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Analysis of Heart Rate Monitor Data of Division 1 Male Soccer Players Over the Course of a Season

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ANALYSIS OF HEART RATE MONITOR DATA OF DIVISION 1 MALE SOCCER PLAYERS OVER THE COURSE OF A SEASON

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Abstract

The purpose of the first part of this project was to compare and contrast heart-rate monitoring and session RPE as tools to assess internal training load, specifically in soccer players. Soccer is a physiologically demanding sport due to the many actions required of a player over the course of match. Knowledge of internal training load, or the individual physiological “load” on a player, may help coaches or trainers better understand many components of a players fitness including under-training, over-training, and overall fatigue levels. A heart-rate monitor’s ability to calculate internal training load is primarily based upon the well-established relationship shared among heart-rate and VO_2. Whereas monitoring heart rate to calculate load is typically viewed as an objective measure, session RPE is a subjective measure of internal training load takes into account global intensity of a training session. This method has been demonstrated to maintain a strong reliability with internal training load calculated via heart-rate monitors and is sometimes favored due to its relative ease of use and absence of expensive equipment. To that end, it seems that each method serves as valuable tool to assess the internal training load of a player, but neither are without limitations and those should be considered carefully when deciding upon a method to be used to monitor training loads in soccer athletes.

The purpose of the second portion of this project was to present a case study to design, execute and evaluate the use of heart-rate monitors as a tool for periodization in a Division I Men’s Soccer team across a competitive season. The periodization schedule was created *a priori* and based upon internal training load information gathered from heart-rate monitors and anchored to known periodization goals as well as coach and team-specific goals. Upon analyzing the data it was shown that, throughout the season, scheduled training loads deviated

slightly from the *a priori* periodization schedule but, in large part, were adhered to and tended to yield the desired effect of sustained maintenance of fitness levels. In turn, this seems to have impacted the team 'on-the-pitch' as the team went on to have one of the most successful seasons in recent program history. Lessons learned from this case-study analysis should serve to strengthen the coaching staff's knowledge regarding heart-rate monitoring and how to best utilize this method in creating an optimal periodization schedule. As the review of literature and case study suggest, the knowledge of internal training load can be a useful tool to a coach or trainer seeking optimize a team or player's potential and ultimately, the decision regarding the method of acquirement and use of internal training load, should be made upon the individual necessities/desires of the coach or trainer.

Introduction

Enjoyed by men, women and children of all ages, soccer is the world's most popular sport (Bangsbo, 1994). This, presumably, is due to the popularity of soccer at the recreational to the professional level. The nature of soccer is physically demanding due to the high number of sprints, changes of direction, jumps, tackles and technical actions including dribbling, shooting and passing (Nédélec, McCall, Carling, Legall, Berthoin, & Dupont, 2012). Throughout a soccer game, players perform about 1,000 of these different activities (Reilly, & Thomas, 1976). This amounts to a change in some sort of physical or tactical activity occurring approximately every six seconds. Moreover, an examination of field players reveals the break-down of the movements during a match consists of approximately 36% jogging, 24% walking, 20% cruising, 11% sprinting, 7% back pedaling with only 2% of the match actually with the ball (Reilly, & Thomas, 1976). Considering the variety of physical demands demanded from a player throughout a match it seems that it would it would, in turn, elicit a variety of energetic demands contributing to overall energy expenditure (Reily, 1997).

During a typical match, top-level players cover approximately 11 km (Bangsbo, 1994; Bangsbo, Nørregaard, & Thorsoe, 1991; Mohr, Krustrup, & Bangsbo, 2003). However, this is a broad generalization as not all players have the same responsibilities and, thus, it seems an important factor that contributes to ground covered is position. Indeed, research has shown that midfielders, outside-backs and attackers all cover greater distances than central defenders (Mohr et al., 2003). Of all the positions, midfielders tend to cover, on average, 10% more distance than defenders and forwards (Bangsbo et al., 1991). Additionally these distances are 5% greater for top-level players playing for higher ranked International Federation of Association Football

(FIFA) national teams compared to the distances covered by moderate-level soccer players playing for higher ranked FIFA national teams (Mohr et al., 2003).

The vast majority of activity comprising the distance covered in a game is submaximal, usually within the range of low to moderate intensity and is largely aerobic in nature (Reilly, & Thomas, 1976; Reily, 1997). However, frequent bouts of sprints and high-intensity efforts incorporate an anaerobic component to a match (Reily, 1997). Therefore the need to maximize the less frequent periods of high-intensity activity becomes increasingly important as these periods elicit higher energy costs (Bangsbo, 1994). Match analyses reveal a discrepancy in the engagement of high-intensity between top-level professional players compared to lower-level professional players. Top-class players had a 28% greater amount of high-intensity running in a match than moderate-level players (Mohr et al., 2003). The differences among elite players and moderate players underscore the importance of an athletes' physical capacity. Not only has the ability to perform more high-intensity exercises been shown to increase field production during a match (Bangsbo, Mohr, & Krustrup, 2006), it will also influence technical and tactical choices and is thought to mitigate injury (Stølen, Chamari, Castagna, & Wisløff, 2005). Additionally, increases in VO_2max (i.e., aerobic capacity) tends to significantly increase the number of sprints, involvement with the ball and distance covered throughout a game (Helgerud, Engen, Wisloff, & Hoff, 2001).

It seems, then, that both a player's aerobic and anaerobic capacity are crucial components of on-field production. To accommodate increases both capacities, a coach or trainer may desire to understand the physiological stress of the player during training to ensure maximum production during matches. In an effort to monitor player workload and to maximize player potential, a frequent unit of measurement employed is training load. Training load is typically regarded as the product of the volume and the intensity of the training (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). Impellizzeri et al. (2004) note that there are two types of loads; external and internal training loads. The external training load is the load prescribed by the coaches, such as their plan for the individual training session. The external training load should, in theory, be nearly identical for every player since they all complete the same drills or games that make up the coach's training session. Conversely, the relative physiological stress that an athlete incurs as a result of this training session is termed the internal training load (Impellizzeri et al., 2004). There are two popular manners in which a coach or trainer may monitor internal training load; the use of heart-rate monitoring and/or the use psychological inventories. Some prefer the quantification of internal training load based off of heart rate monitoring due to heart rate's known linear relationship with VO_2 during most exercise sessions (Achten, & JeuKendrup, 2003). For reasons to be discussed in the following sections, others may prefer to monitor internal workload via the use of the session RPE scale (Foster et al., 2001). When choosing a method to monitor internal training load, the validity and practicality of the parameter chosen must be considered when measuring the intensity of exercise **(**Achten, & JeuKendrup, 2003). Therefore, the primary aim of this part of this project is to assess the utility as well as potential limitations related to methods of monitoring internal training load.

Heart Rate Monitoring: Why It Works

Certainly at rest, a heart rate monitor seems to be a valid measure of tracking heart rate changes, as it closely corresponds to readings from an ECG (Goodie, Larkin, & Schauss, 2000). However heart rate monitors are often employed outside the laboratory to monitor training and assist in the planning of training intensities **(**Achten, & JeuKendrup, 2003). In general, heart rate has been demonstrated to have acceptable levels of reliability as a measure of exercise intensity

(3.9% CV, 0.863% ICC) (Wallace, Slattery, Impellizzeri, Coutts, & Campus, 2013). This mode of heart rate measurement to calculate exercise intensity using a portable heart rate monitor as a tool is based upon two premises. The first being a proposed linear relationship between heart rate and VO_2 and the second being that heart rate is an indirect measure of energy expenditure.

Beginning with heart rate's association with VO_2, it has been proposed that there exists a linear relationship between heart rate, work-rate and oxygen uptake (Astrand and Rodahl, 1986). More specifically, internal training load is most often measured by heart rate due to heart rate's known linear relationship to VO_2 (Impellizzeri et al., 2004). The heart rate-VO_2 relationship is characterized by an elevation in heart rate as a reflection of the fractional utilization of maximum oxygen consumption when performing vigorous activity (Morton, Fitz-Clarke, & Banister, 1990). For this reason, heart rate monitors provide a practical measure of oxygen consumption (Morton, Fitz-Clarke, & Banister, 1990). It is important to note that this relationship is exponential in nature (Morton, Fitz-Clarke, & Banister, 1990). Additionally, the relationship between heart rate and VO_2 is an individual relationship and should therefore be determined on an individual basis **(**Achten, & JeuKendrup, 2003).

Since the direct measurement of oxygen consumption using a metabolic cart during soccer trainings is often impractical, a more reliable manner to measure the aerobic contribution to energy expenditure is to monitor heart rate during training (Drust, Reilly, & Cable, 2000). In an unpublished study, researchers compared VO_2 estimated from heart rate and VO_2 as measured by a portable metabolic cart (Impellizzeri et al., 2005). The experiment was carried out during a six-minute small group-play (five versus five with a goalkeeper and unlimited touches) with 15 semi-professional soccer players (Impellizzeri et al., 2005). Results showed no significant differences between average predicted [47.6 (5.5) ml kg^{-1} min^{-1}] and measured [49.8 (4.7) ml kg^{-}

$^{1}min^{-1}$] VO_2 during non-steady-state intermittent exercise (Impellizzeri et al., 2005). These results were obtained using Bland and Altman's limits of agreement and found a non-significant bias (-1.6 ml $kg^{-1}min^{-1}$; $P > 0.05$) (Impellizzeri et al., 2005). Heart rate's linear relationship with VO_2 occurs at steady-state, submaximal levels (Impellizzeri, Rampinini, & Marcora, 2005). This would suggest that heart rate monitoring is a viable, simple, and objective manner to quantify aerobic internal training load and prescribe exercise intensity in soccer (Impellizzeri et al., 2005).

The individual heart rate-VO_2 relationship is the primary reason heart rate monitoring can be used to estimate energy expenditure (Drust et al., 2000). The measurement of heart rate during match-play is the most widely employed method of estimating energy expenditure (Reily, 1997). Training within a sport consists of three components; frequency, duration and intensity (Jeukendrup & Diemaen, 1998). Many measures of exercise intensity exist including speed, heart rate, percentage of VO_{2max}, lactate threshold and power output (Jeukendrup & Diemaen, 1998). It has been argued that the best measure of exercise intensity should be determined by the amount of ATP that is hydrolyzed and converted into mechanical energy each minute (Jeukendrup & Diemaen, 1998). In other words, exercise intensity may best be defined as the amount of energy expended each minute to perform a certain task ($kJ \cdot min^{-1}$) (Jeukendrup & Diemaen, 1998). The measurement of energy expenditure in the field has been near impossible as there are a number of practical and theoretical limitations (Jeukendrup & Diemaen, 1998). Therefore, a measure closely related to energy expenditure is required (Jeukendrup & Diemaen, 1998). Exercise intensity may be the easiest method to measure and monitor energy expenditure during exercise (Jeukendrup & Diemaen, 1998). There is little research confirming the ideal exercise intensity for training (Jeukendrup & Diemaen, 1998). In addition to energy expenditure, the measurement of heart rate during training does provide a good estimation of physiological strain (Reily, 1997). Therefore, heart rate monitoring may be an ideal indicator of exercise-induced stress as it better reflects whole-body stress levels (Jeukendrup & Diemaen, 1998). To that end, there have been a number of different models designed to use heart rate measurement during exercise to quantify overall training load in order to better guide training periodization.

Banister's Model of Monitoring Training Load

Based upon the premises that establish heart rate as a valid measure of exercise intensity, there are three proposed methods to calculate internal training load from collected heart rate data. The first of these three methods is Banister's training impulse (i.e., TRIMP). Banister's TRIMP can be quantified in a single term that balances exercise duration and intensity (Impellizzeri et al., 2005). This particular method uses the product of training session duration and average intensity of the training session and a sex-specific coefficient (Impellizzeri et al., 2005). Essentially, Banister's TRIMP is computed based-upon the mean exercise heart rate and duration of the exercise (Bannister, 1991). The specific formulas used for calculations can be found below.

TRIMP (Equation 1)

$$\text{Men: duration (min)} \times (\text{HRex} - \text{HRrest})/(\text{HRmax} - \text{HRrest}) \times 0.64e^{1.92x}$$
$$\text{Women: duration (min)} \times (\text{HRex} - \text{HRrest})/(\text{HRmax} - \text{HRrest}) \times 0.86e^{1.67x}$$

Where $e = 2.712$, $x = (\text{HRex} - \text{HRrest})/(\text{HRmax} - \text{HRrest})$, HRrest = average heart rate during rest, and HRex = average heart rate during exercise (Banister)

There are studies that demonstrate the utility of Banister's TRIMP as reliable measure of internal training load. In professional male soccer players, across 29 exercise sessions Bannister's TRIMP was found to be correlated with player load (r = 0.73) (Scott, Lockie, Knight, Clark, & De Jonge, 2013). Player load was determined as a result of individual player movements and accumulated accelerations (Scott, et al., 2013). Additionally, the total distance covered by each player was found to be positively correlated to Bannister's TRIMP (Scott, et al., 2013). Another study compared the measurement of internal training load on steady-state and interval-type exercise sessions (Wallace et al., 2013). Banister's TRIMP was strongly positively correlated to total VO_2 (Wallace et al., 2013). Additionally, Banister's TRIMP produced significantly lower correlations with total VO_2 compared to measures of heart rate alone when compared with percent VO_{2max} (Wallace et al., 2013). The researchers suggest that these results could indicate that this method could be strong alternative method to quantify training load when external training load is not as clearly defined (Wallace et al., 2013).

Since TRIMP is computed based upon the mean exercise heart rate and duration of the exercise, it becomes a useful tool to measure training load in sports with intensities that are of an intermittent nature such as soccer (Bannister, 1991). The mean or average exercise heart rate is a reflection of the summation of every heart rate data point collected by the heart rate monitors (Bannister, 1991).

Edwards' Model of Monitoring Training Load

Some argue that using mean exercise heart rate is impractical to reflect the demands of long-duration, intermittent exercise such as team sports (Stagno, Thatcher & Van Someren, 2007). Thus, Banister's model has been modified to reflect the use of zones in which heart rate's time spent within each zone is accumulated (Foster et al., 2001). Edwards' method of quantifying training load is viewed as a progression of Bannister's model (Borresen & Lambert, 2008). In Edwards' model, the quantification of internal training load is derived from duration spent within five different heart-rate zones (Edwards, 1993). The zones represent percentages of heart rate max (50%-60%, 60%-70%, 70%-80%, 80%-90%, and 90%-100%). With the use of zones, it is suggested that since zones increase in a linear fashion, they are not reflective of exercise responses above an individual's anaerobic threshold (Wasserman, 1987). Therefore a weighting factor is needed for each zone (Stagno et al., 2007). In Edwards' model the duration in each zone is multiplied by the weighting factor which gives more weight to the higher intensity zones as compared to the lower intensity zones (Edwards, 1993). The product of these calculations is then summated to achieve a final score (Edwards, 1993). The formula used for calculating internal training load using Edwards' model can be found below.

Summated-heart-rate-zones method (Equation 2)

(duration in zone 1 x 1) + (duration in zone 2 x 2) + (duration in zone 3 x 3) + (duration in zone 4 x 4) + (duration in zone 5 x 5)
Where zone 1 = 50% to 60% of maximum heart rate, zone 2 = 60% to 70% HR max, zone 3 = 70% to 80% HR max, zone 4 = 80% to 90% HR_{max}, and zone 5 = 90% to 100% HR max (Edwards, 1993)

In addition to Banister's TRIMP, Edwards' TRIMP was found to have high positive correlations with player load (r = 0.73) and total individual distance covered in professional male soccer players (Scott, et al., 2013).

Lucia's Model of Monitoring Training Load

Lucia's TRIMP is yet a further variation in which there are only three heart-rate zones (zone 1 = below the ventilatory threshold, zone 2 = between the ventilatory threshold and respiratory-compensation point and zone 3 = above the respiratory-compensation point) (Lucia, 2003). The duration spent in each zone is multiplied by a coefficient (*k*) which is relative to each zone (*k* = 1 for zone 1, *k* = 2 for zone 2 and *k* = 3 for zone 3) (Lucia, 2003). These adjusted scores are then summated to acquire internal training load (Lucia, 2003).

Similar to Banister's TRIMP, Lucia's TRIMP has been found to be strongly positively correlated to total VO_2 (Wallace et al., 2013). The researchers suggest that these results could indicate that these two methods could be strong alternative methods to quantify training load when external training load is not as clearly defined (Wallace et al., 2013).

Limitations of Heart Rate Methods

As valid and reliable as these heart rate methods of calculating internal training load may be, they are not without numerous potential limitations. For example, it has been noted that in addition to very low and very high intensities, there are occasions when the relationship becomes non-linear **(**Achten, & JeuKendrup, 2003). For example, during intermittent exercise heart rate responds slowly to changes in work and can take up to 3-5 minutes to adapt to the change in intensity **(**Achten, & JeuKendrup, 2003). Other limitations arise concerning the calculation of internal training load when exercising in an intermittent nature. First, Banister's training impulse or TRIMP method multiplies training session duration by average intensity of the training session and sex-specific coefficient (Impellizzeri et al., 2005). Due to this, the validity of the approach could be weakened in soccer due to soccer's periods of non-steady state exercise including bouts of high-intensity work (Impellizzeri et al., 2005). In fact large differences have been reported in heart rate response between soccer-specific intermittent and steady state protocols (Drust, Reilly, & Cable, 2000). To attempt to explain these differences and explain why TRIMP may not capture these bouts of intermittent exercise, it has been suggested that a greater demand is placed on the cardiovascular system during soccer-specific intermittent exercise as compared to steady-state exercise when performed at the same overall average intensity (Drust, Reilly, & Cable, 2000). Heart rate during high-intensity exercise bouts and the maintenance of a high heart rate during low-intensity recovery are possible explanations for the greater demand on the cardiovascular system during soccer-specific intermittent exercise (Drust, Reilly, & Cable, 2000). Little evidence exists to suggest that there is an increase in physiological strain corresponding to performance of soccer-specific intermittent exercise when compared to steady-state exercise at identical average intensities (Drust, Reilly, & Cable, 2000). However, researchers note a difference in the pattern of physiological responses between intermittent and steady-state soccer-specific exercise (Drust, Reilly, & Cable, 2000). This difference can be attributed to different metabolic processes used to support the exercise activity (Drust, Reilly, & Cable, 2000).

Within steady-state exercise, the physiological strain can be attributed to adenosine triphosphate (ATP) production from anaerobic or aerobic metabolism (Drust, Reilly, & Cable, 2000). During intermittent exercise, physiological strain can be thought to be a result of a change in fiber type recruitment between exercise and recovery intervals (Drust, Reilly, & Cable, 2000). Additionally, a lack of relationship was found between Bannister's TRIMP and changes in vLT (velocity at lactate threshold) and vOBLA (velocity at onset of blood lactate accumulation) (Akubat et al., 2012). In soccer, intermittent exercises were found to significantly alter the heart rate-blood lactate relationship (Helgerud, Engen, Wisloff, & Hoff, 2001). In turn, this would affect the calculations of TRIMP that are derived from the individualized heart rate-blood lactate relationship (Helgerud et al., 2001). This alteration could result in the underestimation of the exercise dose and would require a reduction in time spent during high intensity if a desired TRIMP is to be achieved (Helgerud et al., 2001). Additionally, increases in TRIMP are exponential, which could result in disproportionate increases in total TRIMP (Helgerud et al., 2001). The inability of TRIMP to account for soccer-specific intermittent exercise is important because, as previously stated, frequent bouts of sprints and high-intensity efforts incorporate an anaerobic component to soccer and the energy required of a player (Reily, 1997). Therefore the use of average heart rate to calculate internal training load may not accurately capture the nature of these high-intensity bouts required in soccer.

Other potential limitations with the formulas for calculations of internal training load have been cited. For example, the two methods (Banister and Lucia) of TRIMP have been shown to have low levels of reliability for quantifying internal training load (Banister's TRIMP [15.6% CV, 0.818% ICC] Lucia's TRIMP [10.7% Cv, 0.733% ICC]) (Wallace et al., 2013). These discrepancies between the methods of TRIMP and heart rate may be attributed to the possibility of the weighting factors used to determine TRIMP scores (Wallace et al., 2013). Some research has suggested that TRIMP could possibly give a disproportionate importance to high-intensity exercise and underestimate the effect of training at a low-intensity on over training load (Borresen & Lambert, 2008). The weighting factor in the TRIMP equation is based on a fixed lactate-workload relationship (Borresen & Lambert, 2008). The exponential relationship of workload and lactate may change overtime with training (Borresen & Lambert, 2008). Therefore the weighting factor may not be appropriate for quantifying training load in individuals who differ in their training status (Borresen & Lambert, 2008).

Another limitation of using zones to calculate heart rate is that a heart rate at the bottom of one zone will be quantified the same as a heart rate at the top of the same zone despite being different heart rates (Borresen & Lambert, 2008). Between zones, a change in heartbeat of only 1bpm can change the weighting factor of the zone which may alter the calculation of training load disproportionately (Borresen & Lambert, 2008). For instance, each heart rate range comprises 20 bpm (Flanagan & Merrick, 2001). Near the thresholds of each range it could be difficult to categorize a certain heart rate in one range as opposed to the other (Flanagan & Merrick, 2001). Additionally, time spent below 50% of the heart rate max is not calculated

(Borresen & Lambert, 2008). Based upon the evidence outlined, it has been suggested that the weighting factors used in calculating TRIMP may need refinement to increase reliability (Wallace et al., 2013).

Outside of the methods used to calculate TRIMP, there are other potential limitations for relying on heart rate as an indicator of internal training load. One such potential limitation is the phenomenon of cardiovascular drift. Cardiovascular drift is a phenomenon in which a gradual decrease in stroke volume is paired with an increase of heart rate after a couple minutes of mild to moderate exercise (Achten, & Jeukendrup, 2003). When attempting to reach certain heart rate during exercise, cardiovascular drift should be taken into consideration as the heart rate may increase without an increase in the external workload (Achten, & JeuKendrup, 2003).

Cardiovascular drift has been shown to be mediated by variables such as dehydration and heat stress (Achten, & JeuKendrup, 2003). Hydration status appears to play a prominent role in the onset of cardiovascular drift (Hamilton, González-Alonso, Montain, & Coyle, 1991). When compared to participants who received fluid replacement, those who did not saw increases in heart rates of 10% across the 20-120 minute exercise whereas those who received fluid replacement saw only a 5% increase (Hamilton et al., 1991). In another study, heart rate was demonstrated to be affected by increases of up to 7.5% when an individual is exercising in a dehydrated state (Achten, & JeuKendrup, 2003). In accordance with these results, it was concluded that dehydration could explain half of the cardiovascular drift (Hamilton et al., 1991). Additionally the reliability of heart rate monitors to measure exercise intensity decreases as the level of dehydration increases (Achten, & JeuKendrup, 2003).

The ambient temperature has also been suggested as a possible factor to alter heart rate during exercise. In a heated environment, heart rate will overestimate exercise intensity due to an increase in heart rate (Achten, & JeuKendrup, 2003). When compared to exercise in a cold environment, heart rate was shown to be significantly higher by 11-14 beats when exercise was conducted in the heat (González-Alonso, Mora-Rodríguez, & Coyle, 2000). Adjusting to a cold environment precipitates a decrease in skin blood flow and an increase in metabolic rate (Achten, & JeuKendrup, 2003). This increase in metabolic rate could be a result of shivering (Achten, & JeuKendrup, 2003). In cold environments, heart rate remains similar but VO_2 will be higher thus heart rate will underestimate the intensity of exercise (Achten, & JeuKendrup, 2003). From the above evidence, when players train in a dehydrated state or in a hot or cold climate, the reliability of heart rate monitors to accurately reflect internal workload may be compromised.

The altitude at which a soccer player trains, may also affect the calculation of internal workload based on heart rate. At 4,300 meters above sea level, increases were observed in cardiac output at rest (12%), during mild, moderate and maximum exercise (16-18%) and during recovery (20%) (Vogel, Hansen, & Harris, 1967). Researchers note this increase to be a result of an increased heart rate at rest, mild (15%) and moderate (10%) exercise (Vogel et al., 1967). In addition, a maximum attainable heart rate was less (180 to 176 beats per minute) at 4,300 meters above sea level when compared to baseline levels at sea level (Vogel et al., 1967). Within 3-weeks of exposure at 4,300 meters, heart rate was the only variable that had not returned to baseline measure at sea level (Vogel et al., 1967). Therefore it seems that a decrease in heart rate could yield an underestimation of exercise intensity at higher altitude as measured by heart rate.

Lastly, some researchers have outlined other possible limitations of using portable heart rate monitors for calculation of internal training load. For example, it is suggested that the use of heart rate to estimate oxygen consumption is likely to be overstated due to factors inherent to a soccer match such as heat, emotional stress and static exercises (Reily, 1997). Similar to this notion is that the many factors that may contribute to one's personal perception of their physical effort (Borresen & Lambert, 2008). Additionally, hormone and substrate concentrations, ventilations rate, personality traits, environmental conditions, neurotransmitter levels and psychological states are other factors to consider when relying upon heart-rate-based methods for measurement (Borresen & Lambert, 2008). The fact that individual heart rates have been stated to change between 2-4 beats/min on different days is also an important limitation of the use of heart rate **(**Achten, & JeuKendrup, 2003). This is especially important given that a change of just one 1bpm could result in a different weighting factor being used in calculation (Borresen & Lambert, 2008). Perhaps one of the most simplistic limitations of using heart rate to measure internal training load deals with the practicality of using a portable heart rate monitor. For example, if an athlete fails to remember his or her heart rate monitor or if there is a technical difficulty of the heart rate monitor during exercise, the heart rate data becomes compromised (Foster, Florhaug, Franklin, Gottschall, Hrovatin, Parker, & Dodge, 2001).

Overall, heart rate is an accurate measure of energy expenditure due to the individual heart rate-VO_2 relationship. Due to this relationship and the practicality of its use, portable heart rate monitors are valuable tools in the measurement of internal training load within soccer. It's no wonder why the measurement of heart rate during match-play is the most widely employed method of estimating energy expenditure. However, using a heart rate monitor does not come without it numerous potential limitations such as, expense, the training environment, hydration status of the player and/or emotional stress of the training. Perhaps another measure may be employed to gain a more global understanding of internal training load.

Session RPE: Why It Works

The use of portable heart rate monitors undoubtedly has advantages. However, it also has its limitations. Given these limitations, some researchers have desired to develop other more valid and reliable measures to quantify internal training load in soccer players. From this desire, the session rating of perceived exertion (RPE) scale was developed by Foster et al. (1995). It was developed in an attempt to continue to simplify objective measures of measuring internal training load such as those proposed by Bannister, Edwards and Lucia (Borresen & Lambert, 2008). The session RPE scale is the most popularized subjective measure of training load that has been developed (Borresen & Lambert, 2008).

Session RPE is described as an effort rating that considers the entire training session (Foster et al., 1995). Session RPE calculates internal training load by multiplying the RPE of the entire training session by the duration of the session (Impellizzeri et al., 2004). More specifically, the session RPE method includes the use of a category ratio scale designed to assess the global intensity of each training exercise (Foster, 1998). The scale is administered 20 minutes post-exercise to encourage athletes to account for the entire training session while taking into account exercise intensity cues such as heart rate and blood lactate accumulation (Foster, 1998). The product of the session RPE rating is then multiplied by the duration of the entire training session (including warm-up, cool down, and recovery intervals during the training session) (Foster, 1998). This product has been termed the session load (Foster, 1998). In the case that there are multiple training sessions in a day, the session loads of each session are added together to give an overall training load for the day (Foster, 1998).

There is evidence to support session RPE may measure exercise intensity in ways that TRIMP may not. As discussed above, soccer is comprised of many physical demands that contribute to overall energy expenditure such as jumping, changing direction, accelerating and decelerating, and tackling and while the majority of activities are submaximal, there are important albeit brief bouts of high-intensity activity as well. (Reily, 1997). Previous research has suggested that session RPE may be a more sensitive measure of exercise intensity when the exercise involves both aerobic and anaerobic activities which would include those exercise intensities conducted at or above submaximal intensities (Impellizzeri et al., 2004). In other words, session RPE may be a more valid measure of evaluating very high-intensity exercise than heart rate (Foster et al., 2001). In addition, it is suggested that RPE could be more sensitive to accumulated fatigue than heart rate response (Impellizzeri et al., 2004). Due to these advantages, session RPE allows for use in a wide variety of exercise sessions (Foster et al., 2001).

Some other advantages for the use of session RPE as measure of internal training load are the notion that session RPE is a more simplistic and practical technique for evaluating internal training load and it does not require the knowledge of maximal exercise responses to anchor the monitoring method as does heart rate (Foster et al., 2001). Lastly, session RPE can account for perception of effort and difficulty in ways that heart rate alone cannot. For example, although physiological stimulus may be the same in training, athletes may perceive it differently based upon their psychological state (Impellizzeri et al., 2004).

Studies to Support Session RPE

As with the use of any inventory, a level of comprehension by the participants is required to increase the validity of the scale. There is some evidence to suggest that the session RPE scale is comprehended by most. In one study of a basketball team, when administering the session RPE method, most of the players in the study were able to understand and respond to the instructions fairly well by following the verbal anchors associated with the scale (Foster et al., 2001). When asked the question “How was your workout?” most athletes (80%) were able to comfortably report a score that identified the global intensity of the exercise (Foster et al., 2001). However some athletes (20%) need to report session RPE scores for each exercise and then summate these scores for a session RPE (Foster et al., 2001).

The validity and reliability of session RPE has been supported as a practical utility to monitor training load in the scientific literature. Within a group of amateur soccer players, results revealed a positive correlation with session RPE and multiple measures of heart rate response to training (Banister's TRIMP, Edwards' TL and Lucia's TRIMP) (Impellizzeri et al., 2004). In a separate experiment examining the possible benefits of cross-training, internal training load was calculated using session RPE (Foster, Hector, Welsh, Schrager, Green, & Snyder, 1995). Researchers found that there exists a moderate association between average heart rate reserve and session RPE during 30-minute steady-state runs (Foster et al., 1995). Additionally when session RPE was compared to common percentages of time spent below, between, and above blood lactate transition zones (2.5 and 4.0 $mmol \cdot l^{-1}$), a modest correspondence was found (Foster et al., 1995). It should be noted that these 30-minute exercise sessions included both steady state and interval exercise (Foster et al., 1995).

Additional results suggest that the use of session RPE within team sport players seems to be a valid measure of monitoring training stress (Akubat, Patel, Barrett, & Abt, 2012) and that session RPE may be used over a wide variety of exercise sessions (Foster et al., 2001). Lastly, previous research has not found any significant relationships between changes in fitness and session RPE in team sport players (Gabbet & Domrow, 2007).

<u>Comparison Studies of Heart Rate Methods and Session RPE</u>

When directly comparing session RPE to heart rate methods of measuring internal training load, session RPE is often in strong correlation to the heart rate methods. For example, researchers sought to compare heart rate data with session RPE in relation to training load (Foster, 1998). Across 50 training sessions, heart rate data was collected via heart rate monitors. Duration in each zone was calculated and multiplied by the value of the zone as suggested by Edwards (Foster, 1998). The sum of these scores provided a single score for each training session based on the heart rate data (Foster, 1998). This score was compared to the score obtained using the session RPE method (Foster, 1998). Results indicated that session RPE corresponded well with heart rate's time in zone method when quantifying exercise training load (Foster, 1998). Other research by Foster continues to indicate that the use of the session RPE scale is highly correlated to summated heart rate zone methods of evaluating training sessions (Foster, Florhaug, Franklin, Gottschall, Hrovatin, Parker, Doleshal, & Dodge, 2001). In another study using soccer players, Foster's RPE method was correlated against various heart rate based methods to assess its validity in assessing aerobic training load in soccer (Impellizzeri et al., 2005). Significant individual correlations were found between heart rate based training loads and Foster's RPE method ($r = 0.50 – 0.85$; $P < 0.01$) (Impellizzeri et al., 2005). In a final study, TRIMP was found to have a positive correlation ($r = 0.76$) with session RPE in well-conditioned athletes (VO_{2max} of $56 \pm 8mL \cdot min^{-1} \cdot kg^{-1}$) (Borresen & Lambert, 2008). Comparing the summated-heart-rate-zones to session RPE revealed a positive correlation ($r = 0.84$) with approximately 71% of the variance explained (Borresen & Lambert, 2008). Even the mean weekly training loads of soccer players using Bannister's TRIMP were found to be significantly correlated with session RPE (Akubat et al., 2012). From these results, it can be concluded that the use of the session RPE method provides nearly identical information than that of the continuous measures of heart rate used by Banister et al. (1986) (Foster et al., 1995).

As mentioned previously, a compelling limitation of the use of heart rate monitors to measure internal training load, is their inability to consistently account for intermittent exercise (Impellizzeri et al., 2005; Drust, Reilly, & Cable, 2000; Helgerud et al., 2001). Given this limitation, researchers sought to examine the measurement of training load via session RPE across training methods out of steady state exercise (Foster et al., 2001). Results produced a strong relationship between session RPE and TRIMP scores across the different durations, and intensities of cycling exercise (Foster et al., 2001). The researchers note that very high-intensity exercises such as resistance training and plyometrics are unable to be objectively assessed using heart rate criteria (Foster et al., 2001). In another study, researchers found that athletes who spend a higher percentage of their time engaging in high intensity exercise, may have their total workload underestimated by TRIMP when compared to session RPE (Borresen & Lambert, 2008). From the research, it is suggested that session RPE may be a valid approach to evaluating very high-intensity exercise (Foster et al., 2001). Overall, session RPE was found to be supported as a valid measure of training load during non-steady state exercise, including ultra-high-intensity interval training and team sport practice and competition (Foster et al., 2001).

Limitations of Session RPE

Just as the heart rate methods, session RPE does have its limitations. Some researchers have noted that neither heart rate methods nor session RPE is related to changes of the aerobic fitness parameters indicating both measures' limitations for analysis of internal training load (Akubat et al., 2012). In some instances, session RPE was also shown to have poor levels of reliability as measure of internal training load (28.1% CV, 0.763% ICC) (Wallace et al., 2013). Additionally the researchers found the CR-10 scale used for session RPE to have low reliability (28.1% CV, 0.766%) (Wallace et al., 2013). The more traditional RPE 6-20 scale had moderate levels of reliability (8.5% CV,).765% ICC) and it is suggested that since the RPE 6-20 scale is more sensitive than the CR-10 scale in terms of points on the scale and that it is a ratio scale could be a reason for the differences in reliability (Wallace et al., 2013).

Perhaps one of the greatest limitations of the session RPE scale deals with the comprehension of the scale by participants. For example, when asked the question "How was your workout?" most athletes (80%) were able to comfortably report a score that identified the global intensity of the exercise (Foster et al., 2001). However, although 80% comfortably reported their score, this still means that a fifth of the participants did not comfortably report their score which jeopardizes the validity, reliability and ultimately the utility of their responses. It is suggested that participants may require more trial to familiarize themselves with the scale in order to accurately assess the global difficulty of an exercise (Wallace et al., 2013).

Heart Rate vs. Session RPE in the Assessment of Training Load

When a coach or trainer is attempting to decide which method to use assess internal training load, the strengths and limitations outlined above are important considerations. One consideration not mentioned above is the type of session (i.e. a training session vs. a match). Researchers measured physiological differences in soccer players between competitive matches and trainings (Bangsbo, 1994). It is suggested that during match-play, heart rate can be influenced by the stress of the competition (Bangsbo, 1994). A significant difference exists between training and match-play when it comes to duration a player spends in the "high" intensity zone (Bangsbo, 1994). Data from competitive match play suggests players to spend 26% of their time in the high interval area whereas only 4% of their time is spent in the high interval area during training (Bangsbo, 1994). These results indicate that session RPE compared to heart rate monitors may be a more appropriate measure of internal training load during match play because of the more frequent periods of high intensity exercise.

Lastly it is suggested that session RPE method could serve as a substitute for heart rate response measures, but could best be used in collaboration with these measures (Impellizzeri et al., 2004). In fact, it is argued that either method may be used to create a TRIMP score for training evaluation (Foster et al., 2001). Assuming expense is not an issue, it seems that the best solution would be to use both the methods together to gain a more precise overview of the internal training load.

Conclusion

The use of portable heart rate monitors and the session RPE scale have both advantages and disadvantages. As mentioned, perhaps a combined use of both measures may produce the most accurate assessment of internal training load. The use of either or both of these methods remains at the discretion of the coach. He or she must inform themselves about each method and then determine which method works best with the style of training they prefer. It should be noted that regardless of the method selected, there needs to be a familiarization period. For the heart rate monitors, this may mean allowing players time to get used to put on their straps and wearing them over the course of a training session. For the session RPE, familiarization of and repeated use of the scale will allow the players to best indicate their perceived global intensity of an entire training session. Data collected from either or both of these methods should be analyzed cautiously until the players have had a sufficient time period to familiarize themselves with the methods.

If used properly, both the portable heart rate monitors and session RPE can not only provide invaluable data to a coach or trainer, but also serve as a building block for planning the construction of subsequent training sessions. The potential applications of the design and planning of training sessions will be further reviewed in the case study that comprises the remainder of this project.

Analysis of heart rate monitor data of division 1 male soccer players over the course of a season: A case study

Following the review of the literature in the previous section, the practicality of using training load in soccer will now be examined in a case study. The case study centers on a male Varsity Division I collegiate soccer team at a public mid-western university. The data used for the case study comes from the Fall 2014 season in which the team competed in 19 regular season games, one exhibition game at the beginning of the season and two post-season games. All players were between the ages of 18-22 at the time of the study. The use of this data was approved by the local Human Subjects Review Board, Athletic Department and Head Coach of the team. Additionally, each member of the team signed an informed consent form giving the researcher their permission to use their data from the season. Polar's Team 2 System (Polar, Kempo, Finland) portable heart rate monitor's provided the majority of the data used for analysis in this case study.

Rationale for Monitoring Training Load using Heart Rate

The desire for the head coach to use these heart rate monitors came after an unusual change in the team's form in the Fall 2011 season. After starting the season winning seven of the first 10 games, the team went on to lose six of its last eight, drawing the other two games. Certainly, there could have been a myriad factors contributing to this reversal of success, but one factor the coaching staff was particularly interested in was the overall 'fitness' of the team. Being a team that anchored themselves on a philosophy towards out-working their opponents, the required energy to win games seemed to decline over the course of the final eight games with majority of the losses coming on goals conceded within the final 30 minutes of a game. This was in stark contrast to the wins in the beginning of the season with the majority of winning goals coming in the last 30 minutes of a game or in overtime. The coaching staff seemed to identify a drop in fitness level as a possible contributory factor. Ironically, the staff had felt that the team had entered the preseason more 'fit' than in the previous two seasons with the team. One measure that assured their confidence in the team's fitness was their performance on the mile test. At the start of the preseason, nearly all players produced a sub-5:30 mile, a significant improvement from prior years. Additionally, as mentioned before, the team had excelled in late-game situations in their first nine games of the season. Upon further reflection of the course of the season, the coaching staff began to hypothesize the drop in fitness could be attributed to an improper periodization. Essentially the 'work' within the training sessions during preseason and the season may have been a strong contributing factor in the decline of fitness levels through the Fall 2011 season. Searching for a way to quantify their training sessions and the exercises that made up these sessions, the coaching staff turned to the use of portable heart rate monitors.

Polar Heart Rate Monitors

As mentioned in the review of literature, heart rate monitors are able to quantify internal training load using three methods to calculate an internal training load or TRIMP. The Polar heart rate monitors use a method most similar to Lucia's TRIMP. As stated previously, Lucia's TRIMP is a variation of calculating internal training load in which there are only three heart-rate zones (zone 1 = below the ventilatory threshold, zone 2 = between the ventilatory threshold and respiratory-compensation point and zone 3 = above the respiratory-compensation point) (Lucia, 2003). The duration spent in each zone is multiplied by a coefficient (k) which is relative to each zone (k = 1 for zone 1, k = 2 for zone 2 and k = 3 for zone 3) (Lucia, 2003). These adjusted scores are then summated to acquire internal training load (Lucia, 2003).

From the description of Lucia's TRIMP, it can be noted that determining the "boundaries" for each zone is important. Polar calculates the boundaries for each zone by percentages of an individual's maximal heart rate. Using the Polar system, maximum heart rate values are entered into the software manually by the coaches. Therefore it is important for the coaching staff to accurately determine maximal heart rate. This process is done by having the players complete a field test called the Yo-Yo Intermittent Recovery test (Bangsbo, Iaia, & Krustrup, 2008). Previous studies have shown this test to elicit similar maximum heart rates as an exhaustive incremental treadmill test (Krustrup, Mohr, Amstrup, Rysgaard, Johansen, Steensberg, Pedersen, & Bangsbo, 2003). This test is conducted on the first day of preseason and the maximum heart rates are used as a basis for calculating internal training load using the Polar heart rate monitors. It should be stated that if an individual reaches a new maximal heart rate at any point in training throughout the season, it is manually updated with the Polar software but the Yo-Yo test serves a valuable starting point for maximum heart rate.

The zones that are based upon maximum heart rate logically would have individual differences between players. The best way to determine the zones for each player would be to have them complete a maximal oxygen consumption test multiple times throughout a season to account for any changes in ventilatory threshold and respiration-compensation point. However, for the sake of practicality of not having every individual team member run a maximal oxygen consumption test, the zones are calculated based upon a set percentage of maximal heart rate.

Beginning in the Spring 2012 offseason, the coaching staff of the soccer team began to use the portable heart rate monitors to collect quantifiable data from each training session. For each of these training sessions an overall training load or workload was found by averaging the data of a few selected players. These players varied each day and their selection was dependent on the ‘cleanliness’ of their data. Occasionally, some player’s data would be sporadic due to improper placement of the heart rate monitor, the heart monitor falling off during practice or simply a failed or unreliable connection between the monitor and the player’s heartbeat. The rare ability to collect clean data for all players is certainly a limitation of using heart rate monitors to collect training load for reasons outlined above and in the review of literature.

Developing a Periodization Schedule

The Spring of 2012 served as a starting point to learn about the heart rate monitors and the coaching staff began to record data from each training session. Among the data recorded was the overall training, average training load for the day and average workloads per a minute during certain training exercises of the team. During this beginning period, workloads per minute were collected after nearly every training exercise. These provided the coaching staff with a more precise idea of which training exercises elicited the highest and lowest workloads per minute and how the inclusion of these training exercises affected the overall training load for the entire session.

As mentioned previously, the over-arching goal of the program was to develop a fitness plan within the fall season that would allow the players to maintain a high level of both aerobic and anaerobic capacity throughout the season. The use of the heart rate monitors gave the coaching staff a quantifiable measure of a player’s overall workload during each session. With more and more data collected, training sessions could then be divided based upon a target or desired workload for that particular session. Between the Spring 2012 and Fall 2014 seasons, the coaching staff was introduced to methods of periodization carried out by the Men’s Soccer team at the University of Louisville. As Louisville was consistently one of the top collegiate soccer programs in the country, the coaching staff desired to model their periodization schedule based upon the periodization of the this team. The framework is outlined below.

Periodization Model

Based upon information from the University of Louisville's Men's Soccer team and data collected from the heart monitors from the Spring 2012 season and beyond, a periodization schedule was developed for the Fall 2014 season. The periodization schedule of the Fall 2014 season encompassed a total of 13 weeks, with the first week and half being preseason and the remaining schedule making up the regular season. Within the 13-week time frame, there were a total of 20 matches, with only the first of these matches being a preseason competition leaving 19 regular season matches.

The periodization for the soccer team was formulated by the use of three primary types of training sessions. A training session that elicited a workload over 225 AU was considered a "Red day", a workload of 125-225 AU was a considered a "Yellow day" and a workload of 125 AU or less was considered a "Green day". A game was typically considered to carry a workload of around 300 AU so all games were considered to be Red days. In addition to workloads for each day, workloads for each week were also established. As the goal, was to maintain a certain level of fitness throughout the season, the workloads per week decreased every three weeks so as not to overload the players. With the short and intense nature of the season for Division I soccer in the United States, weekly training loads were important considerations. In the first five-week cycle, the overall workload for the week was set to be 1,200 AU. In the second five-week cycle, the overall workload was decreased by 100 AU to 1,100 AU and finally, in the remaining weeks of the season the overall AU was decreased by another 100 AU to 1,000 AU.

Some other important considerations that were made when assembling the periodization schedule included the ordering of the schedule and strategically scheduling off days for the players. Beginning with the ordering of the schedule, as mentioned, training days were projected to be either Red (>225), Yellow (125-225), or Green (<125). Just as important to the periodization, was the planning of off days for the team. In total, each day within the periodization schedule consisted of Green, Yellow, Red and off days.

Red Days

Any time there was a match, this was considered to be a Red day because the expectation was the workload would be well over 225 AU. Depending on the match schedule for the week, Red days were also planned in training sessions. These only occurred if there were at least 72 hours before the next match. Given an intense college soccer season, Red training days were only planned six times over the course of the season.

Yellow Days

Different from prior seasons, the training before a match was planned to be a Yellow day, but with a target workload closer to the lower end of the yellow spectrum. This was denoted on the periodization schedule as a half-green, half-yellow block. Yellow days were also used in conjunction with Green days the day following a match. Those players who did not play more than 70 of the 90+ minutes of the game the day prior, were scheduled to have a Yellow day of training the following day. This was implemented with the reasoning that these players needed to maintain their fitness and since they did not reach a Red day the night before, their bodies required sufficient stimulation. It could be argued that this training session after a match needed to be a Red day for players who did not play that much or at all to totally balance out the entire fitness of the team. However, the reason their training session after a game was not scheduled to be a Red day, was so that these players could be adequately recovered by the following day when the entire team returned to training as a whole. Had they completed a Red day, their bodies would not be adequately recovered to return to training since they would have had one less day of recovery compared to their teammates who competed significantly in the match. This could be a problem as it could lead to overuse injuries or fatigue which may hinder their performance should they be given a more significant role in the next match.

Green Days

The training session 48 hours prior to a game were scheduled to be Green days. A reduction in workload would allow the coach more time interject and prepare the team for any tactical or important nuances of an upcoming opponent.

In general, following an off day, a Green day was planned. This was designed to allow players the chance to ease their bodies back into the pace of training and avoid any injuries as a result of training too hard after a day of rest. Lastly, Green days were scheduled for players who played significant minutes (~70 minutes or more) in a match the day before. As mentioned in the Yellow days section, during this period, the team would be divided into two training groups. Players who did not play significant minutes would have a Yellow day and players who did play significant minutes would have a light Green day in which they used the time to recover by engaging in light exercises to increase blood flow to their muscles.

Off Days

Per NCAA rules, the team was required to have at least one off day per a 7-day period. These off days were to be considered to be total off days from soccer. This meant players would not engage in training, lifting or soccer meetings during these days. Additionally, the head coach preferred to give the team two consecutive days off, once a month during the season. This was done to allow the players time to rest both physically and mentally, catch up on academic studies and take care of any injuries or issues the players may have acquired through the season.

Additional Components Influencing Planned Training Load

In addition to the four types of days (Red, Yellow, Green and Off), there were also three other components of the periodization calendar. The first is a Recovery day, which as mentioned, occurs the day after a match for the players who contributed significant minutes to the match the day before. During a recovery day, players engaged in minimal activity, most often a light jog and stretch. The second component, marked by an asterisks on the periodization schedule, is a Phosphate day. On these days, the players engaged in exercises designed to work their anaerobic systems. The goal was to maintain and even build upon the explosiveness of the player within a short space. The primary exercise used was to be five band resistance runs (i.e., resisted sprint training) of five to 10 yards. As for scheduling Phosphate days, the only stipulation was that these not occur within 24 hours of the next match or within 24 hours of the prior match. In terms of the color of the day, phosphate days were scheduled on Green, Yellow and Red days.

A third component of the periodization schedule in addition to the color of the day were Strength days. Strength days were implemented in an effort to maintain strength of the players over the course of the season. The strength exercises were to primarily occur using an apparatus on the soccer field. The exercises were mostly to consist of upper-body, body-weight movements such as chin-ups, push-ups, and dips. In addition, band exercises of pull-aparts, upright rows, and bent over rows were also to be implemented. Lastly, core exercises such as V-ups, planks, and twists were also completed on a Strength day. A high repetition range was to be used for all the exercises in an effort to develop a leaner mass for each player rather than a more dense mass associated with heavy weight. Similar to phosphate days, the main contingency of strength days was that they would not occur 24 hours prior to or 24 hours after a match.

The full periodization schedule can be found in Figure 1. This schedule was created prior to the start of the Fall 2014 season. The schedule begins on Thursday, August 14th and ends on Sunday, November 10th. It is important to note that the team's season continued into the post season one week further than the periodization schedule. The team's entire season came to an end on Sunday, November 17th.

Figure 1 Team Periodization Schedule prior to the start of the season

		Mon 11	Tues 12	Wed 13	Thurs 14	Fri 15	Sat 16	Sun 17	Total
Week 1	*Target*				*		> Thursday	Scrimmage	1200
	Actual							300	300
		Mon 18	Tues 19	Wed 20	Thurs 21	Fri 22	Sat 23	Sun 24	Total
Week 2	*Target*	Strength		Marshall	Recover	*/Strength		OFF	1200
	Actual								0
		Mon 25	Tues 26	Wed 27	Thurs 28	Fri 29	Sat 30	Sun 31	Total
Week 3	*Target*	OFF	Strength			IUPUI	OFF	*/Strength	1200
	Actual								0
		Mon 1	Tues 2	Wed 3	Thurs 4	Fri 5	Sat 6	Sun 7	Total
Week 4	*Target*		Findlay	Strength		Niagra	Recover	Duquesne	1200
	Actual								0
		Mon 8	Tues 9	Wed 10	Thurs 11	Fri 12	Sat 13	Sun 14	Total
Week 5	*Target*	OFF	OFF	*/Strength		NKU	Recover	*/Strength	1200
	Actual								0
		Mon 15	Tues 16	Wed 17	Thurs 18	Fri 19	Sat 20	Sun 21	Total
Week 6	*Target*		Michigan	Recover Strength		Eastern Illinois	OFF	*	1100
	Actual								0
		Mon 22	Tues 23	Wed 24	Thurs 25	Fri 26	Sat 27	Sun 28	Total
Week 7	*Target*	Strength		Michigan State	Recover	*/Strength		St. Bonnies	1100
	Actual								0
		Mon 29	Tues 30	Wed 1	Thurs 2	Fri 3	Sat 4	Sun 5	Total
Week 8	*Target*	OFF		IPFW	Recover		OFF	*/Strength	1100
	Actual								0
		Mon 6	Tues 7	Wed 8	Thurs 9	Fri 10	Sat 11	Sun 12	Total
Week 9	*Target*		Cleveland State	Recover	*/Strength		Akron	OFF	1100
	Actual								0
		Mon 13	Tues 14	Wed 15	Thurs 16	Fri 17	Sat 18	Sun 19	Total
Week 10	*Target*	OFF	*	Strength			Buffalo	OFF	1000
	Actual								0
		Mon 20	Tues 21	Wed 22	Thurs 23	Fri 24	Sat 25	Sun 26	Total
Week 11	*Target*	*/Strength		Ohio State	Strength		West Virginia	OFF	1000
	Actual								0
		Mon 27	Tues 28	Wed 29	Thurs 30	Fri 31	Sat 1	Sun 2	Total
Week 12	*Target*	*/Strength		Detroit	Strength		Western Michigan	OFF	1000
	Actual								0
		Mon 3	Tues 4	Wed 5	Thurs 6	Fri 7	Sat 8	Sun 10	Total
Week 13	*Target*		Wright State	Recover Strength	*		NIU	OFF	1000
	Actual								0

< 125   125 - 225   > 225   *Phosphagen

Season Summary

Overall, the Fall 2014 season can be considered a success for the BGSU Men's Soccer team. The team finished with a final record of 14 wins, 6 losses and 1 tie. This left the team with an overall win percentage of 67%. The full list of game summaries and scores can be found in Table 1. The team scored 38 goals, averaging 1.81 goals per game. Only 20 goals were conceded throughout the entire season with the team averaging less than one per a game. Of their 22 games, seven of them were still tied at the end of the 90 minutes and required an overtime period. In NCAA Division 1 College Soccer, overtime consists of two, 10-minute halves. Every overtime is played in a golden-goal format meaning whichever team scores first automatically wins the game regardless of the time still left in the overtime period. If no goals are scored, the match results in a tie during the regular season. Of these seven overtime games, the team won five, lost one and tied another. In total, 18 of the teams 38 goals came at the 60-minute mark of a match or later. Also during this time period, the team only conceded 11 goals. The scoring summaries for each game can be found in Table 2.

Table 1 Fall 2014 Game Summaries and Scores

	Opponent	Location	Result	Score
1	Marshall (exhibition)	Huntington, W. VA	W	1-0
2	IUPUI	Bowling Green, OH	W	2-0
3	Findlay	Bowling Green, OH	W	8-0
4	Niagara	Pittsburgh, PA	W	4-0
5	Duquesne^{+}	Pittsburgh, PA	L	2-3
6	Northern Kentucky	Bowling Green, OH	W	2-1
7	Michigan	Ann Arbor, MI	W	1-0
8	Eastern Illinois	Bowling Green, OH	W	3-1
9	Michigan State	Bowling Green, OH	L	0-1
10	St. Bonaventure	Olean, NY	W	1-0
11	IPFW	Fort Wayne, IN	W	1-0
12	Cleveland State^{+}	Cleveland, OH	W	1-0

13	Akron	Bowling Green, OH	L	0-1
14	Buffalo+	Bowling Green, OH	T	1-1
15	Ohio State	Columbus, OH	L	0-3
16	West Virginia	Morgantown, W. VA	L	1-2
17	Detroit+	Detroit, MI	W	1-0
18	Western Michigan+	Bowling Green, OH	W	2-1
19	Wright State+	Bowling Green, OH	W	2-1
20	Northern Illinois	DeKalb, IL	W	2-1
21	West Virginia+*	Akron, OH	W	3-2
22	Akron*	Akron, OH	L	1-2
	+ Overtime Game *Conference Tournament			

Table 2 Fall 2014 Scoring Summaries

Opponent	**Scoring Summary**
Marshall (exhibition)	BG, '64
IUPUI	BG,'27
	BG, '61
Findlay	BG, '18
	BG, '23
	BG, '32
	BG, '35
	BG, '36
	BG, '40
	BG, '44
	BG, '87
Niagara	BG, '12
	BG, '32
	BG, '51
	BG, '53
Duquesne+	DUQ, '32
	DUQ, '56
	BG, '61
	BG, '88
	DUQ, '105
Northern Kentucky	BG, '44
	NKU, '64
	BG, '85
Michigan	BG, '17

Eastern Illinois	BG, '39
	EIU, '48
	BG, '79
	BG, '90
Michigan State	MSU, '80
St. Bonaventure	BG, '77
IPFW	BG, '84
Cleveland State+	BG, '98
Akron	UA, '16
Buffalo+	BG, '19
	UB, '24
Ohio State	OSU, '3
	OSU, '31
	OSU, '64
West Virginia	BG, '28
	WVU, '39
	WVU, '78
Detroit+	BG, '109
Western Michigan+	WMU, '64
	BG, '76
	BG, '100
Wright State+	BG, '44
	WSU, '63
	BG, '100
Northern Illinois	BG, '33
	BG, '38
	NIU, '61
West Virginia+*	BG, '33
	WVU, '55
	WVU, '61
	BG, '82
	BG, '91
Akron*	BG, '67 UA, '67 UA, '79

+Overtime game
*Conference Tournament

Reflection of the Periodization Schedule

As can be seen by the data above, the 2014 Fall season was in many respects a success for the BGSU Men's Soccer Program. The team recorded some of the largest season-highs in numerous categories for the past decade. Knowing the team's success can now lead one to re-examine the periodization schedule set forth at the beginning of the season. Figure 2 shows the periodization schedule with the actual training load numbers that were collected during the season.

Figure 2 Team Periodization Schedule post-season

Week 1		Mon 11	Tues 12	Wed 13	Thurs 14	Fri 15	Sat 16	Sun 17	Total
	Target				*		> Thursday	Scrimmage	1200
	Actual							300	300
Week 2		Mon 18	Tues 19	Wed 20	Thurs 21	Fri 22	Sat 23	Sun 24	Total
	Target	Strength		Marshall	Recover	*/Strength		OFF	1200
	Actual			300			300		600
Week 3		Mon 25	Tues 26	Wed 27	Thurs 28	Fri 29	Sat 30	Sun 31	Total
	Target	OFF	Strength			IUPUI	OFF	*/Strength	1200
	Actual					300			300
Week 4		Mon 1	Tues 2	Wed 3	Thurs 4	Fri 5	Sat 6	Sun 7	Total
	Target		Findlay	Strength		Niagra	Recover	Duquesne	1200
	Actual		300			300		300	900
Week 5		Mon 8	Tues 9	Wed 10	Thurs 11	Fri 12	Sat 13	Sun 14	Total
	Target	OFF	OFF	*/Strength		NKU	Recover	*/Strength	1200
	Actual					300		145	300
Week 6		Mon 15	Tues 16	Wed 17	Thurs 18	Fri 19	Sat 20	Sun 21	Total
	Target		Michigan	Recover Strength		Eastern Illinois	OFF	*	1100
	Actual	92.5	300	190	96	300		154	1133
Week 7		Mon 22	Tues 23	Wed 24	Thurs 25	Fri 26	Sat 27	Sun 28	Total
	Target	Strength		Michigan State	Recover	*/Strength		St. Bonnies	1100
	Actual	71	88.5	300	175	140	112	300	1187
Week 8		Mon 29	Tues 30	Wed 1	Thurs 2	Fri 3	Sat 4	Sun 5	Total
	Target	OFF		IPFW	Recover		OFF	*/Strength	1100
	Actual		109	300	165	174		165	583
Week 9		Mon 6	Tues 7	Wed 8	Thurs 9	Fri 10	Sat 11	Sun 12	Total
	Target		Cleveland State	Recover	*/Strength		Akron	OFF	1100
	Actual	102	300	166	130	110	300		1108
Week 10		Mon 13	Tues 14	Wed 15	Thurs 16	Fri 17	Sat 18	Sun 19	Total
	Target	OFF	*	Strength			Buffalo	OFF	1000
	Actual		170	213	106	96	300		885
Week 11		Mon 20	Tues 21	Wed 22	Thurs 23	Fri 24	Sat 25	Sun 26	Total
	Target	*/Strength		Ohio State	Strength		West Virginia	OFF	1000
	Actual	119	131	300			300		850
Week 12		Mon 27	Tues 28	Wed 29	Thurs 30	Fri 31	Sat 1	Sun 2	Total
	Target	*/Strength		Detroit	Strength		Western Michigan	OFF	1000
	Actual	174	99	300		120	300		993
Week 13		Mon 3	Tues 4	Wed 5	Thurs 6	Fri 7	Sat 8	Sun 10	Total
	Target		Wright State	Recover Strength	*		NIU	OFF	1000
	Actual	120	300	88	88	81	300		889

< 125 (green) 125 - 225 (yellow) > 225 (red) *Phosphagen Training

Upon review of the periodization schedule, the first observation is that there is quite a bit of missing data, particularly from the first five weeks of the season. This data is missing for reasons unknown to the researcher who acquired the data from the Men's Soccer coaching staff. This missing data could be crucial to analysis of the season, but the data that was collected can still be analyzed.

Beginning with the total weekly workloads, these were in general a bit off from what was planned prior to the season. There were some weeks however, that were pretty close to their desired weekly training load. For example, Week's 9 and 12, were both within 8 AU of the desired weekly training load. Interestingly enough, in the games during these weeks, the team won three out of the four games and all three victories came in overtime. This could suggest the importance of maintaining the weekly training loads throughout the season. To further examine this suggestion, weeks in which the weekly training load was off must be reviewed.

The two weeks in which the largest discrepancy existed between the planned weekly training load and actual weekly training load were Weeks 8 and 11. During these two weeks, the team won only one of their three games, with both losses coming in Week 11. During this week the team conceded three goals against Ohio State and a late game-winning goal against West Virginia. It is interesting to note that although Week 8 had the largest discrepancy between the planned weekly training load and the actual weekly training load (417 AU), the team won its game that week with a late goal against IPFW (minute 84). Additionally, as already mentioned, the team won their next game in Week 9 in overtime against Cleveland State and, from subjective point of view, played Akron well, with fitness not seeming to be an issue given many late chances that BG produced in the final minutes of the game. Lastly, Week 8 contained two-days off. Perhaps a lighter workload in Week 8 may have given the team a bit more rest allowing them to feel more energized for their game during Week 8 and their games in Week 9.

Red Days

As mentioned previously, there were only six Red days planned into the periodization schedule given their intense nature. As a reminder, to be considered a Red day, the average total training load for the session must exceed 225 AU. Unfortunately, only three of the six planned Red days had data to reflect the overall intensity of the session. Interestingly, for each of the three Red days in which data was obtained, the overall workload for these days was never high enough for them to be considered Red days. For example, the first of these days came in Week 6, on Sunday September 21. On this day, the average total training load was only 154 AU. Upon closer examination of Week 6 as a whole, it may not have been that bad that the Red day on the 21st was not a true Red day. The team had already played two matches that week and with their weekly training load already being over the planned total of 1100 AU, the additional 71 AU that a true Red day would have elicited, may have unnecessarily taxed the team, leaving them prone to excess fatigue, injuries or even burnout. The remaining two Red days came in Week 8 on Friday, October 3 and in Week 10 on Wednesday, October 15. In contrast to the September 21 Red day, this Red day may have been beneficial to the team had it been closer to 225 AU. As stated previously, Week 8 had the lowest weekly training load which may suggest that the team's fitness had room to be stretched to a true Red day. Week 10's Red day was the closet to 225 as it had an average training load of 213 AU. Given how close this training load was to 225, it is possible that it was within the range of error of the entire team's average of their individual workloads. Subjectively, it did not seem to have a negative effect on the following game against

Buffalo. Although the team did not play its greatest that night, from a subjective point of view, it was not an issue of fitness and the team did not concede any goals in overtime.

Yellow Days

Upon examination of the periodization schedule, Yellow days generally took place the day before a match and the day following the match for players who had not played significant minutes in the match. Beginning with days before a match, these Yellow days were scheduled to be on the lower end of the 125-225 spectrum that makes up a Yellow day. However no specific number was given for these Yellow days before a match. Of all the data that was obtained from the season, only one Yellow day before a match contained an average training load between 125-225 AU. No other Yellow day before a match exceed an average training load of 125 AU. The one day it did exceed 125 AU was on Tuesday, October 21^{st}. In conjunction with the purpose of this day, the training load was close to 125 AU at 131 AU. Interestingly, this was the day before the team played Ohio State. This game was the worst loss of the team's season (0-3) and besides the score, it was unanimously agreed on by the coaches as the team's worst performance of the entire season. It is possible, the higher training load left the team unprepared and possibly still recovering from fatigue. Perhaps, this evidence may shed light on the logic of have Yellow days before a game. As mentioned, this was the only day considered to be a true Yellow day while all the other days before a match were considered Green days based upon the training loads that were collected for those days. This evidence could suggest that a Green day may be a more suitable target training load before a game.

The day following a match, heart rate data was only collected for those players who did not play significant minutes in the match the day before. These days generally fell within the range for a Yellow day. The only day that did not meet the criteria for a Yellow day was in

Week 13, on Wednesday, November 5th. During this day, the training load was lower and would be considered a Green Day. Although the day called for a Yellow day, it may not have been too detrimental that this day was a Green day as it occurred in the final week of the regular season when general fatigue of the season has been accumulated and at this point a safer option may have been to go lighter to avoid anyone being over-fatigued.

Overall, the Yellow days following a match could be considered a success. At certain points within the season, some players were called upon to play more and more minutes. As observed as a coaching staff, none of these players seemed to be lacking from a fitness perspective. This could be due to a number of factors, but upon examination of the data from the heart rate monitors, it seems that the maintenance of fitness established through Yellow days following a day after a match for players who did not play significant minutes the day before, is a contributing factor, if not a large contributing factor.

Green Days

About half of the scheduled Green days on the periodization schedule, exceeded the criteria to be considered a Green day. The general pattern of a Green day was to be the training session 48 hours prior to a match and have a Yellow day 24 hours before a match. As already mentioned, the majority of the Yellow days before matches were actually Green days based upon the data that was collected. Interestingly, some of the Green days scheduled to take place before these Yellow days actually fit the criteria of a Yellow day, eliciting average training loads over 125 AU. Out of the five reported occasions this scenario occurred, in their next match, the team won four games and only lost one. Two of these four victories occurred in overtime. This may give further evidence to support the notion that a Yellow day 48 hours before a match followed by a Green day 24 hours before a match may be a more suitable arrangement when organizing the periodization schedule.

Another interesting note about Green days, is that the training loads for these days often exceed the prescribed training load on days when there was a strength and phosphate component added to the session. This evidence could suggest that these two exercise, paired together on the same day, may contribute more than originally expected to the overall training load of the session.

Off Days

The Off days were given as originally planned. For most players, these days were true Off days in which they had no involvement with soccer. However, for some players, particularly those who were not seeing significant minutes, some of these Off days served as opportunities to better their skills or meet with the coaching staff about any relevant topics on or off the field.

Overall

The Fall 2014 BG team was arguably the most 'fit' team the program has seen in a number of years. A piece of evidence to support this notion is the fact that 18 of the teams 38 goals this season came at the 60-minute mark of a match or later. This suggests that team was able to maintain concentration in the latter part of games increasing their chances to score many crucial goals. Perhaps an even stronger reflection of the team's fitness was their five overtime victories. This evidence suggests that the team was better able to maintain a higher-level of soccer based upon their fitness level than their opponents. Even more impressive, all five of these overtime victories came in the final half of the season. This suggests, the team was able to not only maintain a high level of fitness within the game but over the course of the season as well. It could be argued that the team's fitness was at its highest point in the conference tournament as it won the conference semifinal scoring goals in the 82nd minute and in overtime and then played one of the top teams in the country down to the wire in the conference final less than 48 hours later. Compare this to the 2011 season, in which the team's fitness, and more importantly their form dropped significantly in the second half of the season costing them a chance to even make it to the conference tournament.

Extenuating Factors

As with any other sport, soccer is made-up of many different components, with fitness only being one part of the whole. In addition to the tactics and technical side of the game, there are also other external factors that may have contributed to a player's individual feelings of fatigue and that, for better or for worse, may not have been recorded using the heart rate monitors. Perhaps the biggest contributor to physical fatigue may have been travel. As about half of the teams games were on the road, this often required players to step on a bus immediately after playing and drive a significant length of time. This time spent on the bus could have hindered a player's recovery follow a game and could therefore have led to under-recovery and a sense of physical fatigue. From an emotional perspective, the season was short and emotionally draining. There were many ups and downs (fortunately many ups this season) and the emotional energy spent during these games may have been draining both physically and mentally for a player.

Off the field, as members of a collegiate soccer team, the players were faced with the challenges of balancing their school work with their athletics. It is quite possible that important papers, homework or exams could have added a level of emotional fatigue causing a change in overall fatigue of the player. Along these lines, the players also needed to maintain a healthy social life. For some, this desire may have extended their emotional or physical fatigue if for example, they were in a fight with a friend or girlfriend or if they chose to stay out later and thus lose critical hours of sleep. On the other hand, a player may have become too focused on their studies or athletics and therefore not have a balanced social life which may have negatively contributed to the overall wellness of a person and their levels of emotional and physical fatigue.

Concluding Thoughts on Monitoring Training Load throughout a Season

From a subjective point of view, the periodization schedule was successful in that it provided the coaching staff with a guide to implement their training sessions. Looking ahead to the 2015 season, perhaps the greatest change necessary to the schedule would be switch order of Green and Yellow days leading up to a match. It seems that a Yellow day followed by a Green day may adequately prepare the team for an upcoming match from a fitness perspective.

It is important to note that the data collected from the Fall 2014 season was incomplete. The first five weeks of the periodization schedule were missing heart rate data and therefore, the conclusions made about this schedule were based upon only the information presented. Had there been complete data, this may or may not have altered any conclusions come upon by the researcher.

The Polar heart rate monitors seemed to have served and continue to serve their purpose for the BGSU Men's Soccer Program. Since their implementation in the Spring of 2012, the team has continued to grow from a fitness perspective and this growth has been reflected in their on the field performance culminating in the successes of the Fall 2014 season. In addition to the growth of the team, the coaching staff has also grown in its ability to understand the purpose of the data the heart rate monitors provide. Fitness is a crucial component of soccer, but it is not the only component of soccer. The coaching staff continues to work from this philosophy as it continues to use the heart rate monitors to collect valuable data. This data provides an important piece of the puzzle as the program continues to constantly grow and meet its ultimate goal of winning a National Championship.

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