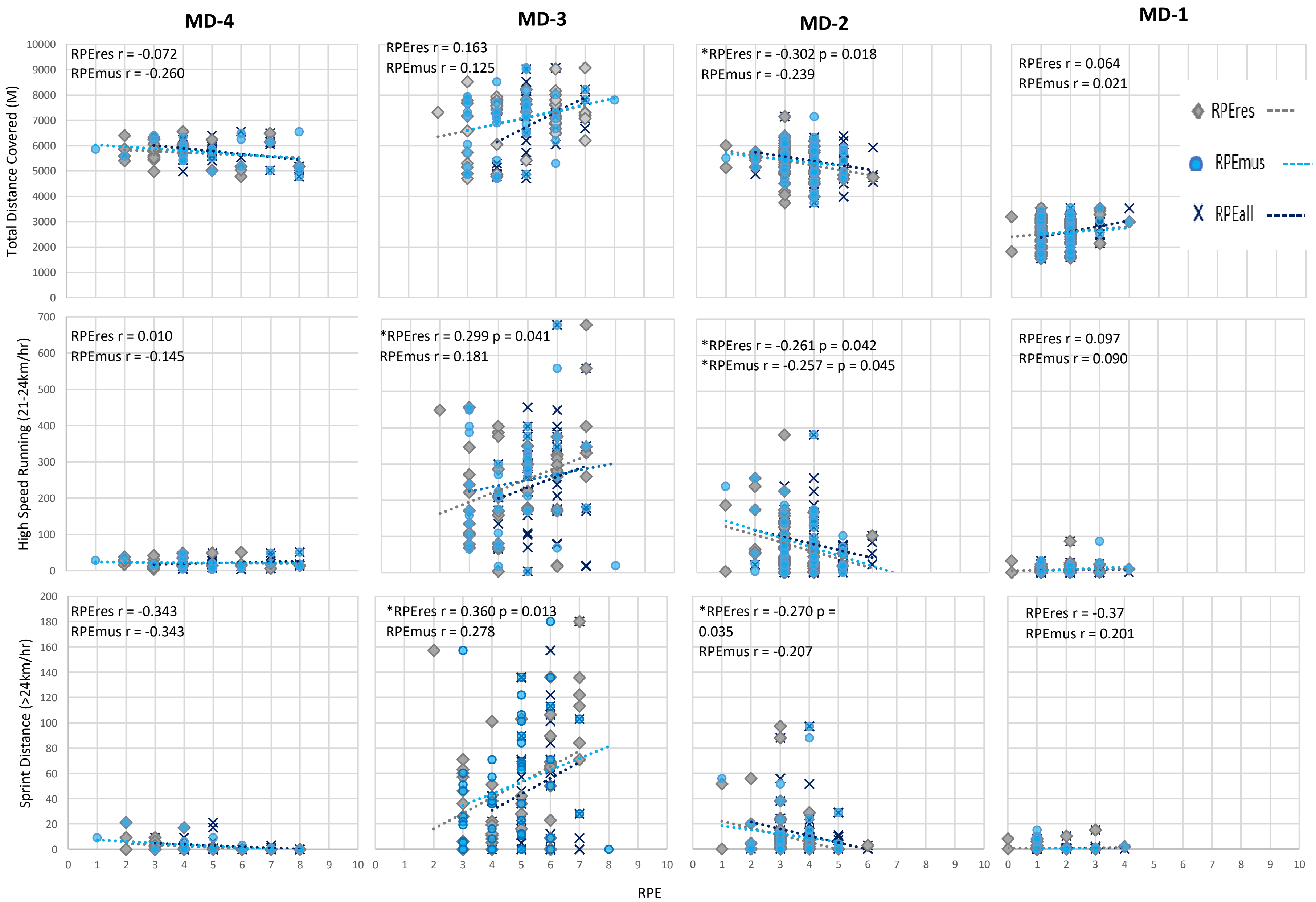
Figure 6: Graph displaying the median including standard error of median bars for each training day over one representative four-day lead in period. * denotes significant difference between respiratory and lower limb ratings of perceived exertion. For all tests significance level was set a $P \leq 0.05$.

4.3 Validity of Differential RPE

The following section of results displays the relationship between RPE and external GPS measures. This is to determine whether the differential RPE measure provided by athletes are specific to each training day by validating them against an objective GPS measure for that given day. All individual RPE measures from the data collection phase are represented in Figure 7. The use of scatterplots allows for the visualisation of the relationships between overall/ differential RPE measures and GPS metrics for each of the training days. All player data were used in the analysis and are represented by the markers on the scatter plot, aided by a trendlines to display the orientation of the relationship. Spearman rank correlation coefficients were used to measure the strength of association between the differential RPE measures and GPS outputs. The plots in Figure 7 show that the relationship with GPS outputs and differential RPE measures differ both within and between training days and GPS variables.

Weak and non-significant correlations were seen for both RPE measures and GPS outputs for MD–4, these are displayed as both positive and negative correlations. Significant positive correlations were found between respiratory RPE and high speed running distance for MD-3 ($r = 0.229$, $p = 0.014$). A positive correlation was also found with lower limb RPE however not significantly ($r = 0.181$). Similar results were seen for sprint distance and respiratory RPE ($r = 0.360$, $p = 0.013$) and lower limb RPE ($r = 0.278$, $p = 0.058$). Both accelerations and decelerations show weak positive correlations for differential RPE on MD-3. No correlation was found between high intensity time and differential RPE.

MD–2 shows predominantly negative relationships between differential RPE measures and GPS metrics with the exception of high intensity time, which provides positive relationships. A significant negative correlation was seen between respiratory RPE and total distance covered ($r=-0.302$, $p=0.018$) on MD-2. Significant negative correlations were also found between respiratory RPE, lower limb RPE and HSR ($r = -0.261$, $p = 0.042$; $r = -0.257$, $p = 0.045$ respectively). For MD–1 there is a mix of weak positive and negative correlations, with the exception of high deceleration and high intensity time. Both respiratory RPE and lower limb RPE show a significant positive correlation with high decelerations ($r = 0.252$, $p = 0.033$; $r = 0.326$, $p = 0.002$, respectively). A similar result is seen for high intensity time ($r = 0.234$, $p = 0.033$; $r = 0.274$, $p = 0.012$, respectively).


MD-4
MD-3
MD-2
MD-1
Total Distance Covered (M)
High Speed Running (21-24km/hr)
Sprint Distance (>24km/hr)
RPEres r = -0.072
RPEmus r = -0.260
RPEres r = 0.163
RPEmus r = 0.125
*RPEres r = -0.302 p = 0.018
RPEmus r = -0.239
RPEres r = 0.064
RPEmus r = 0.021
RPEres
RPEmus
RPEall
RPEres r = 0.010
RPEmus r = -0.145
*RPEres r = 0.299 p = 0.041
RPEmus r = 0.181
*RPEres r = -0.261 p = 0.042
*RPEmus r = -0.257 = p = 0.045
RPEres r = 0.097
RPEmus r = 0.090
RPEres r = -0.343
RPEmus r = -0.343
*RPEres r = 0.360 p = 0.013
RPEmus r = 0.278
*RPEres r = -0.270 p =
0.035
RPEmus r = -0.207
RPEres r = -0.37
RPEmus r = 0.201
RPE

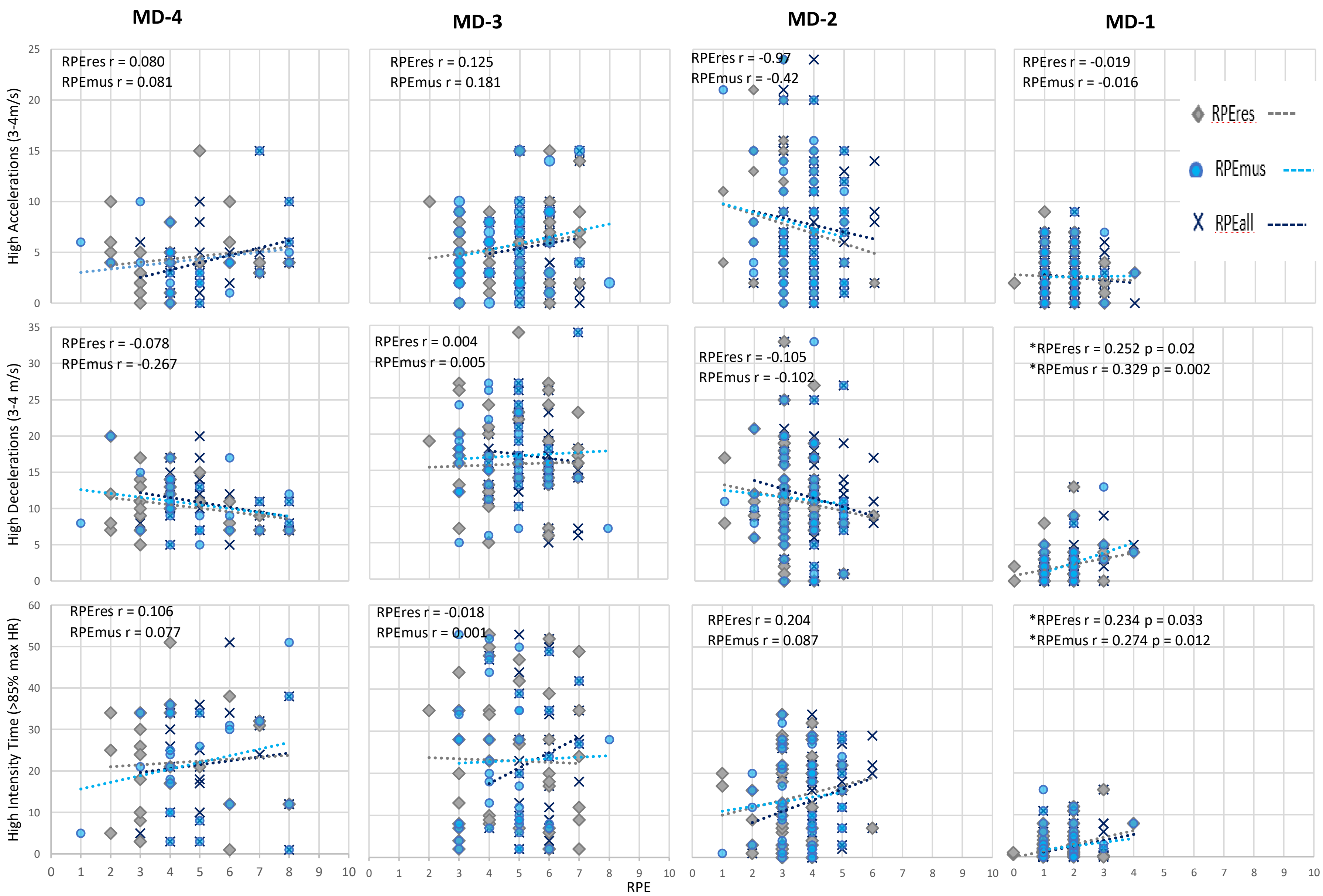


Figure 7: Scatterplots with trendline to illustrate the relationship between overall and differential RPE and GPS / HR variables. * denotes significant correlation. Respiratory RPE presented as RPEres and Lower Limb RPE presented as RPEmus.

4.4 Sensitivity of Differential RPE

The next section of results examines the sensitivity of differential RPE. This includes the varying volume and intensity of training under two different conditions, where trainings were found to be most variable. This was done by investigating the differences with the two most prevalent training schedules, a four-day lead in and a two-day lead in. Centred on MD-2 as it is common in both timelines, these specific days provided the largest volume of data.

Bar charts (Figures 8-11) are used to compare the median overall and differential RPE on two separate 'speed' themed training days, along with mean GPS measures included on the secondary axis. The speed session found within the two-day lead in (79 minutes in duration) involved a smaller number of players who were not involved in the match the previous day. These players therefore had the previous day off, certain players may have completed sprints after the match, however, this was not recorded. The speed session found within the four-day lead in (97 minutes in duration) involved all available players.

Under the two conditions, lower limb RPE was perceived to be significantly greater for the speed session found within the two day lead in comparison to the four day lead in. Overall and respiratory RPE showed no significant differences between the two conditions. There were however certain GPS outputs including; High Speed Running, Sprint Distance and Accelerations which were found to be significantly greater for speed day within the four-day lead in.

The intensity of training based on high speed running (distance covered between 21–24 km/hr) and high accelerations (3-4 $m.s^{-2}$) were found to be significantly greater for the speed day during the four day lead in, 165.7 km/hr vs 23.4 km/hr, p=0.00 and 16.1 $m.s^{-2}$ vs 8.4 $m.s^{-2}$, p=0.00, respectively. Distance per minute was similar over both training sessions. The speed day found within the two day lead in was 57.8 m/min. The speed day found within the four day lead was 58.3 m/min.

The volume of training was found to be significantly greater for the speed day during the two day lead in (6131.7 m) in comparison to four day lead in (5672 m), p=0.03.

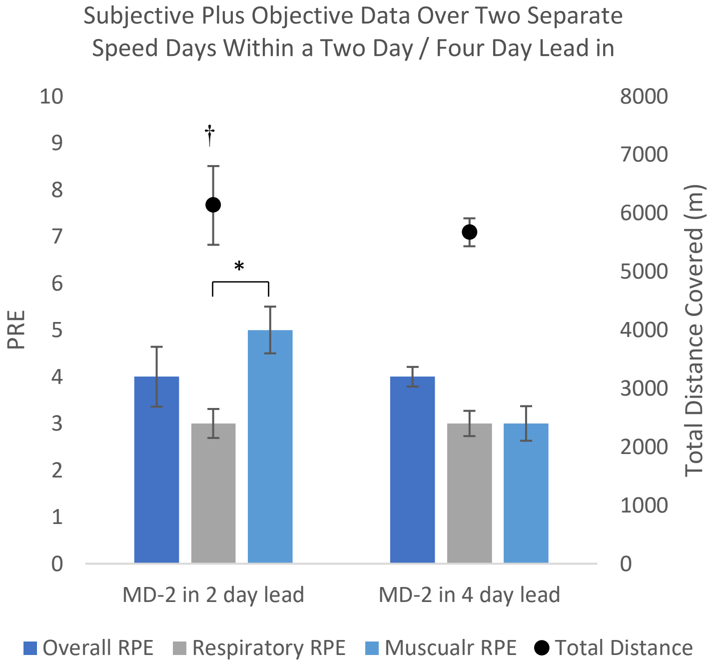


Figure 8: Bar chart representing overall and differential RPE, plus Total distance data for MD-2 found within a two day lead in and a four day lead in. * denotes significant difference in differential RPE measures. † denotes significant difference in external loads between the two training sessions. For all tests the significance level was set at $P \leq 0.05$.

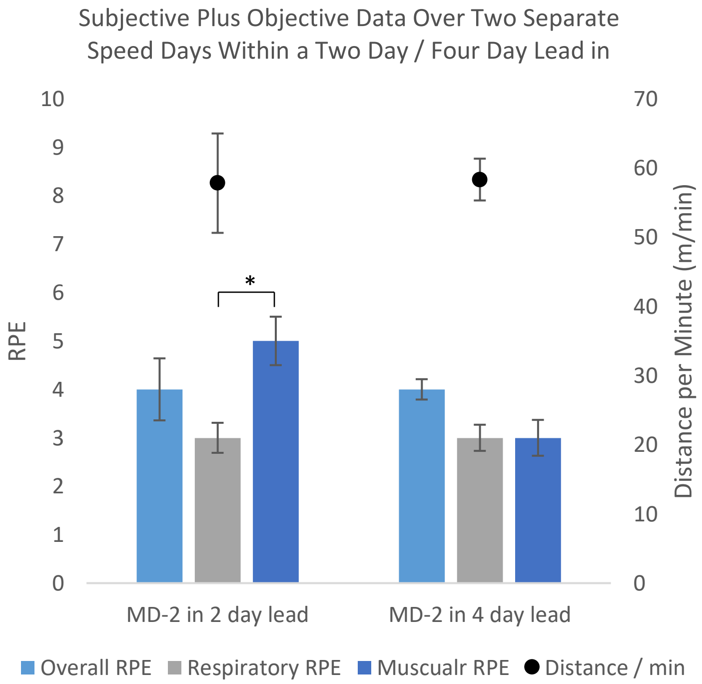


Figure 9: Bar chart representing overall and differential RPE, plus distance per minute data for MD-2 found within a two day lead in and a four day lead in. * denotes significant difference in differential RPE measures. For all tests the significance level was set at $P \leq 0.05$.

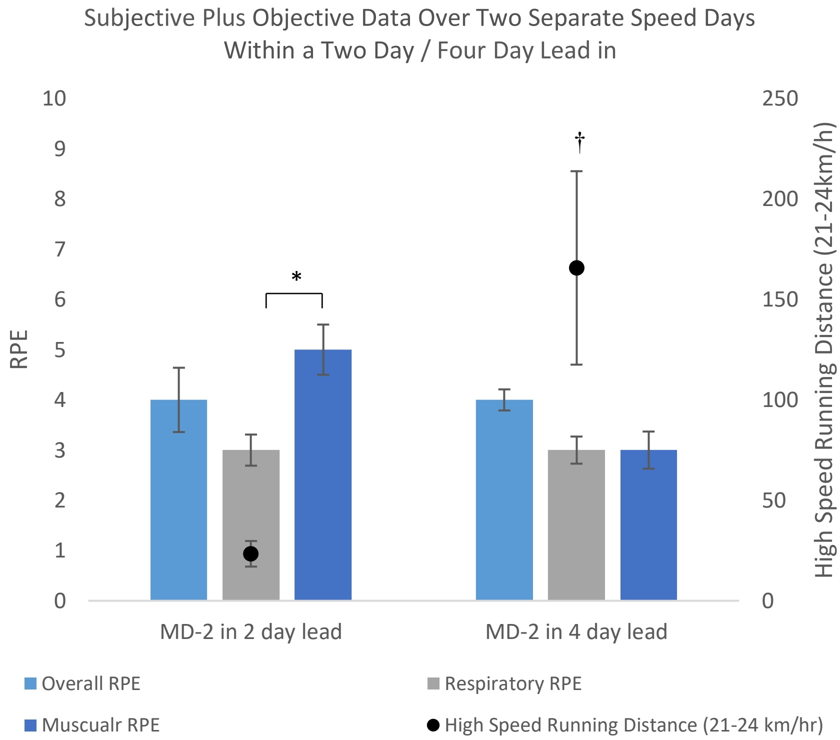


Figure 10: Bar chart representing overall and differential RPE, plus high speed running data for MD-2 found within a two day lead in and a four day lead in. * denotes significant difference in differential RPE measures. † denotes significant difference in external loads between the two training sessions. For all tests the significance level was set at $P \leq 0.05$.

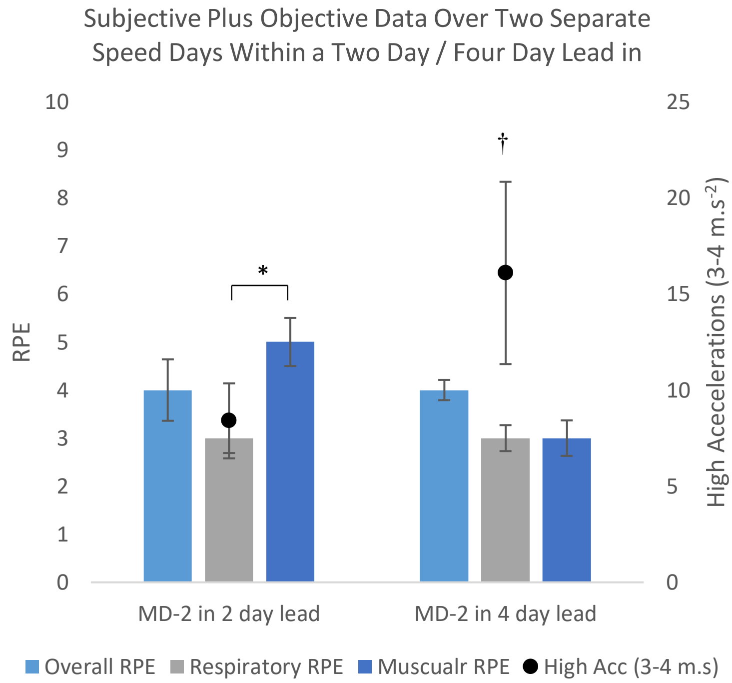


Figure 11: Bar chart representing overall and differential RPE, plus Acceleration data for MD-2 found within a two day lead in and a four day lead in. * denotes significant difference in differential RPE measures. † denotes significant difference in external loads between the two training sessions. For all tests the significance level was set at $P \leq 0.05$.

4.5 Specificity of Differential RPE

The last section of results includes data from individual players in order to analyse the specificity of overall and differential RPE. These players were selected primarily on the basis that they presented the best attendance throughout the data collection phase. The players attended all of the same training sessions (over 80% of all training sessions recorded). Players were numbered randomly one, two and three for confidentiality and identification purposes. The median overall and differential RPE and mean GPS and HR measures for each individual, over the four main training days, are presented in Table 6. Following this, box plots were created to display the inter-individual differences presented over specific training days.

As noted previously, when data is gathered for the team as a whole, an obvious training load pattern is observed. However, when broken down to investigate individual response, the typical training load pattern is not always seen. Player 2 provides their highest rating on MD–4, this is followed by a gradual downward trend towards to the lowest rating on MD–1, this trend is seen for all ratings measured. Player 2 generally rates all sessions higher compared to players 1 and 3. On MD-4, player 2 rates the session significantly higher for overall and respiratory RPE and rates lower limb RPE significantly greater on MD–3.

Individual Training Load Measurements

Training Load Variable	MD -4	MD - 3	MD - 2	MD – 1
Player 1				
Overall RPE	5 ± 0.7	5.5± 0.4	3.5 ± 0.3	2 ± 0.7
Respiratory RPE	4 ± 0.4	5 ± 0.8	3 ± 0.2	2 ± 0.7
Lower Limb RPE	5 ± 1.5	4.5 ±0.8	3.5 ± 0.4	2 ± 0.6
Total Distance (m)	6062.7 ± 430.6	6010.1 ± 843.9	5614.5 ± 304.4	2574.0 ± 837.8
Distance / min (m/min)	66.3 ± 7.6	65.6 ± 8.9	61.6 ± 6.16	40.8 ± 14.1
High Speed Running (21–24km/hr)	12.7 ± 2.1	207.8 ± 161.6	85.1 ± 17.3	9.0 ± 11.1
Sprint Distance (>24km/hr)	0.0 ± 0.0	46.7 ± 64.1	17.3 ± 34.7	0.20 ± 0.5
High Accelerations (3 -4 $m.s^{-2}$)	4.0 ± 1.0	4.3 ± 2.4	7.3 ± 6.7	2.2 ± 2.8
High Decelerations (3 -4 $m.s^{-2}$)	12.7 ± 4.04	11.50 ± 5.1	13.8 ± 4.1	2.2 ± 2.2
High Intensity time (minutes >85%HR Max)	36.0 ± 21.2	24.0 ± 23.3	6.5 ± 5.3	0.9 ± 1.4
Player 2				
Overall RPE	7 ± 0.4	6.5 ± 0.6	4 ± 0.3	2 ± 0.6
Respiratory RPE	7 ± 0.4	5.5 ± 0.6	3 ± 0.4	2 ± 0.6
Lower Limb RPE	7 ± 0.7	6.5 ± 0.8	3.5 ± 0.3	2 ± 0.6
Total Distance (m)	5943 ± 684.1	7649.3 ± 241.3	5472.3 ± 416.2	2533.3 ± 714.4
Distance / min (m/min)	65.3 ± 9.6	75.8 ± 11.6	60.5 ± 10.2	39.3 ± 10.2
High Speed Running (21–24km/hr)	12.9 ± 6.5	263.8 ± 289.6	55.8 ± 44.03	5.8 ± 4.2
Sprint Distance (>24km/hr)	0.0 ± 0.0	44.25 ± 48.4	5.00 ± 6.2	0.40 ± 0.9
High Accelerations (3 -4 $m.s^{-2}$)	3.8 ±0.6	4.3 ± 3.3	5.7 ± 4.0	3.6 ± 2.5
High Decelerations (3 -4 $m.s^{-2}$)	7.8 ± 1.2	15.0 ± 6.6	12.67 ± 5.5	3.0 ± 3.7
High Intensity time (minutes >85% HR Max)	25.0 ±11.3	26.8 ± 1.9	19.7 ± 11.3	3.2 ± 3.6
Player 3				
Overall RPE	5 ± 1.1	5 ± 0.3	5 ± 0.4	1.5 ± 0.4
Respiratory RPE	3 ± 0.8	4 ± 0.8	4 ± 0.4	1 ± 0.3
Lower Limb RPE	6 ± 1.1	3.5 ± 0.6	4 ± 0.7	1.5 ± 0.4
Total Distance (m)	5627 ± 605.02	7144.9 ± 1518	5601.3 ± 660.8	2343.7 ± 710.7
Distance / min (m/min)	60.1 ± 5.9	70.3 ± 14.0	68.3 ± 10.7	37.22 ± 13.4
High Speed Running (21–24km/hr)	23.4 ± 22.3	233.8 ± 157.1	90.7 ± 39.3	11.0 ± 8.9
Sprint Distance (>24km/hr)	1.4 ± 1.5	19.3 ± 31.3	4.9 ± 3.5	1.5 ± 3.0
High Accelerations (3 -4 $m.s^{-2}$)	6.3 ± 7.6	6.3 ± 5.8	12.0 ± 8.0	6.8 ± 1.7
High Decelerations (3 -4 $m.s^{-2}$)	14.0 ± 3.0	17.5 ± 6.9	14.0 ± 5.3	3.0 ± 3.4
High Intensity time (minutes >85% HR Max)	24.0 ± 8.5	19.5 ± 9.0	23.0 ± 9.5	3.02 ± 3.5

Table 6: Median RPE measures and mean external and internal load for Player 1, Player 2 and Player 3 over the four main training days

Individual Subjective Training Load Measurements

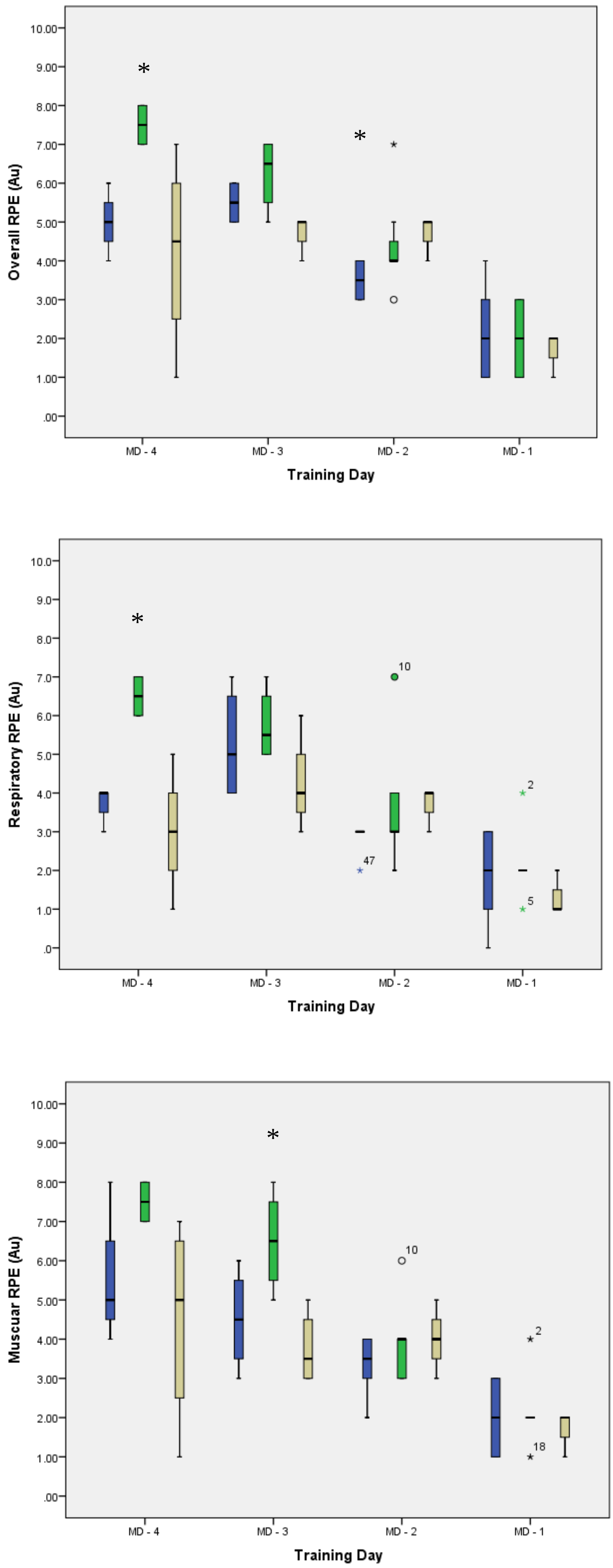


Figure 12: Box Plots representing overall, respiratory and lower limb RPE for each player (Player 1: Blue, Player 2: Green, Player 3: Yellow) over each training day. * denotes significant difference between Player 1, 2 and 3 within each training day.

5. Discussion

The main findings of the present study were that firstly, the four main training days in the lead up to a match display significant objective differences across a given microcycle. Furthermore, the subjective ratings of perceived exertion differ significantly across the training days. It was also found that certain days relate more to either central or peripheral ratings of perceived exertion, depending on the specificity of the training session. However, correlations were weak. RPE is not a single entity and is affected by many factors including previous activity.

5.1 Prescribed Training Loads

Accurate measures of training load are important for team sports and athletes to aid our understanding of the training load strategies, especially for coaching staff, in order to help guide the training and recovery process. The planning and periodisation of training is generally structured around weekly microcycles. Stone et al., (2007), describes microcycles as the most important functional tool in the overall training process. Over the course of data collection phase there are four main training days, monitored via internal and external loads. The daily prescribed sessions are found within a consecutive four day period in the lead up to a match.

When examining the tactical periodisation protocol, it was found that training days were significantly different with regard to the external output, determined by GPS measures. This means trainings were physically different in respect to the prescribed session set out by the coaches. Analysis revealed the overall training session durations were found to have no significant variation over the training week. This may provide evidence that differences in training loads will be determined by specificity of individual trainings rather than time spent on the pitch, as the duration of training can have can affect the athlete's response to training (Foster, et al., 2001). On average the team spent 96 minutes on the field, this is similar to data found by Wrigley, et al., (2012), who noted the mean duration of field training in elite junior soccer players was 104 minutes.

Scheduled training sessions were dependent on match schedule and recovery status of the players. The external training load profile varies with different performance metrics, however, the midweek training session (MD-3) generally produces the greatest external load. On average the total volume of work completed was greatest on MD–3, determined by the GPS metric total distance covered, and on average was measured at 7017.4 ± 112.8 m. This is similar for the intensity of training, as the greatest high speed running distance and sprint distance occurred on MD–3 (249.8 ± 47.5m and 49.6 ± 47.5m, respectively). This was significantly increased from the previous training session (MD–4). This differs from external loads found in the literature (Martin-Garcia, et al., 2018), which notes the total distance covered during training by a Spanish elite, reserve football team were 5828.5 ± 1060.6m, similar to the current study the greatest volume if work was found to be on MD-3. The high speed running distance (>19.8 km/hr) of training in Martin-Garcia's study (228.6 ± 121.8m) was similar to that of the current study, however was greatest on MD-4, there is a similar finding with regard to sprint distance.

This is followed by an obvious taper towards the match, with MD-1 producing significantly lower loads than previous training sessions. This unloading process is similar to that found in previous research (Malone, et al., 2014; Los Acros, et al., 2017; Martin-Garcia, et al., 2018). It is set out by coaches in order to limit fatigue leading into a match, providing optimal conditions for the athlete before a competitive match. Unlike the current study, however, Malone, et al. (2015), did not observe differences across previous remaining training days. This may be due to the different calibre of players and specificity of training sessions. The importance of training load variation is highlighted, as previous research has suggested that lack of variation over a period of time may lead to training monotony and strain and fail to elicit further adaptions (Foster, 2001). As well as the physiological impact, this can also lead to negative psychological effects, as a repetitive nature in training may lead to performance staleness. Overall, this would lead to ineffective training sessions and lack of performance benefits for individual players and the team as a whole.

Within the typical four day lead in microcycle, we observed clear evidence of training periodisation. Total distance covered and high speed running was greatest on MD-3 (7535.3 ± 897.1m and 293 ± 66.5km/hr, respectively), and displayed progressive daily reductions in external load in the lead up to the match day. In comparison to previous work, the training load data is in agreement with previous literature, specifically MD-3 which shows similar training load outcomes (Malone, 2014). However, the training load data for the remaining days in the current study was lower than that previously reported by Stevens, et al., (2017). This may be due to the different level and status of players, within the current study players were on average 4 years younger compared to players in the study by Stevens.

There is a similar trend when internal measures were used to monitor training load. The overall RPE increased from MD–4 to MD–3 followed by a gradual decrease towards the match day. This is in agreement with results found by Impellizzeri, et al., (2005), where RPE based internal load increased to mid-week then tapered in the lead up to the match. This differs however, form research by Wrigley, et al., (2012), who noted RPE based training load was greatest at the beginning of the week, followed by a slight decrease in the lead up to the match.

Both the internal and external differences seen across training days provides evidence that training days differ with regard to the session prescribed by coaches. Overall, in comparison with elite football players, it would appear that the training loads applied in the current study, both internal and external, falls within the boundaries of what has previously been observed (Wrigley, et al., 2012; Impellizzeri, et al., 2005; Malone, et al., 2014).

5.2 Differential Ratings of Perceived Exertion

As noted above there were significant differences in internal loads across the four day lead in. However, differential RPE could enhance the internal load monitoring process, discriminating between central and peripheral perceived exertion. The main focus of this study was to validate the use of differential RPE as an additional method when monitoring training load and to investigate how it is affected by the tactical periodisation protocol.

When using differential RPE to monitor internal training load it was found that on certain training days there are significant differences between respiratory and lower limb ratings (Figure 6). Differential RPE may provide a better understanding of the stress associated with training sessions and overcome the limitations of the standard single gestalt measure. Differential RPE distinguishes between the central and peripheral feelings of effort and is said to be a useful addition to the training load monitoring process within team sports in general. In rugby union, McLaren, et al., (2016b), found moderate to large between protocol differences between perceived ratings of breathlessness and leg muscle exertion both within and between training modes.

The application of differential RPE is most prominently shown within a typical four-day lead in, following the tactical periodisation protocol. There are significant differences between respiratory RPE and lower limb RPE on MD–4 and MD–3. Throughout the four day lead in there is a clear training load profile observed during the most representative week

(Figure 6). This includes four training sessions in the lead up to one official competitive match. The training week begins with MD–4, post a rest day and recovery session. Training load is then built up to a mid-week peak on MD–3 and subsequently decreases from MD–2 to MD-1. A similar training schedule was observed by Los Acros, et al., (2014, 2017), when examining internal training load during a typical microcycle. They observed variations in respiratory and lower limb muscular RPE across the competition period, although, these variations were limited (Los Acros, et al., 2017). Within the current study the significant differences in differential RPE noted across the training days, were consistent with the significant differences in external load across those days found within previous literature.

In the current study there were variations found between lower limb and respiratory training loads across the week. Within the typical microcycle, we found statistical differences between respiratory and lower limb RPE during the most demanding sessions located mid-week (MD-4 and MD–3). With lower limb ratings significantly greater than respiratory on MD–4. This may be a reflection of the prescribed session set out by coaching staff, as MD–4 is said to be 'strength' session. This is a conditioning phase involving greater eccentric loading and multidirectional movements. When comparing the relationship between internal and external loads, on MD-4, Spearman rank correlations (Figure 7) show weak non-significant correlations between GPS variables and differential RPE. The scatterplots display a range of RPE measures. However, lower limb ratings are seen towards the upper end of the scale compared to respiratory ratings with regard to the volume and intensity of training sessions on MD-4.

The greater lower limb ratings may in part be due to residual fatigue from the previous match. Los Acros, et al., (2014), found that players at the end of a strenuous competitive match had higher perception of strain from working muscles and joints compared to cardiovascular and central functions. This can be due to the physiological changes that occur during the match and have the potential to produce muscle damage. The repetitive changes in direction, accelerations and decelerations throughout a football match can induce muscle damage and lead to an inflammatory response (McCall, et al., 2012). Studies have found players have reduced glycogen stores at the end of matches (Asp, et al., 1998). It was noted that this was still the case two days after eccentric exercise. As MD-4 is two days post-match, it may partly explain the significantly greater lower limb RPE compared to respiratory RPE for that training in the current study. This demonstrates the importance of the careful monitoring of overall and differential RPE in order to avoid residual fatigue and minimise the effect of training related injuries (Gabbett, 2016).

Internal training load peaks mid-week (MD-3), providing the highest overall, respiratory and lower limb ratings. Respiratory ratings are significantly greater than lower limb ratings on this day. This follows the prescribed session for MD–3, which is characterised by open spaces, increasing the area per player. This is the heaviest aerobic training session, as players will cover greater overall distances, including high speed running and sprint distances. Positive, albeit still relatively weak correlations, are seen for differential RPE and locomotive variables (total distance covered, high speed running distance and sprint distance). Additionally, a significant positive correlation is seen for respiratory ratings and high speed running and sprint distance on this day (Figure 7). This provides evidence contributing to the validity and usefulness of differential RPE measures. This association seems logical as the greater muscle contraction during locomotor activities is dependent on the ability to provide oxygen to the working muscles, therefore, increasing oxygen consumption and cardiac output (Vanrenterghem, et al., 2017).

It has been previously noted that higher respiratory ratings are in agreement with higher heart rates and maximal oxygen consumption (McLaren, et al., 2016a). However, when the relationship between respiratory RPE and high intensity time is compared for MD-3 in the current study no significant correlation is observed. This may be caused by individual differences in heart rate response and the bands at which the heart rate zones are set. In the current study measuring heart rate became difficult as not all players consistently wore their heart rate monitor on their skin for optimal readings.

Fixture congestion leading to bi-weekly matches meant the team only had two days between their matches, therefore, MD-2 sessions become part of the recovery process for players who competed in the match. This two-day lead in will alter the structure, volume and intensity of training compared to a four day or even three day lead in. This may be a reason for the lack of correlation and even negative correlations seen within MD-2 for differential RPE and GPS / HR variables (Figure 7). Training sessions that fall closer to match become less prescriptive as more technical and tactical aspects are trained. This is where positional demands can have a greater effect on ratings of perceived exertion. The oppositional demands can also alter how these training sessions are carried out. For these reason speed days are not as specific as previous training days.

5.3 Sensitivity of Ratings

The analysis of differential RPE over two specific training days show ratings are sensitive to many factors and not only external load. Figures 8-11 shows two training sessions that are notionally the same; both represented as ‘speed’, characterised by quick movements and change of direction with reduced area per player. Both days are said to be based on the same characteristics, although found within two separate timelines, this demonstrates that the external load applied during a two-day lead in differs from a four-day lead in. This also demonstrates the possibility that differential RPE does not recognise the session but how that session fits into a microcycle. The disparity between speed days, with examples shown in Figures 8-11 may be a reason for the weak and negative correlations seen with scatterplots on this training day (Figure 7).

The differences may be due to those who participated in each training session and the consequence of different previous activities. There is evidence that ratings of perceived exertion capture a range of psychophysiological sensations and are affected by previous actions both physically and mentally (Impellizzeri, et al., 2005). Although certain external activities produce greater loads, the exertion perceived was significantly less. Correlations examining the relationship between the ratings of perceived exertion and the external measures were noted to be weak and non significant, providing evidence that differential RPE is affected by multiple factors.

This demonstrates that ratings of perceived exertion are not solely dependent on external load. The psychological basis of players not selected for the match may have led them to rate their training as difficult while other teammates recovered from the match. Brink, et al., (2014), investigated and compared the perceptions of training dose between soccer coaches and players. In general, they found that players perceived sessions as harder than what was intended by coaches. The sessions in the lead up to the match become less prescriptive, although given the same title they are not as specific as previous sessions. These sessions become more dependent on the fixture schedule, opposition strategy and positional demands. The activities and perception may also be a reflection of the different backgrounds of players coming into the training session. Players are selected by their coaches for matches every week, they may therefore feel that they need to convince their coach of their superior qualities compared to teammates, this may lead to alterations in the RPE.

In addition to this, in the current study, there is a known awareness connected within the typical four-day lead in within the club. Players are aware of the unloading process in the 48 hours that lead up to the match. This may therefore entice athletes to rate the session as easy by giving a certain RPE score as they feel that this is what is expected of them. This contrasts with Brink's study as they used various periodisation cycles, this therefore, may have led to coaches and players being less aware of the comparison between their perceptions.

Hutchinson and Tenenbaum (2006), noted that during exercise participants can also differentiate between sensory discriminative, motivational affective and cognitive evaluation sensations during sustained physical tasks. This could provide reason for further differentiation of RPE into cognitive / technical demand. Alternatively, the use of questionnaires (Profile of Mood States POMS, Recovery-Stress Questionnaire for athletes REST-Q-Sport) can gain further subjective information on the psychological state of the athlete. The current data suggest that internal load measured, as subjective differential RPE, is a sensitive rating and is influenced by many factors including previous activity. It is transferable across different circumstances and so sensitive to change. This signifies the complex nature of differential RPE yet demonstrates its importance when monitoring training.

As well as previous activities and psychological state of the athletes, elite youth athletes face a range of external pressures. For example, nutritional status, different social pressures and distractions may predispose athletes to a greater level of stress, meaning athlete's RPE may not be a direct representation if the training session (Scantlebury, et al., 2018). A commonly reported symptom of overtraining is mood disturbances and increased perception of effort with training and competition (Kentta & Hassmen, 1998).

For certain GPS variables however, it was found that greater external load leads to greater rating of perceived exertion. When examining total distance, a significantly greater distance covered was measured by a significantly greater rate of exertion when comparing the two training days; this is similar to high intensity time. This provides evidence of the importance of volume of training and how it can affect response. Previous research found that total distance covered has the strongest association with internal load in response to training and match play (McLaren, at al., 2018), based on the delivery of oxygen and substrates to the peripheral system. It is noted that a higher lower limb rating compared to respiratory was found on both training days, possibly due to increased strength endurance, in agreement with previous literature in that local RPE is generally higher than central (Hutchinson & Tenenbaum, 2006; Borg, et al., 2010). This also corresponds with the tactical periodisation protocol as speed days put greater strain on the muscles and tendons due to the higher number of accelerations and decelerations.

This section provides evidence that teams should not use RPE values without understanding the objective measures. Subjective and objective measures should be used in combination when monitoring training load. This will provide a holistic approach in understanding the training effects. Due to the evidence of the psychological impact on differential RPE, we went on to look at individual case studies to further examine the sensitivity and specificity of differential RPE.

5.4 Specificity of Differential RPE

As well as differential RPE used for the team as a whole, it is also of significant importance when monitoring athletes on an individual basis. Although external loads may be similar, players may perceive the stimuli differently. This can provide practitioners and coaches with important information on player fitness levels and may lead to extra assessment in order to avoid injury. Figure 12 demonstrates the inter-individual and intra-individual differences presented during each training day. When training load data is analysed for the team, there is a clear pattern observed (Figure 6). Within this typical microcycle, the pattern shows how RPE peaks mid-week (MD-3) then follows a gradual, yet significant taper towards the match. When examining RPE based training load on an individual basis, it was noted that this same pattern is not always followed. There is a clear range of results for each player, especially at the beginning of the microcycle. This shows the difference between respiratory and lower limb RPE on an individual basis and how it is affected the type of training. Therefore, the best way to see how you can use differential RPE as a practitioner is to look at specific case studies. This encourages practitioners to look at data in different ways.

Figure 12 shows how Player 2 rates overall and differential RPE greatest on MD-4, with overall and respiratory RPE being significantly greater than Player 1 and Player 3. In general, Player 2 was found to rate training sessions harder compared to playing counterparts. This may be in relation to a lower level of fitness experienced by the player. However, without fitness or muscular testing it cannot be conclusively said that the higher RPE's relate to lower levels of fitness. To gain further information in the status of the players, it could be beneficial for practitioners to combine match data and take into account positional differences. Player

2 perceives MD-4 session to be the hardest, however, external parameters (Table 3) do not significantly exceed those of the other two players being analysed. There may be outward factors which lead to the greater ratings of exertion by Player 2, such as poor sleep patterns or other lifestyle choices. However, to determine accurately if this is the case Wellness Scores would need to be collected for each athlete.

It has been found in the literature that higher internal training loads are associated with greater injury rates in team sport athletes (Anderson, et al., 2013; Gabbett, 2004; Gabbett, 2017). Gabbett (2004), found a strong relationship between training loads derived from session RPE and training injury rates across a playing season in semi-professional rugby league players. It is acknowledged that this study was with athletes that were of a higher impact sport compared to football. However, this demonstrates the importance of the careful monitoring of training loads on an individual basis, as a high individual RPE compared to teammates may warrant investigation in order to avoid injury.

It is also acknowledged that questions remained the same after every training session. Questions did not influence players to take into consideration their previous game. This demonstrates that although ratings of perceived exertion are of importance and provide coaches and practitioners with vital results in response to exercise, in order to fully understand ratings, it is advised that they are accompanied with external measures.

Ratings of perceived exertion are subjective measures which differ based on each individual and provide a more sensitive value on training load. Using differential ratings gives the coaches and medical staff further insight into psychophysiological state of the athlete and how this is affecting throughout the training periodisation protocol.

5.5 Limitations

A limitation to the study was the fact that it was only carried out over a short period of the season, omitting the important phases, such as the pre-season period. This only allows a snapshot of what is occurring within the team therefore is not representative of the whole season and how perceptions change over that time period. Due to the unpredictability of this field research and match scheduling, the number of training days were not consistent. This led to only a very small number of four-day lead-in periods (n=2), which was one of the main focuses of the study. Adverse weather conditions also prevented outdoor training for a period of time, restricting GPS use and cancellation of fixtures, therefore later match rescheduling. This again altered the training structure. Additionally, as some players moved between the development squad and the first team the number of participants taking part in each training session varied throughout the course of the study. This also occurred as a result of injuries over the course of the study. These factors demonstrate the difficulties that can arise when collecting data within an applied setting. Additionally, in this uncontrolled setting we could not monitor what players had done outside regular training hours. Some players went to gym after training, lower body workout may have influenced lower limb ratings of subsequent training sessions.

The absence of match data within the study restricts the comparisons of how exactly match play affects the training sessions that follow. Additionally, the data is not positional specific, as this could further differentiate the specificity of training sessions and how certain positions may directly or indirectly affect differential RPE. It can also provide coaches with a view of the demands of positions and how trainings can be altered to better suit specific positional needs.

The use of GPS as a validation tool has its limitations, as there is reduced levels of validity and reliability at high speeds (Johnston, et al., 2014). Within the current study there were generic pre-set absolute speed thresholds used, with high speed running set as 21-24 km/hr. To overcome this, thresholds relative to individual speeds may be used, based on maximal speed tests. The acceleration and deceleration data were based on pre-set absolute thresholds set by the club.

Additional tools may have been helpful to validate differential RPE, such as biological factors of blood lactate level or direct indicators of muscle damage such as Creatine Kinase (CK) enzyme level, as muscle damage and associated inflammation contributes to fatigue after matches (McCall, et al., 2012). Results show that various elements, including non-load related factors can influence ratings of perceived exertion, therefore, additional measurements may aid differential RPE results. The addition of wellness questionnaires could be a beneficial tool incorporated by the club to gain further information on the state of the athlete. Monitoring athlete’s wellness often covers a range of topics, such as how they slept the previous night and their current stress level. This may lead to some explanation as to why certain individuals rate training session higher when external GPS parameters have not been shown to exceed that of their teammates.

To be fully confident when examining external load, information on the specific format of training such as information on training drills, duration and parameters becomes a useful tool.

6. Practical Implications and Conclusion

Accurate monitoring of training load enhances knowledge of training response, aiding the training programme structure and design. The use of RPE provides an extra opportunity for communication between players and coaches / support staff. While overall RPE has been found to be a valid and reliable measure when monitoring internal training load, it has the potential to misinterpret the internal load of specific training sessions. Distinguishing between central and peripheral feelings of exertion provides an extra dimension to the training load monitoring and recovery process, as differential RPE can enhance the sensitivity and specificity of internal load measurement.

This study looked at the relationship between differential RPE and external loads that occurred during the four main training days. Results suggest that there is a significant relationship with certain GPS variables with either respiratory or lower limb RPE on certain training days. Therefore, providing extra information on aspects of training and how individuals respond. Such information may highlight any injury risks that may be imminent.

In conclusion, there are significant differences between respiratory and lower limb, muscular RPE during taxing training sessions in the lead up to a match. The data suggest that scores represent distinct sensory inputs that coincide with certain training sessions and their characteristics, providing a more accurate evaluation of imposed training load. This will allow sports scientists, coaches and practitioners the opportunity to gain extra information on how athletes respond to their training sessions during the tactical periodisation protocol. Highlighting weekly training fluctuations of central, respiratory RPE and peripheral, lower limb muscular RPE. However, data also suggest that in order to gain a full picture of how training affects an individual, differential RPE measures should be used alongside external measures. This provides training load data for the team and on an individual basis, offering important information on the psychophysiological state of the athlete, their training status and predicting performance and/or injury. This study can therefore add to the knowledge and supplementation of the ever popular RPE based training load monitoring process and warrants further investigation into the topic in order to understand it more.

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