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Methods of monitoring the training and match load and their relationship to changes in fitness in professional youth soccer players

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Abstract
Previous studies examining methods of monitoring the training and match load in soccer players have simply compared those methods to each other, not to changes in fitness. Training and match load measures from nine professional youth soccer players were collected for a period of six weeks. A lactate threshold test was conducted before and after this period. Mean weekly training and match load as determined by session-RPE, Banister’s TRIMP, Team TRIMP and individualised TRIMP (iTRIMP) were correlated with each other, percentage changes in the velocity at 2 mmol-L⁻¹ (vLT) and 4 mmol-L⁻¹ (vOBLA) blood lactate concentration, and heart rate at 2 mmol-L⁻¹ (LTHR) and 4 mmol-L⁻¹ (OBLAHR). There were no significant changes in fitness across the six weeks: vLT (p = 0.54), vOBLA (p = 0.16), LTHR (p = 0.51) and OBLAHR (p = 0.63). Banister’s TRIMP was significantly correlated with session-RPE (r = 0.75; p = 0.02) and Team TRIMP (r = 0.92; p < 0.001). The percentage change in vLT was significantly correlated to mean weekly iTRIMP (r = 0.67; p = 0.04). The results suggest that an individualised measure of internal load (iTRIMP) related better than other methods to changes in vLT in professional youth soccer players.

Keywords: training impulse, session-RPE, individualised

Introduction
The monitoring of training and match load is important for the periodization of training and assessment of the physical ‘dose’ during training and match play. Previous studies in soccer have shown how the prescribed external training load can influence the physiological response (Rampinini, Impellizzeri, et al., 2007; Hill-Haas, Rowsell, Dawson, & Coutts, 2009). However, very little attention has been given to the role of the internal training and match loads on changes in fitness, especially in soccer. Two studies (Impellizzeri, Rampinini, Coutts, Sassi, & Marcara, 2004; Alexiou & Coutts, 2008) have examined the relationships between a number of methods for measuring the internal load in soccer players. Impellizzeri et al. (2004) and Alexiou and Coutts (2008) both used HR based methods as ‘criterion’ measures of load to validate the use of session-RPE (Foster et al., 2001).

The three HR based methods used were Edward’s TRIMP (Edwards, 1993), a blood lactate threshold based TRIMP similar to that used by Lucia, Hoyos, Perez, and Chicharro (2000) and Banister’s TRIMP (Banister, 1991). Edwards’ (1993) TRIMP uses the accumulated time in five arbitrary heart rate zones multiplied by a weighting factor (1–5). Lucia’s (2000) TRIMP uses three heart rate zones (weighted 1–3), which are anchored around individually determined parameters, in this case LT and OBLA. Banister’s (1991) TRIMP uses the exponential relationship between fractional elevation in heart rate and blood lactate concentration, as observed during incremental exercise, to ‘weight’ exercise at a particular intensity.

Significant relationships were reported between session-RPE and all heart rate methods in both studies. However, in both studies the different methods were simply correlated against each other rather than to changes in fitness or performance. There are also potential limitations to the ‘criterion’ measures of training and match load used in these papers. Edward’s TRIMP (Edwards, 1993) is based on arbitrary zones with arbitrary weightings, which does not reflect the individualised response to
exercise (Abt & Lovell, 2009). Although the zones used in the LT based TRIMP were individualised and based on physiological thresholds, the weightings provided are arbitrary and a relationship between this method and changes in fitness or performance has not been shown. A more appropriate method would be to assign weightings in accordance with an individual’s own physiological response to exercise. Although endurance performance has been successfully modelled using Banister’s TRIMP (Morton, 1990; Busso, 2003), this method is generic for each gender and the use of mean heart rate is not likely to reflect the intermittent nature of soccer training or match play. In an attempt to alleviate some of these issues Stagno, Thatcher, and van Someren (2007) introduced a modified ‘team’ TRIMP for hockey where five zones were created around LT and OBLA, and each zone weighted according to the regression equation of the curve. Although an individual’s own data contributes to the generation of the ‘team’ regression equation, the resultant weightings for each of the five zones are the same for each player.

Session-RPE has been popularised due to its ease of use and reported relationships with other methods of monitoring the training load (Impellizzeri et al., 2004; Alexiou & Coutts, 2008). Indeed, RPE has been reported to be a good measure of intensity during intermittent exercise and may also act as a ‘global’ measure of training stress by taking into account non-physiological factors (Impellizzeri et al., 2004). While these attributes of the method are a strong attraction for those working with team sport players, a valid method of monitoring training stress should also be sensitive to changes in fitness or performance. However, previous studies have failed to detect significant relationships between session-RPE and changes in fitness in team sport players (Gabbett & Domrow, 2007).

In order to address the limitations discussed above we propose the use of an individualised TRIMP (iTRIMP) (Manzi, Iellamo, Impellizzeri, D’Ottavio, & Castagna, 2009) in soccer. Here, each individual’s own data is used to calculate the relationship between fractional elevation in heart rate and blood lactate concentration, with each heart rate data point measured during training or match play weighted according to this relationship. Such an approach alleviates the problems encountered with arbitrary zones and weightings (Edwards, 1993) and moves away from the use of generic weightings (Banister, 1991; Stagno et al., 2007). Manzi et al. (2009) have recently shown that in distance runners the iTRIMP method relates better to changes in both aerobic fitness and endurance performance compared to Banister’s TRIMP.

Therefore the aim of this study was to compare the relationships between session-RPE, Banister’s TRIMP, a modified version of Stagno’s Team TRIMP, and iTRIMP, to changes in parameters of aerobic fitness in professional youth soccer players.

**Methods**

Fourteen professional youth soccer players agreed to participate in the study. However, due to playing commitments, injury and player compliance to training the sample was reduced to nine for the final analysis (N = 9; mean age 17 ± 1 years; stature 1.81 ± 0.05 m; body mass 72.9 ± 6.7 kg). The study was approved by the departmental ethics committee and conformed to the Declaration of Helsinki. Informed consent was provided by the players and the club prior to the commencement of the study. All participants played for the same club in the English Football League Youth Alliance, which is the second highest level of competition for youth players in England. On some occasions participants also played in the club’s reserve team in midweek. Players trained 4 to 6 times a week consisting of both technical training and physical conditioning. Training sessions were usually 60 to 120 mins in duration. Typically the team would play their competitive fixtures on a Saturday and would train twice on Mondays, Tuesdays, and Thursdays, which comprised of both technical and physical conditioning sessions such as sprint training, speed endurance training and high intensity aerobic training. The players had rest days on Sundays and Wednesdays and a light technical session before games on Fridays. Occasionally players would be called up to represent the reserve team, which resulted in their training being changed with recovery sessions being incorporated into their schedule. Players who didn’t play as often as others (substitutes) would typically do individual work to increase their weekly load. The team played six league matches over the six-week period, although there was a range of four to nine matches per player because of squad rotation and/or players being called up to the reserve team. Figure 1 shows the typical weekly training and match load for two players (one having played a single match during the week and the other having played two matches during the week), together with the mean (SD) iTRIMP over the six-week period.

Prior to the start of the training period the players performed two laboratory tests. Players avoided any strenuous exercise in the 24 hours prior to these tests. An incremental test on a motorised treadmill (Woodway EL G55, Weil an rhein, Germany) was conducted for determination of maximal heart rate ($HR_{max}$). The protocol consisted of 3 mins at 5 km·h$^{-1}$ and then increased at a rate of 1 km·h$^{-1}$·min$^{-1}$. Participants were instructed to run
until volitional exhaustion. The heart rate was recorded using recordable heart rate monitors (Polar Team System, Polar Electro, OY, Finland). The highest heart rate recorded was taken as HRmax. On a separate occasion players completed a modified lactate threshold test on a motorised treadmill (Woodway PPS 55sport, Weil an rhein, Germany) consisting of five stages at 8, 10, 12, 14, and 16 km · h⁻¹. Each stage was four minutes in duration with 1-min rest between stages where a fingertip capillary blood sample was taken and immediately analysed for blood lactate concentration (YSI 2300, YSI inc, Yellow Springs, OH). The dependent variables derived from this test were (1) the velocity at 2 mmol · L⁻¹ (vLT), (2) the heart rate at 2 mmol · L⁻¹ (LT_HR), (3) the velocity at 4 mmol · L⁻¹ (vOBLA), and (4) the heart rate at 4 mmol · L⁻¹ (OBLA_HR). These dependent variables were chosen as they are typically used to track changes in aerobic fitness and have previously been used in training load studies (McMillan et al., 2005; Manzi et al., 2009). The high reliability of these dependent variables has previously been reported (Weltman et al., 1990; Pfitzinger & Freedson, 1998). The mean heart rate in the last minute of each stage was used for the generation of TRIMP curves. Measurements of resting heart rate were also taken prior to exercise. Players were instructed to lie supine in the morning for 10 mins. The lowest 5 s heart rate measured was taken as the resting heart rate. At the end of the training period the players again performed the modified lactate threshold test.

Collection of training and match load data started at the beginning of the competitive season in September and continued for six weeks. Players were familiarised with use of the RPE scale and heart rate belts for two weeks prior to the start of the six-week training period during which training and match load data were collected. Heart rate was measured in all training sessions and matches throughout the six-week period. Approximately 30 mins after each training session or match, players reported their RPE as per the method of Foster et al. (2001). Heart rate data were downloaded using the Polar Precision software (Polar, OY, Finland) and analyzed using a bespoke spreadsheet (Microsoft Excel, Microsoft Inc).

Session-RPE was calculated as the RPE multiplied by the duration of the training session or match (Foster et al., 2001). Banister’s TRIMP (Banister, 1991) was calculated as described in formula 1:

\[
\text{Duration} \times \Delta HR \times 0.64e^{1.92x}
\]

where \(\Delta HR\) equals \(HR_{\text{exercise}} - HR_{\text{rest}}/HR_{\text{max}} - HR_{\text{rest}}\), \(e\) equals the base of the Napierian logarithms, \(x\) equals \(\Delta HR\), and 1.92 is a constant for males. Team TRIMP was modified from the original method because not all players met the ‘zoning’ criteria as used by Stagno et al. (2007). That is, the LT and OBLA for two of the players in our study fell outside zone 2 and 4 as described by Stagno et al. (2007), which highlights a limitation in their method. We therefore modified the method of Stagno et al. (2007) by using the exponential formula generated from the pooled data of all players, but without breaking up the subsequent equation into zones. The Team TRIMP equation as used in the present study is described in formula 2:

\[
\text{Duration} \times \Delta HR \times 0.2053e^{3.5179x}
\]

where \(\Delta HR\) equals \(HR_{\text{exercise}} - HR_{\text{rest}}/HR_{\text{max}} - HR_{\text{rest}}\), \(e\) equals the base of the Napierian logarithms, \(x\) equals \(\Delta HR\), and both 0.2053 and 3.5179 are constants for the whole group. The TRIMP for each heart rate measured at 5 s intervals was calculated and then all values summated to provide a TRIMP.
for the entire session. The same approach was taken for calculating iTRIMP, however each players formula was generated from their own data and hence each had their own equation as per the method of Manzi et al. (2009).

Descriptive results are presented as means ± standard deviations. After verification of underlying assumptions, pre and post vLT, vOBLA, LTHR, and OBLAHR were compared for differences using paired t-tests. Statistical significance was set at p < 0.05. The mean difference and 95% confidence intervals for the mean difference are also reported. Cohen effect sizes and their qualitative interpretation as defined by Hopkins (2002) (0–0.19 trivial; 0.2–0.59 small; 0.6–1.19 moderate; 1.2–1.99 large; ≥ 2.0 very large) are reported for all significant correlations. The Statistical Package for the Social Sciences (SPSS) (Version 16.0 for Windows; SPSS Inc, Chicago, IL) was used for conducting these analyses.

Results

The mean weekly training and match load (Arbitrary Units [AU]) for session-RPE, Banister’s TRIMP, Team TRIMP and iTRIMP were 2094 ± 466, 460 ± 98, 1538 ± 359 and 1830 ± 1805, respectively. There were no significant changes after the six-week period for vLT (mean change: −0.21 ± 0.98 km·h⁻¹; p = 0.54; CI: −0.96 to 0.54), vOBLA (mean change: 0.26 ± 0.53 km·h⁻¹; p = 0.16; CI: −0.14 to 0.67), LTHR (mean change: −2 ± 9 beats·min⁻¹; p = 0.51; CI: −9 to 5) or OBLAHR (mean change: 0 ± 7 beats·min⁻¹; p = 0.63; CI: −6 to 6). Figure 2 shows the correlations between mean weekly session-RPE with mean weekly Banister’s TRIMP (r = 0.75; p = 0.02; CI: 0.17 to 0.94; ES = large) and mean weekly Team TRIMP with mean weekly Banister’s TRIMP (r = 0.92; p < 0.001; CI: 0.66 to 0.98; ES = nearly perfect). There were no significant correlations between mean weekly iTRIMP and any of the other training load methods. Correlations of measures of training and match load against changes in fitness (vLT, vOBLA, LTHR, OBLAHR) resulted in only one significant correlation (Table I). The change in vLT was correlated to mean weekly iTRIMP (r = 0.67; p = 0.04; CI: 0.01 to 0.92; ES = large) (Figure 3).

Discussion

The novel finding in the present study was the significant correlation between iTRIMP and changes in vLT, which is consistent with the results reported by Manzi et al. (2009) who examined the same individualised training load method in distance runners. The lactate threshold has previously been found to be a sensitive indicator to changes in fitness in professional soccer players (Edwards, Clark, & Macfadyen, 2003). Manzi et al. (2009) also reported significant relationships between the iTRIMP method and running performance over 5,000 and 10,000 m. However ‘performance’ in soccer is not as easily determined, as factors such as skill and decision making also contribute to successful performance. Physical performance in terms of distance

![Figure 2](image-url)
covered or distance covered at high-intensity could potentially be used as it has previously (Helgerud, Engen, Wisløff, & Hoff, 2001). However, issues surrounding high match-to-match variability of such measures (Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007; Gregson, Drust, Atkinson, & Salvo, 2010) makes meaningful changes difficult to interpret, and is why we focused on examining the changes in aerobic fitness as opposed to performance.

The aim of the current study was to examine many of the previous methods of measuring the training and match load and relate them to changes in training status and not merely to each other as done previously (Impellizzeri et al., 2004; Alexiou & Coutts, 2008). Results from the present study indicate that mean weekly Banister’s TRIMP correlates with session-RPE and Team TRIMP. However, none of these methods were related to changes in aerobic fitness parameters, highlighting the limitations of using such analyses as a basis for the validation of a measure of internal training and match load. It has been suggested that only methods that show an association with changes in fitness or performance should be considered as measures of load for that particular group of athletes (Thomas, Nelson, & Silverman, 2005; Manzi et al., 2009). Previous studies have reported a correlation between session-RPE and heart rate based measures, namely Banister’s TRIMP (Impellizzeri et al., 2004; Alexiou & Coutts, 2008; Borresen & Lambert, 2008). We also found that session-RPE correlated with bTRIMP \( r = 0.75 \), although we correlated the mean weekly training loads and not individual sessions as was done in previous studies. While previous studies assessing the validity of session-RPE have suggested that RPE correlates well to criterion measures of intensity such as heart rate (Foster et al., 2001), this doesn’t necessarily mean that this extends to the calculation of ‘load’ of which intensity is just one term in an equation with two or more. There is also evidence that the correlation between RPE and other measures of intensity such as heart rate may not be as high as previously thought, particularly during intermittent exercise (Chen, Fan, & Moe, 2002). It could be that this variability in the relationship between RPE and heart rate partly explains the lack of relationship between session-RPE and iTRIMP.

Our results also showed that there was no significant change in aerobic fitness as determined by vLT and vOBLA. The period during which the data was collected for this study can be described as in-season and therefore the present results are similar to those previously described for youth soccer players (Impellizzeri et al., 2004; McMillan et al., 2005). The iTRIMP was not related to any of the other measures of load and showed large variation between players as indicated by the large standard deviation. This might suggest that the iTRIMP is more sensitive to individual differences, that is, how different players respond to the same external load. Although there was a significant relationship between iTRIMP and vLT, there was no such relationship with vOBLA. This is in contrast to the findings of Manzi et al. (2009) who reported a significant correlation of 0.74 between iTRIMP and the percentage speed improvement at OBLA. However, the runners in their study were partially detrained, resulting in quite large increases in both the speed at 2 mmol·L\(^{-1}\) (mean 21%) and 4 mmol·L\(^{-1}\) (mean 11%). As previously discussed, the players in our study were at the start of their competition period when large increases in fitness are not typically observed (McMillan et al., 2005). The use of a continuous test to assess changes in fitness in soccer players (Hill-Haas, Coutts, Rowsell, & Dawson, 2009). This has been shown with soccer referees where despite no significant improvement in maximal oxygen uptake, Yo-Yo Intermittent Recovery Test performance increased by ~30% over the course of a 12 week training period (Krstrup & Bangsbo, 2001). As such, future studies should aim to include more soccer-specific tests of aerobic fitness and/or physical performance. While there were no changes in mean vLT or vOBLA across the training period, mean changes are not reflective of the individual variation within the group. In the current study we observed individual increases in vLT of ~15% through to decreases of ~12%, a finding that has been observed in other training load studies (Gabbett & Domrow, 2007). Hence, the presence of a significant relationship between iTRIMP and vLT despite no change in mean vLT highlights the value in examining individual changes, rather than just group changes.

Although the iTRIMP method has been reported to relate to changes in fitness for both runners (Manzi et al., 2009) and now soccer players in the

Figure 3. Scatterplot showing the significant relationship between vLT and iTRIMP \( n = 9 \).
present study, closer examination of the correlations show that for similar training loads there are varied changes in fitness and vice versa. There is also a large variation in iTRIMP values as can be seen by the mean (±SD) of 1830 ± 1805 AU and also the spread of values in Figure 3. However, this also shows the large variability in individual response to training and match-play. The heterogeneous nature of the iTRIMP data also needs to be taken into consideration, particularly in relation to the correlation with vLT (Figure 3). Five of the nine players have relatively similar mean weekly iTRIMP values with the remaining three being much larger. This is in contrast to Manzi et al. (2009) who reported mean weekly iTRIMP values between ~550 and 800 AU. In this regard, we acknowledge the effect of our relatively small sample size on this correlation and its associated confidence intervals, and therefore suggest that the significant relationship between iTRIMP and vLT be confirmed by a larger study.

The significant correlation between iTRIMP and vLT (r = 0.67) in the current study shows that about 45% of the variation in aerobic training adaptation can be explained by variation in the iTRIMP. This would suggest that other training factors that have an effect on the vLT are not necessarily reflected in the iTRIMP. This is not unexpected, given the intermittent nature of soccer and the mix of aerobic and anaerobic demands during training and match-play. This also highlights the fundamental difference in the physiological demands of endurance and intermittent sports, as Manzi et al. (2009) reported a stronger correlation (r = 0.87) between the percentage change in the speed at 2 mmol · L⁻¹ and iTRIMP compared to the same relationship in the current study (r = 0.67). These differences could also be explained by factors such as initial fitness level, and/or genetics (Viru & Viru, 2000; Impellizzeri, Rampinini, & Marcora, 2005). Therefore the modelling of the individual dose-response relationship in soccer using contemporary approaches that have been used in endurance sports (Busso, 2003; Taha & Thomas, 2003) appears to be a logical step forward with the iTRIMP method. As the quantitative measurement of soccer ‘performance’ remains a matter of debate amongst researchers, the modelling of performance in soccer still remains a challenge. Furthermore a greater understanding of the dose-response relationship in soccer is required as the response to a training dose is not merely a fitness response but also a fatigue response (Banister, 1991). Although attempts to model endurance performance have been successful using other methods of quantifying load (Morton, 1990; Busso, 2003), the continuous nature of the exercise in those studies may have made the use of such methods appropriate. Given the findings of the present study researchers should consider if these methods are appropriate for intermittent sports. In addition to this if an individual’s training response is dependant on numerous factors (Viru & Viru, 2000; Impellizzeri et al., 2005) and different to other players, then it is logical to assume that their fitness and fatigue decay constants (Banister, 1991; Busso, 2003) used in the modelling process are also individual and that these will vary not only between players but also over time (Busso, 2003). Therefore future research in soccer should aim to gain a greater understanding and clarity of these issues in order to develop a successful modelling strategy.

One of the limitations of the present study and others (Stagno et al., 2007; Manzi et al., 2009) is the small sample size. Unfortunately in training studies there are a number of factors that can impinge on the sample size including small squad sizes, player compliance and injuries. As discussed in the Method section, the sample size at the start of this study was 14, but due to the factors listed that was reduced to nine prior to the final testing session. We have reported the precision of our results with 95% confidence intervals so the results of this study should be interpreted in light of those. While the duration of the study was only six weeks and also in-season, it seems that this period was enough for meaningful changes in aerobic fitness to occur. However, the duration of the training period and the time of the season also need to be kept in mind when interpreting the results of the current study. There is also a potential issue with the use of blood lactate measures for quantifying the change in aerobic fitness. It could be suggested that as the iTRIMP method itself uses the blood lactate response to ‘weight’ exercise intensity, then our use of vLT and vOBLA might result in a spurious correlation. While other studies (Stagno et al., 2007; Manzi et al., 2009) have used a similar method, future studies examining the changes in aerobic fitness in soccer players should examine this issue in more detail. Certainly, the use of additional laboratory and field tests that are more specific to soccer will provide a more complete picture regarding the validity of the iTRIMP method. One of the fundamental issues in relation to the validity of the iTRIMP method is the use of the exponential nature of the weighting applied to each heart beat based on an individualised blood lactate profile. As discussed by Akubat and Abt (2011), the question remains as to whether the lactate concentration observed in the blood is representative of the overall ‘stress’ imposed on the player’s body. While some authors suggest that exercise intensity and physiological stress increase in an exponential fashion similar to the manner in which blood lactate increases with exercise intensity (Norton, Norton, & Sadgrove, 2010), studies from comparative physiology suggest
a linear relationship (Kram & Taylor, 1990). Future studies examining the iTRIMP method (and other measures of training load) need to examine these fundamental questions, and particularly in relation to intermittent sports such as soccer.

In conclusion, the results of this study suggest that an individualised approach to monitoring internal training and match load (iTRIMP) related better than other methods to changes in lactate threshold in professional youth soccer players. Furthermore, to take into consideration the intermittent nature of soccer training and match play the use of mean heart rate does not appear to be as useful as shown by the lack of a relationship between Banister’s TRIMP and changes in vLTT or vOBLA. The use of heart rate monitors, calculation of iTRIMP and monitoring of training load does require both technical and scientific expertise that needs to be resourced, and these issues should be kept in mind if clubs wish to implement the findings of the current study.

References


