TARTU ÜLIKOOL

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# Measures of internal training load and its comparison with coach's intended rating of exertion in amateur soccer players.

Sisemise koormuse mõõtmise meetodid ning võrdlus treeneri koormushinnanguga amatöörjalgpalluritel

Magistritöö

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# TABLE OF CONTENTS

## ABBREVIATIONS

HR - Heart Rate

$\%HR_{max}$ - Percent of maximal heart rate

RPE - Rating of Perceived Exertion

RPEi - Individualized Rating of Perceived Exertion

RIE - Rating of Intended Exertion by coach

$VT_1$ – First ventilatory threshold

$VT_2$ – Second ventilatory threshold

## ABSTRACT

**Aim:** to investigate three different measures of internal training load and to compare these to the intended training load by the coach (Rating of Intended Exertion – RIE).

**Methods:** Internal training load using heart rate (HR), Rating of Perceived Exertion (RPE) and individualized Rating of Perceived Exertion (RPEi) in 19 amateur soccer players were measured. HR was measured by HR monitors and later using Lucia's Training Impulse (TRIMP) to calculate HR-based training load. To measure RPE, the subjects filled in a training diary approximately 30 minutes after a training session. Each of the methods was quantified into three intensity zones: light, moderate and intensive. We quantified the RPE data two ways: either with a method suggested by Seiler & Kjerland and using an individual method based on RPE during each load of the incremental test results.

**Results:** There was a strong correlation between both RPE measures and HR-based training load in total training load (r=.949) Relationships were somewhat weaker for light, moderate and intensive load between different methods (r=.49 to .67). The correlation between RPE and RPEi was significant for moderate and intensive zones (r=.63 to .71), but not the light intensity zone. The distribution of trainings was significantly different between training load measured by HR, RPE and RPEi measures, where HR based load seemed to underestimate the effort of training sessions, when compared to RPE and RPEi. The comparison of athletes and coaches mean ratings showed RIE being significantly lower in the intensivey zone (7.83±0.89 vs 8.6±1.18, *p<.001*), but session distribution showed a difference in light zone in addition.

**Conclusions:** HR based calculation of training load underestimates the load measured by athlete subjective rating in amateur soccer players. Furthermore, coaches seem to overestimate the difficulty of the light trainings and underestimate the difficulty of hard trainings.



Keywords: *internal training load; rating of perceived exertion (RPE); training impulse, intensity zone; athlete vs coach*

# LÜHIÜLEVAADE

**Eesmärk:** vaadelda kolme erinevat sisemise koormuse mõõtmise meetodit ning võrrelda neid treeneri koormushinnangutega.

**Metoodika:** Treeningkoormust mõõdeti pulsikelladega, lisaks sportlaste subjektiivselt hinnatud pingutust (*Rating of Perceived Exertion – RPE*) ja selle individualiseeritud versiooni (*RPEi*). Katses osalesid 19 amatöörjalgpallurit. Pulsikelladest saadud info korrutati Lucia treeningimpulsi (TRIMP) metoodika kohaselt koefitsentidega, et saada vastav treeningkoormus. RPE leidmiseks pidasid katsealused treeningpäevikuid, kus hindasid lõppenud treeningu raskust kümnepalliskaalal umbes 30 minutit pärast treeningu lõppemist. Iga meetodi tulemused jagati kolme intensiivsustsooni: kerge, mõõdukas ja raske. RPE andmed jagasime tsoonideks kahte erinevat viisi: kasutades Seileri ja Kjerlandi metoodikat, või leides tsoonid individuaalsete koormustestide põhjal.

**Tulemused:** Pulsi ja RPE meetoditega mõõdetud treeningkoormuse vahel oli tugev korrelatsioon (r=.949). Kolme erineva treeningtsooni vahel oli korrelatsioon mõnevõrra nõrgem (r=.49 kuni .67). RPE ja RPEi vahel oli korrelatsioon ainult mõõdukas ja raskes tsoonis (r=.63 kuni .71), aga mitte kerges. Treeningaja jagunemine tsoonidesse oli väga erinev kõigi kolme meetodi vahel. Pulsiga saadud andmete puhul oli ülekaalus kerges tsoonis veedetud aeg, mis aga jätab treeningust tõenäoliselt kergema mulje, kui seda tajub sportlane. Sportlaste hinnangud treeningute raskusele olid märgatavalt kõrgemad raskete treeningute puhul, võrrelduna treeneri hinnangutega (7.83±0.89 vs 8.6±1.18, p<.001), kuid tsoonidesse jagunemise puhul oli erinevus ka kerge treeningtsooni korral.

**Kokkuvõte:** Tulemused peegeldavad kõigi kolme meetodi mõnevõrrast sarnasust, kuid näitavad väga selget erinevust pulsiandmetes võrrelduna RPE andmetega. Kasutades pulsiandmeid võib saadud treeningkoormust amatöörjalgpallurite puhul pidada kergemaks, kui sportlaste hinnang. Samuti võis välja lugeda treeneri kalduvust alahinnata treeningute raskust.


Märksõnad: *sisemine koormuse suund; treeningimpulss; subjektiivselt mõõdetud koormus;*

# 1. LITERATURE OVERVIEW

## 1.1 Different methods of measuring training load

The use of different monitoring tools has been the norm for high-level athletes for decades. Whilst in individual sporting events, such as track and field, a coach or a team of coaches will be working with one single athlete. In team sports however, the focus is more on the whole line-up rather than an individual (Impellizzeri et al., 2004). This makes monitoring team sport athletes a challenge, because even if subjected to the same training loads, the physiological and psychological responses between athletes will differ (from individual to individual) (Impellizzeri et al.. 2004; Manzi et al., 2010). The training load prescribed by the coach (external training load) does not always correlate with the load felt by the athletes (internal training load).

The way external training load has been monitored before, was by using distance and pace as variables (Foster et al., 2017). For progress, coaches would prescribe a certain amount of kilometres to be fulfilled in a week and as the athlete would progress, the amount would increase (Foster et al., 2017). While external training load has always had a fairly simple measurable component to it, measuring internal training load has only begun to be possible thanks to a set of technological advancements. For example, it is linked to portable HR monitors, blood lactate analyzers and respiratory gas analyzers (Foster et al., 2017).

For a while, measuring HR has been the golden standard for internal training load in endurance sports (Foster et al., 2017). HR has shown relatively good accuracy and reliability for categorizing the intensity of a training session (Foster et al., 2001a; Foster et al., 2017; Impellizzeri et al.. 2004; Manzi et al., 2010). The reasoning behind this is HR's almost linear correlation with $VO_2$ in steady environments (Herman et al., 2006; Impellizzeri et al.. 2004). In team sports, such as soccer, a steady environment is a rarity. The game consists of many high-intensity bouts of high speed running, jumping, dribbling, shooting and tackling and so on (Bangsbo et al.. 2006; Di Salvo et al.. 2009). The ongoing, seemingly random, change of intensity and speed however makes it harder to quantify the training load by simply measuring HR (Impellizzeri et al., 2004; Scott et al.. 2013).

Since most team sports also have a component of unpredictability (in form of a ball or a puck), these sports utilize more open skills, in which quick decisions have to be made, which in turn leaves less time for actions, since first a decision on which action to perform needs to be made (Nuri et al., 2013) Making decisions requires quick and intense thinking, which provides an extra component of psychological load to trainings and matches (Buchheit et al., 2012; Impellizzeri et al., 2004). For example, the heart-rate of a soccer player will fluctuate between 65% and 98% of maximum heart rate tens of times during match play (Bangsbo et al., 2006). This has led to more elaborate heart rate related measures to be used, such as heart-rate variability (HRV) (Halson, 2014) and percent maximal heart rate ($\%HR_{max}$) (Halson, 2014; Malone et al., 2015). However, these methods all need specific equipment and the personnel trained to adequately analyze this data and make suggestions based on this data to the coaching staff.

To get around this, there have been several different algorithms quantifying HR-based training load, that do not require elaborate technology. One of the first of these was proposed by Edwards (1993), who divided HR values into five zones and tied them to a coefficient. This is called TRIMP - short for "Training Impulse" (Banister, 1991; Edwards, 1993). While Edwards' method has been proven to be valid (Foster et al., 2001a; Impellizzeri et al., 2004; Manzi et al., 2013; Scott et al., 2013; Wallace et al., 2009), there are also other methods. One of these was proposed by Lucia and colleagues (2003). This consists of dividing HR into three zones: light (HR below $VT_1$), moderate (HR between $VT_1$ and $VT_2$) and high intensity (HR above $VT_2$). Compared to Edwards' method, this method uses individual parameters from the athletes obtained in a laboratory (Impellizzeri et al., 2004). While Lucia et al. (2003) used this method on endurance cyclists, Impellizzeri et al. (2004) tried this method on soccer players and subsequently called it Lucia's TRIMP. In comparison of three different TRIMP methods, Lucia's method had the highest correlations to sRPE, when compared to Banister's or Edwards' TRIMP (Impellizzeri et al., 2004), hence our usage of this method.

### 1.2 Session-RPE method

Foster et al. (2001a) have suggested a new method to quantify internal training load. This method consists of players' subjective assessment of the effort demanded by a training session, rated on a scale of 1...10, with 10 being maximal exertion. This scale is shown in Table 1, originally developed by Borg (1982).

**Table 1.** Borg's Category Ratio (CR10) Scale (Borg 1982).

| Rating | Description |
|---|---|
| 1 | Very, very easy |
| 2 | Easy |
| 3 | Moderate |
| 4 | Somewhat hard |
| 5 | Hard |
| 6 | |
| 7 | Very hard |
| 8 | |
| 9 | |
| 10 | Maximal exertion |

The rating is then multiplied by the duration of the workout in minutes. The resulting unit is known as the arbitrary unit (AU). This gives an abstract measurement a value, which can be used to better monitor the internal load of a training session on each participant. An upside to this method, when compared to measuring HR is that it also takes psychological stress into account (Eston. 2012; Halson, 2014). Session-RPE has also been found to react quicker to changes in training load, when compared to objective measures, such as $\%HR_{max}$ or HRV (Buchheit et al., 2012; Saw et al., 2015), which makes it a really simple, cheap and useful tool for coaches. To quantify the difficulty of trainings, Seiler and Kjerland (2006) have used $VO_2max$ tests to determine ventilatory thresholds

($VT_1$ and $VT_2$) to which corresponding BORG values were assigned. These zones are shown in Table 2.

**Table 2**. Intensity zones on the BORG CR10 scale (Seiler & Kjerland, 2006)

| RPE value | VT Zones |
|---|---|
| 1...4 | $<VT_1$ |
| 5...6 | $VT_1...VT_2$ |
| 7...10 | $>VT_2$ |

VT - ventilatory threshold; RPE - rating of perceived exertion

The authors used this method on four different types of training sessions: long distance, interval training, threshold sessions and speed sessions. Strength training sessions were not used. A total of 60 training sessions was analyzed. The correlation between CR10 and heart rate zones in high level international skiers was very high and there were no significant differences between the amount of trainings done in different intensity zones if alternative methods were used, meaning this method works very well for endurance athletes (Seiler & Kjerland, 2006).

### 1.3 Training load monitoring in soccer

While HR monitoring has been used widely in endurance sports and team sports, it also has a downside - it is prohibited to use external gear during competitive play. This means, that a considerable amount of weekly training load will be unaccounted for (Impellizzeri et al., 2004). Therefore, in order to wholly understand the load athletes are exposed to, in soccer, additional methods, such as sRPE are recommended (Foster et al., 2001a; Hill-Haas et al., 2011; Impellizzeri et al., 2004; Manzi et al., 2010). This method has so far yielded good results when used in different team sports, such as soccer, rugby or Australian-rules football (Coutts et al., 2008; Lovell et al., 2013; Weston et al., 2015). However, in male elite soccer players the correlation between these two factors was significantly lower, when compared to endurance athletes (Algroy et al., 2011). For example, the time spent in a certain heart rate zone was significantly shifted towards lower intensity zones, when compared to sRPE data. This means, that in elite soccer players, heart rate based training zones might not be adequate for monitoring soccer training. Similar conclusions have been drawn by Brink and colleagues (2010), who stated, that even though a linear relation between HR and $VO_2max$ exists during aerobic exercise, in intermittent sports (such as soccer), merely measuring HR could lead to an underestimation of training intensity, because of frequent anaerobic movements.

While there have been multiple studies investigating the validity of this method on professional soccer players (Casamichana et al., 2013; Impellizzeri et al., 2004; Malone et al., 2015; Scott et al., 2013; Thorpe et al., 2016), this association in amateur players is still unknown. This is, because in contrast to elite athletes, amateur players can have additional school or work sessions adding to life stress (Brink et al., 2017) and most likely, the character of trainings in amateur teams differs from that of professional teams, because of the lower skill level of the athletes (Dellal et al., 2011).

To be properly used for training load modification, sRPE can be augmented with a Rating of Intended Exertion (RIE), which is to be given by a coach before training and/or a Rating of Observed Exertion (ROE), given after a training session (Brink & Frencken, 2018). These have been used on a scale of 6 to 20 (Brink et al., 2017) along with RPE being on the same scale. This because of the school grading system being on a 10 point scale, which in turn means, that young athletes might want to avoid using lower grades (Brink et al., 2017). When this is not a problem, the category ratio 10 point scale can be used for each measurement instead (Foster et al., 2001b). However, Brink and colleagues (2017) did find, that both RIE and ROE were significantly lower than RPE. This shows, that it is very difficult for a coach to evaluate the effect, that a training session can have on athletes (Brink et al., 2017). Still, measuring RIE and/or ROE in addition to RPE could potentially prove to be a useful training load monitoring tool for coaches of both amateur and elite athletes.

# 3. AIM OF THE PAPER

The aim of this paper was to investigate three different methods of measuring internal training load and the interactions between them, as well as to compare these methods to the coaches intended training load.

To support the aim, the following tasks were created:

1. To calculate respective RPE and heart rate at aerobic and anaerobic threshold
2. To compare different internal load measures based on heart rate and session rating of perceived exertion and individualized session of rating of perceived exertion.
3. To compare coaches intended rating of training load (RIE) to the training load perceived by the athletes (RPE).

# 4. METHODS

## 4.1 Research group

This study was a part of a bigger research project titled "Internal and external training load concepts for training monitoring in adolescent athletes". The whole project consists of athletes from three different sports disciplines: soccer, swimming and cross-country skiing. The current study makes up half of the soccer discipline research along with one other Master's thesis comprised from the same collected data.

## 4.2 Subjects

The subjects of this study were amateur soccer players (n=19), playing in the First League of Estonian Football Association. All subjects played for one club and all of the first-team players were involved in the study. The age range of the subjects was 15-28. The subjects had four team training sessions and one competitive match per week, or in case of two matches a week, three training sessions. Mean training hours were 6 hours a week in one matchday weeks and 4.5 hours in two matchday weeks. The anthropometric parameters of the subjects are shown in Table 3. For player-coach training load analysis, the first team coach volunteered his training load data.

**Table 3.** Mean anthropometric measures of the subjects

| Parameters | Mean ± SD |
|---|---|
| Age (y) | 20.3±4 |
| Height (cm) | 179.4±7.9 |
| Weight (kg) | 73.6±9.6 |
| BMI (kg/m$^2$) | 22.8±1.6 |
| BF% | 14.8±2.8 |
| $VO_{2max/kg}$ (mL/(kg·min)) | 55.2±3.4 |

BMI- Body Mass Index; BF% - Body fat percentage; $VO_{2max/kg}$ - Maximal oxygen uptake per kilogram bodyweight

## 4.3 Testing procedures

Before testing, the athletes had their weight (A&D Instruments, UK) ±50 grams and height (Martin metal anthropometer) ±0.1 cm measured in the laboratory and their body composition measured via DXA (Hologic Discovery, Marlborough, USA). This method was used to register the changes in body mass, body fat percentage and muscle mass before and after the collection of data.

The players then had to undergo an incremental exercise test on a treadmill (h/p/cosmos quasar med 3p, Nussdorf (Traunstein), Germany). The gradient of the treadmill was set on 1% throughout the whole test. The starting speed was set at 7 km/h and was increased by 0.5 km/h every minute. During this test we measured the players' maximal oxygen uptake ($VO_2max$) and ventilatory thresholds ($VT_1$ and $VT_2$, respectively) and used those parameters to calculate heart-rate intensity zones (per Impellizzeri et al., 2004) to be used in training. To define $VO_2max$, we used a period of 30 sec, where the average oxygen uptake was highest. For $VT_1$, the defining point was, when there was a clear increase in $V_E/VO_2$, but not in $V_E/VCO_2$. $VT_2$ was defined as the intensity, where $V_E/VCO_2$ also began to increase (b et al., 2011). Maximal running time was used as an indicator of physical performance.

In addition to objective performance and intensity parameters, the participants evaluated the level of their effort subjectively, using the modified Borg CR10 scale (Foster et al., 2001a), which they were prompted to do at the end of every speed increment. The thresholds ($VT_1$ and $VT_2$) were compared to the HR signal and the CR10 value given at the same time to then calculate individual RPE zones.

We used both, the individual RPE zones (RPEi) and the zones designed by Seiler & Kjerland (2006), in order to investigate, whether there would be differences between the two, when compared to HR data. For sRPE we multiplied the length of a training session (in minutes) by the CR10 rating (1...10) given by the athlete to that same training session, by answering the question "How hard was your workout?" approximately 30 minutes after the workout (Foster et al., 2001a). For HR-based training load (or Lucia's TRIMP), the time spent in each training zone was multiplied by either 1, 2 or 3 for light, moderate and intensive zones, respectively (Impellizzeri et al., 2004). The comparison of each training zone described by different measuring methods is shown in Table 4.

**Table 4.** Breakdown of different training zone measuring methods and the description of each.

| VT Zones | HR value | RPE value | RPEi value | Description |
|---|---|---|---|---|
| $<VT_1$ | $HR < VT_1$ | 1...4 | $RPE < VT_1$ | **light** |
| $VT_1...VT_2$ | $VT_1<HR<VT_2$ | 5...6 | $VT_1<RPE<VT_2$ | **moderate** |
| $>VT_2$ | $VT_2<HR$ | 7...10 | $VT_2<RPE$ | **intensive** |

VT - ventilatory threshold; HR - heart rate; RPE - rating of perceived exertion; RPEi - rating of perceived exertion individualized

## 4.4 Training related data collection

Data was collected during a ten-week period between March (start of the season) and June 2017 (mid-season break). In order to collect training data, participants recorded training diary daily. The diary had logs for every single exercise session the players participated, not just team trainings. The training logs consisted of RPE evaluations subjectively given by the athletes and the duration of the training. In order to compare the subjective ratings given by the athletes to the aim of team training sessions, the trainings were also graded by the head coach of the team, who gave his ratings before each session. The subjected ratings were later compared to recognize, whether this could be used in practice by a coach to monitor training loads.

Additionally, the players wore HR monitors (chest strap) to monitor their heart rate (Polar M400, Polar Electro Oy, Finland).

The training plan was created by the team's coaches and there was no intervention to these procedures. Following the data collection period, the laboratory tests were run again.

The participants signed a written letter of consent (athletes under the age of 18 had them signed by a parent or guardian). The research was approved by the Ethical Committee of Tartu University (267T-20).

## 4.5 Analysis of training load data.

The collected data was initially analyzed as follows:

First, the HR data from the watches was examined, and corrupted files were excluded or treated for correct data, if possible. For example, if the subject had forgot to turn off the recording after practice, i. e the file included the drive home, the irrelevant part was removed based on the time of HR sampling. Irrelevant training files were also excluded, for example training files of a different sport. In total, 370 training sessions from 19 players and the coach were extracted. Then, the training diaries containing sRPE were summarized, and the logs were matched with the HR files for each training session. The sessions where either sRPE or HR data was missing were all excluded. After this procedure, data was collected from 274 training sessions and the average time spent in trainings was 1937 (±726) minutes.

## 4.6 Statistical analysis

For statistical analysis IBM's SPSS (Statistical Package for the Social Sciences) was used. Means and standard deviations of the parameters were calculated. The normality check for the data was done and as part of the data were not normally distributed, Spearman's rank correlation coefficient was used, Statistical significance was set at $p<0.05$. Additionally, to compare means between two groups, Wilcoxon matched pairs signed-rank test was used.

# 5. RESULTS

## 5.1 Correlations between HR-based training load and sRPE

First, correlations between HR and RPE measures were analyzed. We compared HR-based training load to the time spent in different RPE-measured training zones. We found significant correlations between training load in light intensities, ($r = .669$, $p < .001$) as well as time spent in moderate training zone ($r = .531$, $p = .019$) and intensive training zone ($r = .490$, $p = .033$) to the HR based training load. There was also a significant correlation ($r = .478$, $p < .038$) between HR-based load and individualized RPE training load in moderate training zone, but not in light ($r = .419$, $p = .074$) or intensive ($r = .232$, $p = .340$) training zones. Between RPE and RPEi, a strong correlation was found between moderate ($r = .713$, $p < .001$) and intensive ($r = .637$, $p = .003$) training zones, but not in light ($r = .446$, $p = .056$) training zone. In addition, there was a very strong correlation between the total training load, when measured by HR or RPE ($r = .949$, $p < .001$).

## 5.1 Difference between time spent in different training zones

To analyze the differences between training time distribution, measured by either HR and RPE or RPEi, we eliminated the subjects, who's correspondence to trainings was low and whose training load was less than a total of 6000AU. As a result, the number of subjects was decreased to 10 for this analysis. The distribution between HR and RPE minutes is shown in Figure 1, and Figure 2 shows the different distribution of training minutes between methods of RPE and RPEi. The RPE and RPEi distributions were significantly different in light and intensive training zones (28.7% vs 15% and 27.5% vs 43.2% in light and intensive zones, respectively) ($p < 0.05$), but no difference was found in moderate training zone (43.8% vs 41.7%).

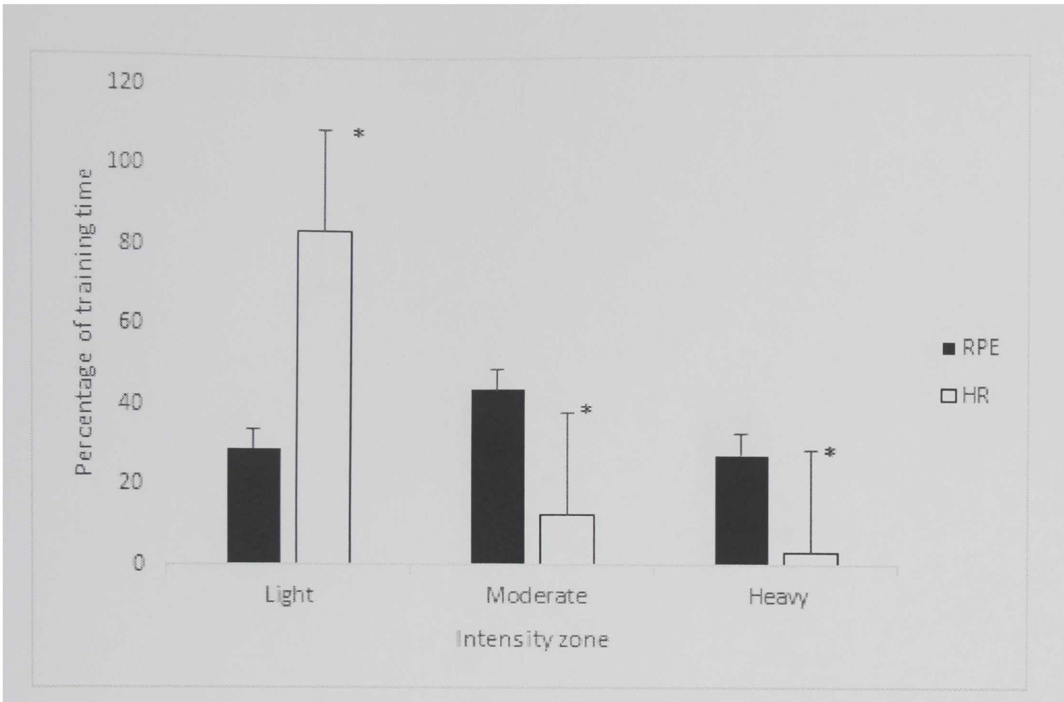


**Figure 1.** Percentage of practice time spent in each training zone, differences between HR and RPE. * - Significant difference between groups ($p<0.05$). *RPE - Rating of perceived Exertion; HR - Heart Rate*

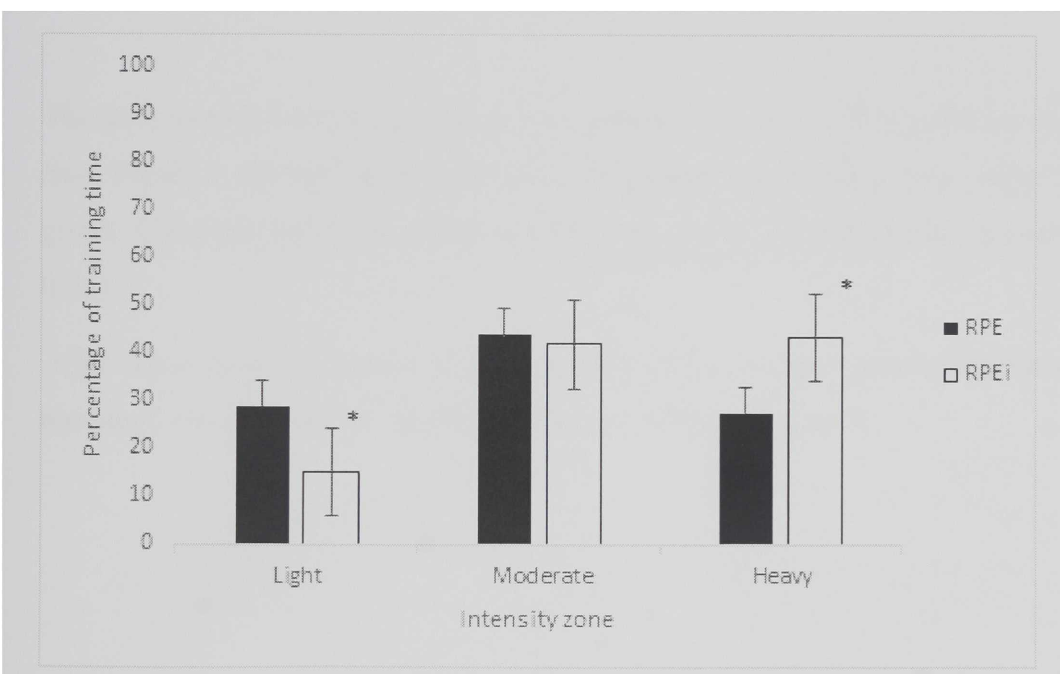


**Figure 2.** Percentage of practice time spent in each training zone, differences between RPE and RPEi. * - Significant difference between groups ($p < 0.05$). *RPE - Rating of perceived exertion; RPEi - Individualized Rating of Perceived Exertion*

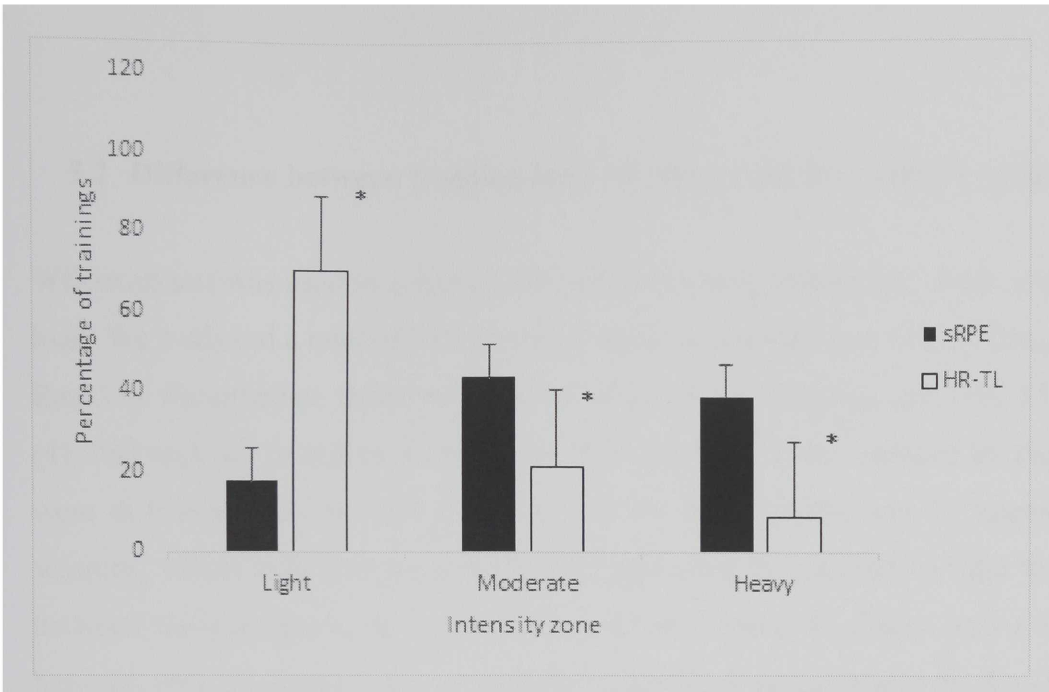


**Figure 3.** Distribution of training load between different intensity zones, measured by RPE and HR methods.. * - Significant difference between groups, ($p < 0.05$). sRPE - Session Rating of Perceived Exertion; HR-TL - Heart rate-based training load.

The time spent in each training zone was different between HR and RPE measures. As can be seen from Figure 1, the HR graph is shifted towards the light training zone, when compared to the RPE graph. There is significant difference between the two distributions in every training zone ($p < 0.05$).

After calculating HR-based training load, the difference between the distributions of training load remained significant in all training zones ($p < 0.05$), (Figure 3).

### 5.2 Difference between training load ratings in coach vs athlete comparison

Wilcoxon test was used to compare the means between athlete and coach given ratings of training load. We analyzed a total of 370 trainings, each categorised into one of three zones by RPE value. Rated by the athletes, there were a total of 110 light trainings (29.7%), 153 moderate trainings (41.4%) and 107 intensive training (28.9%) sessions. When assessed by the coach, the trainings were distributed to 141 light (38.1%), 148 moderate (40%) and 81 intensive training (21.9%) sessions, which indicated significant differences for the amount of light and intensive trainings between the perception of a coach and athlete (Figure 4). There was a significant difference between only the mean value of intensive training sessions graded by the athletes and the coach (7.83±0.89 vs 8.6±1.18, respectively, $p < 0.001$). Interestingly, the coach assessments for the light training sessions only had the grades 3 or 4, whereas the athletes had repeatedly graded training sessions with a 1 or 2.

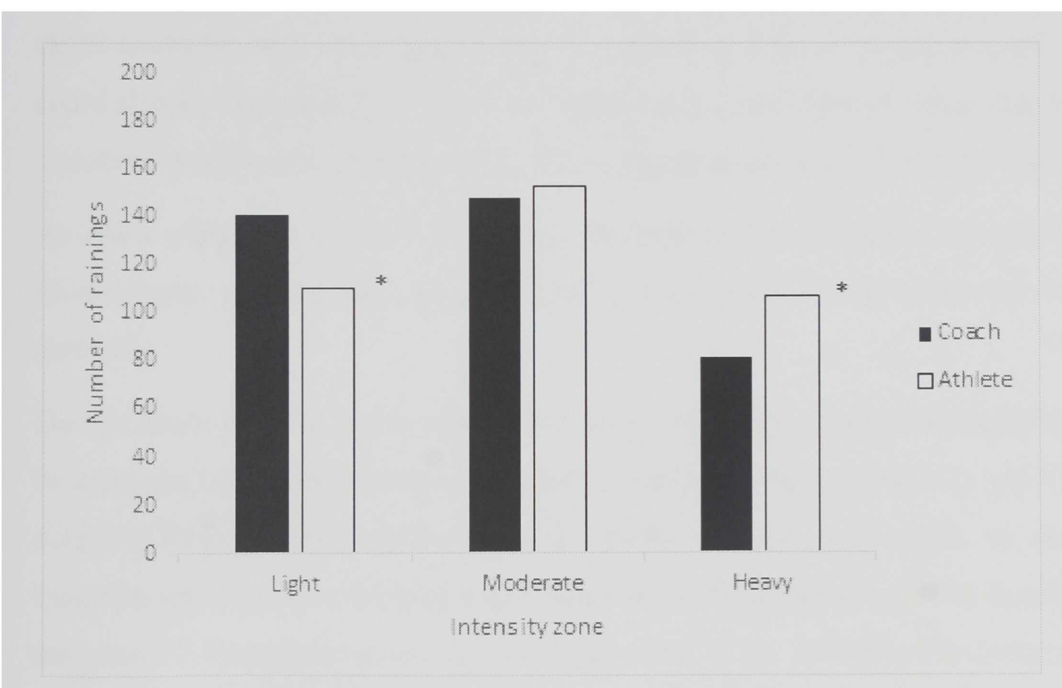


**Figure 4.** Distribution of training intensity zones, rated by athletes and the coach. * - Significant difference between groups, $p < 0.05$)

# 6. DISCUSSION

## 6.1 Correlations between HR-based training load and sRPE

The aim of this study was to measure internal training load using three different methods - HR, RPE and RPEi. Our results indicate a relatively strong correlation between all the measures, but when more specifically investigating the data, clear discrepancy between HR and the two RPE measures could be seen.

The HR-based training load of each training zone had a moderate correlation to the RPE measured training load in each zone ($r = .49$ to $.67$; $p < 0.05$). A strong correlation between HR-based training load and sRPE has been shown in previous studies (Foster et al., 2001a; Impellizzeri et al.. 2004; Scott et al., 2013; Wallace et al., 2009). In our study, the total training load measured by HR and RPE also had a strong correlation ($r = .949$, $p < .001$). This way of measuring HR training load has been done previously by Impellizzeri et al. (2004), as well as using the HR zones suggested by Edwards (1993) as a percentage of $HR_{max}$. It could be discussed, whether using Edwards' (1993) or Banister's (1991) TRIMP would have yielded different results, but limited by the low volume of this study. we did not run the comparisons between these methods. This gives further proof that sRPE could be used to measure changes in training load of soccer players. Hence, this method could also be used instead of Edwards' (1993) five-zone method, which has proven to be valid in a soccer setting before (Foster et al., 2001a; Impellizzeri et al.. 2004; Scott et al., 2013).

As a new addition to research, our study also indicated a correlation between HR and RPE in each training zone, not just solely the total training load, which further shows the similarity of these two methods.

Derived from Seiler & Kjerland's (2006) study, we further tried individualizing RPE training zones by using the incremental running test, during which we determined $VT_1$ and $VT_2$ and measured the subjects' RPE for each incremental load during the test. As a result, we personalised the light, moderate and intensive training zones from Seiler & Kjerland's (2006) distribution (1-4 light, 5-6 moderate, 7-10 intensive) to ones corresponding to the individual incremental test results. This means, for example. a player who in the incremental test gave a Borg rating of 5 during the time he surpassed $VT_1$, his light training zone would incorporate ratings from 1-5. Although our group of athletes was relatively young, it has been shown before. that athletes over the age of 15-16 are mature enough to comprehend the RPE method and give according ratings (Barroso et al., 2014). When comparing RPEi to HR-based training load, we found significant correlation only in the moderate training zone, but not in light and intensive training zones.

The comparison of RPE training zones, as per Seiler & Kjerland (2006), to the individual ratings from the incremental test (RPEi) revealed a strong correlation between moderate ($r = .713$; $p < .001$) and i ($r = .637$; $p = .003$) training zones, with no correlation for light zone ($r = .443$; $p = .056$).

However, since while we did measure two different types of subjective training load (RPE and RPEi), we do not have the power to rate the accuracy of these methods. Therefore, it could serve as a focus for future research to compare these methods to other, valid measurements and find out which one is more accurate in soccer practice.

### 6.2 Difference between time spent in different training zones

In comparison of time distribution, based on different measuring methods, our results showed a clear discrepancy between HR and RPE methods, when used in amateur soccer trainings. This difference was significant between all three training zones ($p < 0.05$). This is in accordance with some previous research, that have also shown that using HR will shift a huge amount of time towards the light training zone (Algroy et al., 2011, Foster et al., 2001a) and that the inclusion of psychological and physiological load caused by high-intensity intervals and decision making is better seen in RPE results (Algroy et al., 2011, Buchheit et al., 2012, Scott et al., 2013).

The discrepancy might be further influenced by the fact that these measurements are only compared by the sum of time spent in each particular intensity zone, since HR monitors give feedback for every second, but RPE ratings can only be collected for the whole session. Hence, in RPE ratings, one whole training session is assumed to one single training zone, compared to HR data having certain amount of time spent in each zone for one session.

Whilst there exists a strong correlation between the total training load, the distribution between three intensity zones suggests a tendency to underestimate the difficulty of trainings when using HR-based training load.

### 6.3 Difference between training load ratings in coach vs athlete comparison

When analysing the difference between coaches (RIE) and athletes ratings (RPE) of training session intensity we found a statistically significant difference only between intensive training zone ratings, but not between light and moderate training zone ratings. However, the difference was close to be significant also for light training load, which is in conformity with findings of Foster and colleagues (2001b). While we did compare the means of intensive training sessions and the mean of coaches ratings was higher (8.6±1.18) than the athletes' (7.83±0.89), the number of training sessions in the intensive training zone was higher for the athletes (n=107) than for the coach (n=81). With more than 20 extra sessions in the group, this inevitably changes the dynamic that goes into measuring the mean.

The fact, that athletes rated more trainings as "intensive" has been shown multiple times before in literature (Brink et al., 2017; Brink & Frencken, 2018; Wallace et al., 2009). In our results, only the intensive zone was rated significantly differently, which hints on the possible suitability of this method for less intensive training sessions. However, more research on this exact method is warranted.

Brink and colleagues (2017) have also stated that the coaches do not underestimate the training load when evaluating it before trainings (RIE), but also shortly after the training sessions. However, the difference between RIE and RPE was found to be bigger than the difference between the rating after the training and RPE (Brink et al., 2017), even though both of these values decreased after giving the coach feedback and instructions (Brink & Frencken, 2018). Therefore, in the future, it might be reasonable to have the coaches also rate the training load of the session shortly after the session, in addition to beforehand (Brink et al., 2017).

The difference in training zone distribution between coach and athletes, that we found, also supports the notion, that the perceived exertion of a training session by the athletes surpasses the coaches intended training load (Martínez-Santos et al., 2015), however there have been studies, that found no difference between RPE and RIE (Redkva et al., 2017). Moreover, additional personal factors in the athletes' everyday life, like school stress or family issues, are unknown to the coach and cannot be factored in, when designing training sessions, but will most likely have an effect on the perceived exertion (Brink et al., 2017). In addition to this, the results from our research might be affected by the different performance level of the amateur players, since players who have better technical skills and perhaps have a higher physical work capacity, could sense the trainings as easier, compared to players who are not as capable. Finally, there might be a tendency from the athletes to give more effort on light training days, a phenomenon that has been noted before in endurance athletes (Foster et al., 2001b).

More factors, that could affect the results of our research and also future research, are related to player position. For example, in many teams, goalkeepers do not take part of the conditioning trainings the way, that outfield players do. They do not participate in interval training, instead they have position specific exercises instead (i.e reaction time training). The differences between players of different playing positions should also be taken into consideration when possible.

Furthermore, attempting to cater to every athletes' needs is nearly impossible in a large team, since recovery between training sessions is an individual's responsibility and requires sufficient sleep and nutrition, which is out of the team staff's control, especially in amateur teams. Factors like these make rating players' internal training load very difficult, even when the external training load applied is the same (Brink et al., 2017, Gaudino et al., 2013).

## 6.4 Implications for further research

The importance of monitoring internal training load is of high importance, because, as previous research (Brink et al., 2017; Brink & Frencken, 2018; Wallace et al., 2009) has shown, athletes perception of the training load is very much different from the external training load prescribed by the coach. Secondly, by only monitoring external training load, the effect of the applied load on the athlete is unknown and the risk of overreaching or even overtraining syndrome is higher (Foster et al., 2017). In a team sport such as soccer, it is relatively difficult to quantify external training load (Gaudino et al., 2013), because this requires GPS sensors to measure the amount of high-intensity bouts in the training session. In addition, external training load gives a fairly poor insight to how much time the players need to recover between training sessions and especially before competitive matches (Impellizzeri et al., 2004). Using RPE to guide the design of training sessions is recommended, because in comparison to HR methods, this requires no specific equipment and thus match data can also be obtained.

This puts more pressure on future research to investigate methods of measuring internal training load and also possibly methods to more accurately measure intended or observed training load.

## 6.5 Study limitations

There are several limitations on this study.

First, the correspondence of the athletes in filling in the training diary and wearing their HR monitors to trainings was relatively low for some of the subjects. This in turn made it impossible to do a proper intrasession analysis for the whole team and making the variation of inter-individual training load relatively high. In addition, this made us set a lower threshold on the total training load (6000AU), equivalent of approximately 6 high-intensity football sessions (Gabbett, 2016), for statistical analysis, to keep standard deviations in limits.

Next, the low amount of subjects in this study did not enable us to include player position specific analysis or intercycle analysis between micro- or mesocycles.

The inclusion of only one team and one coach restricts generalizing the results, especially on coach-related research.

Because of the design of the study, it is complicated to involve a control group, since there was no intervention of training methods involved. In a setting like a soccer team, it is highly unlikely a study of this design can be done with a control group.

# 7. CONCLUSIONS

Based on this Master's thesis, the following conclusions were made:

1. HR-based training load was highly related to subjectively rated difficulty of a training session (sRPE).
2. The distribution of training load when using HR-based measurements significantly underestimates the difficulty of trainings when compared to the athletes' perception (RPE and RPEi)
3. There is a tendency for coaches to underestimate the intensity of their intensive training sessions (RIE) when compared to athletes perception of these sessions (RPE), and to overestimate the intensity of light training sessions, compared to RPE.

## REFERENCES


1. Algrøy EA, Hetlelid KJ, Seiler S, Pedersen JI. Quantifying training intensity distribution in a group of Norwegian professional soccer players. International Journal of sports physiology and performance. 2011 Mar;6(1):70-81.
2. Bangsbo J, Mohr M, Krustrup P. Physical and metabolic demands of training and match-play in the elite football player. Journal of sports sciences. 2006 Jul 1;24(07):665-74.
3. Banister EW. Modeling elite athletic performance. Physiological testing of elite athletes. 1991:403-24.
4. Barroso R, Cardoso RK, Carmo EC, Tricoli V. Perceived exertion in coaches and young swimmers with different training experience. International journal of sports physiology and performance. 2014 Mar;9(2):212-6.
5. Borg GA. Psychophysical bases of perceived exertion. Medicine and Science in Sports and Exercise. 1982 Jan 1;14(5):377-81.
6. Brink MS, Frencken WG. Formative feedback for the coach reduces mismatch between coach and players' perceptions of exertion. Science and Medicine in Football. 2018 Apr 7:1-6.
7. Brink MS, Kersten AW, Frencken WG. Understanding the mismatch between coaches' and players' perceptions of exertion. International journal of sports physiology and performance. 2017 Apr;12(4):562-8.
8. Brink MS, Nederhof E, Visscher C, Schmikli SL, Lemmink KA. Monitoring load, recovery, and performance in young elite soccer players. The Journal of Strength & Conditioning Research. 2010 Mar 1;24(3):597-603.
9. Buchheit M, Simpson MB, Al Haddad H, Bourdon PC, Mendez-Villanueva A. Monitoring changes in physical performance with heart rate measures in young soccer players. European journal of applied physiology. 2012 Feb 1;112(2):711-23.
10. Casamichana D, Castellano J, Calleja-Gonzalez J, San Román J, Castagna C. Relationship between indicators of training load in soccer players. The Journal of Strength & Conditioning Research. 2013 Feb 1;27(2):369-74.
11. Coutts AJ, Reaburn P. Monitoring changes in rugby league players' perceived stress and recovery during intensified training. Perceptual and motor skills. 2008 Jun;106(3):904-16.

12. Dellal A, Hill-Haas S, Lago-Penas C, Chamari K. Small-sided games in soccer: amateur vs. professional players' physiological responses, physical, and technical activities. The Journal of Strength & Conditioning Research. 2011 Sep 1;25(9):2371-81.
13. Di Salvo V, Gregson W, Atkinson G, Tordoff P, Drust B. Analysis of high intensity activity in Premier League soccer. International journal of sports medicine. 2009 Mar;30(03):205-12.
14. Edwards S. The heart rate monitor book. Medicine & Science in Sports & Exercise. 1993 May 1;26(5):647.
15. Eston R. Use of ratings of perceived exertion in sports. International journal of sports physiology and performance. 2012 Jun;7(2):175-82.
16. Foster C, Florhaug JA, Franklin J, Gottschall L, Hrovatin LA, et al. A new approach to monitoring exercise training. The Journal of Strength & Conditioning Research. 2001 Feb 1;15(1):109-15. (a)
17. Foster C, Heimann KM, Esten PL, Brice G, Porcari JP. Differences in perceptions of training by coaches and athletes. South African Journal of Sports Medicine. 2001 Jun 1;8(2):3-7. (b)
18. Foster C, Rodriguez-Marroyo JA, de Koning JJ. Monitoring training loads: the past, the present, and the future. International journal of sports physiology and performance. 2017 Apr;12(Suppl 2):S2-2.
19. Gabbett TJ. The training-injury prevention paradox: should athletes be training smarter and harder?. British Journal of Sports Medicine. 2016 Jan 12:bjsports-2015.
20. Gaudino P, Iaia FM, Alberti G, Strudwick AJ, Atkinson G, et al. Monitoring training in elite soccer players: systematic bias between running speed and metabolic power data. International Journal of Sports Medicine. 2013 Nov 1;34(11):963-8.
21. Halson SL. Monitoring training load to understand fatigue in athletes. Sports Medicine. 2014 Nov 1;44(2):139-47.
22. Herman L, Foster C, Maher MA, Mikat RP, Porcari JP. Validity and reliability of the session RPE method for monitoring exercise training intensity. South African Journal of Sports Medicine. 2006 Mar 1;18(1):14-7.
23. Hill-Haas SV, Dawson B, Impellizzeri FM, Coutts AJ. Physiology of small-sided games training in football. Sports medicine. 2011 Mar 1;41(3):199-220.

24. Impellizzeri FM, Rampinini E, Coutts AJ, Sassi AL, Marcora SM. Use of RPE-based training load in soccer. Medicine & Science in sports & exercise. 2004 Jun 1;36(6):1042-7.
25. Lovell TW, Sirotic AC, Impellizzeri FM, Coutts AJ. Factors affecting perception of effort (session rating of perceived exertion) during rugby league training. International journal of sports physiology and performance. 2013 Jan;8(1):62-9.
26. Lucia AL, Hoyos JE, Santalla AL, Earnest CO, Chicharro JL. Tour de France versus Vuelta a Espana: which is harder?. Medicine and Science in Sports and Exercise. 2003 May;35(5):872-8
27. Malone JJ, Di Michele R, Morgans R, Burgess D, Morton JP, et al. Seasonal training-load quantification in elite English premier league soccer players. International journal of sports physiology and performance. 2015 May;10(4):489-97.
28. Manzi V, Bovenzi A, Impellizzeri MF, Carminati I, Castagna C. Individual training-load and aerobic-fitness variables in premiership soccer players during the precompetitive season. The Journal of Strength & Conditioning Research. 2013 Mar 1;27(3):631-6.
29. Manzi V, D'ottavio S, Impellizzeri FM, Chaouachi A, Chamari K, et al. Profile of weekly training load in elite male professional basketball players. The Journal of Strength & Conditioning Research. 2010 May 1;24(5):1399-406.
30. Martínez-Santos R, Los Arcos A, Sautu L. Factors of disagreement between coaches and players of a high-level basketball team when assessing individual session perceived exertions. Revista de psicología del deporte. 2015;24(3):0069-72.
31. Nuri L, Shadmehr A, Ghotbi N, Attarbashi Moghadam B. Reaction time and anticipatory skill of athletes in open and closed skill-dominated sport. European journal of sport science. 2013 Sep 1;13(5):431-6.
32. Redkva PE, Gregorio da Silva S, Paes MR, Dos-Santos JW. The relationship between coach and player training load perceptions in professional soccer. Perceptual and motor skills. 2017 Feb;124(1):264-76.
33. Saw AE, Main LC, Gastin PB. Monitoring the athlete training response: subjective self-reported measures trump commonly used objective measures: a systematic review. British Journal of Sports Medicine. 2015 Sep 9:bjsports-2015.

34. Scott BR, Lockie RG, Knight TJ, Clark AC, Janse de Jonge XA. A comparison of methods to quantify the in-season training load of professional soccer players. International Journal of Sports Physiology and Performance. 2013 Mar;8(2):195-202.
35. Seiler KS, Kjerland GØ. Quantifying training intensity distribution in elite endurance athletes: is there evidence for an "optimal" distribution?. Scandinavian journal of medicine & science in sports. 2006 Feb 1:16(1):49-56.
36. Thorpe RT, Strudwick AJ, Buchheit M, Atkinson G, Drust B, et al. Tracking morning fatigue status across in-season training weeks in elite soccer players. International journal of sports physiology and performance. 2016 Oct;11(7):947-52.
37. Wallace LK, Slattery KM, Coutts AJ. The ecological validity and application of the session-RPE method for quantifying training loads in swimming. The Journal of Strength & Conditioning Research. 2009 Jan 1;23(1):33-8.
38. Weston M, Siegler J, Bahnert A, McBrien J, Lovell R. The application of differential ratings of perceived exertion to Australian Football League matches. Journal of Science and Medicine in Sport. 2015 Nov 1;18(6):704-8.

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