Exercise Physiology and Performance Volume2 Issue2 (2025): 149-169

 DOI: 10.71951/EPP.2025.1192749

Original Article

Comparison of the Effect of Eight Weeks of HIIT and SSGs Training on the Changes in Daily Heart Rate in Training Zone and Training Impulse in Soccer Players

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Submission date: 07-08-2024 Acceptance date: 08-10–2024

Abstract

Background: Heart Rate Variability (HRV) in soccer training provides important indicators for coaches to evaluate and monitor training. High-Intensity Interval Training (HIIT) and Short-Game Sprints (SSG) have also been used and tested for athletes to enhance soccer performance. For this reason, this experimental study aimed to compare the effects of SSGs and HIIT on Heart Rate (HR) key indicators for continuous and targeted monitoring of training sessions of soccer players.

Methods: Twenty-four male U-15 soccer players were divided into two groups with 12 people. The duration of both training protocols was 20 minutes. daily Heart Rates(d.HR), Resting Heart Rate (RHR), Maximum Heart Rate (MHR), Training zone Heart Rates (Tz.HR), were observed and recorded using a Polar team HR monitor app. TRIMP was calculated using the Edwards training load method that determines the internal load by measuring the product of the accumulated training [1]duration of five HR zones by a coefficient related to each zone. The results were considered significant at the 95% confidence level ($p \leq 0.05$).

Results: HIIT and SSG showed no significant difference in MHR, HR reserve, HR mean, HRmax and TRIMP-Edwards of pre and post-test. Among SSG group, recorded a significant improvement in RHR (P=0/001) also, among HIIT group recorded significantly improved RHR (P=0/001). The HR mean for each training session, the HR mean in five minutes, and The HR mean in the associated training zones were monitored and recorded.

Conclusion: In general, the results of this research showed that the HRV and other HR indicators in the training program are important for monitoring training by soccer coaches, and that through these indicators, the goals of progress in training will be achieved.

Keywords: HRV; Training load; Training monitoring, Interval training; Soccer.

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Introduction

Soccer is an effective sport to develop the cardio metabolic fitness, and physical fitness health especially in young and adolescent athletes(1). In recent years, not only has there been a great variety in improving the physiological components of this sport, but the huge financial rewards and visual appeal have also led to a great trend and interest in this sport among teenagers and their parents, attracting them towards it. soccer training is an effective activity for all ages to enhance physical fitness, psychology and health. However, increasing physical fitness in youth soccer players is a complex and important issue, especially in U-15 group due to the interaction of growth, maturation, and training specialization, which makes chronological age a determining factor for designing training programs in which training parameters such as intensity, volume, frequency, etc. are taken into account(2-5).

Heart rate variability (HRV) is among the monitoring tools that are increasing in popularity due to its measurement ease and validity to provide an internal load measure(6, 7).The relationship between HRV and the external load parameters during the matches and exercises could be an effective method to assess the player's readiness for the game(8). According to the study by Dellal et al, the mean HR recorded during match play ranges between 165 and 175 b·min−1, both in competitive and friendly match play. In relation to age, some peculiarities have been observed both in youth and older soccer players(9). Capranica et al(10), reported that youth soccer players' mean HR exceeded 170 b·min−1 for 84% of total match duration during official matches with regular field dimensions (100 × 65 m). in contrast, Tessitore et al(11). Reported absolute HR values ranging between 120 and 140 b·min−1 for older amateur players (62.8 ± 5.9 years old) during a match play. Recent studies have also considered HR monitoring in adolescent and young adult age groups(12-14).

HR monitoring for training and competitions has another very important advantage, in that it takes into account the recovery conditions of players after training and competitions. Optimizing recovery is crucial for youth players, whose bodies are still growing and developing, to support healthy development and avoid long-term health issues(15, 16).

GPS technology has helped team sports to better understand the physiological demands and characteristics of the game and to the same extent(17), devices that monitor HR-a key indicator of autonomic nervous system function and recovery status-are now commonplace in youth sports settings(14). Furthermore, wearable devices can track movement patterns and physical exertion using accelerometers and global positioning system (GPS) technology(18), providing detailed information on distances covered, speeds attained, and the intensity of movements during training and competition. Such comprehensive data collection offers a holistic view of an athlete's workload and recovery needs(19).

High-intensity interval training (HIIT) is one of the common training methods used in soccer for developing the locomotor profile and physical fitness of players(20). HIIT has been shown to enhance maximal oxygen uptake, the lactic threshold, intermittent high intensity effort capabilities, and rapid recovery between intense efforts(21).HIIT is one of the most effective training methods and is frequently used to improve the player's cardiorespiratory and metabolic function and as a training method involves performing repeated periods of high-intensity work (>85%HRmax) above the lactate threshold (4 mmol/l), interspersed with periods of low-intensity intervals (30–50% HRmax) or full recoveries (>3 min)(20, 22-24). The performance characteristics of soccer, namely the high intensity of activities and explosive and intermittent actions, have led to frequent attention to HIIT training(25, 26). Running-based HIIT can be performed using various approaches, such as submaximal short or long intervals, repeated sprint training (maximal effort), sprint interval training (maximal effort), or game-based drills, as seen in small-sided games (SSGs)(24).

SSGs stand out as one of the most common methods employed by soccer coaches worldwide(27). SSGs are now widely adopted by both professional and amateur teams as an optimal tool for aerobic training, which consist of smaller pitch sizes, different rules, and reduced player numbers compared to traditional soccer practices, are considered an enjoyable and effective training method to improve physical fitness and tactical skills in soccer(28-30).

This training approach allows for more time spent under conditions resembling actual competitions compared to non-specific training methods, which lack the characteristics aligned with the internal logic of the sport (e.g., continuous HIIT runs without a ball). Consequently, the majority of exercises in team sports training sessions, including soccer, basketball, and rugby, incorporate SSGs with reduced numbers of players in smaller areas than those used in official matches. Indeed, some SSGs' intensities can be similar to those of soccer matches(31-33). SSGs are also considered a time-efficient training method, as they can develop technical skills, physical performance, and tactical awareness simultaneously (34). All these advantages make SSGs a popular and ecological training method for the majority of soccer coaches(32).

Training zones

Five training zones, which assess players' heart rates based on aerobic and anaerobic thresholds, define a range of activity with high and low limits of training intensity(35). Each training zone plays a different and important role in the metabolism, health, and development of endurance ability of players and can be used for training purposes. The low-intensity zone focuses on fat and carbohydrate aerobic metabolism, the high-intensity zones focus on lactate and anaerobic metabolism, and the other intensity zones focus on the transition from aerobic to anaerobic activities to support recovery after exhausting training as well as enhance mental and physical recovery. Thus, it is possible to accurately estimate the intensity of the training zone for each athlete through performance diagnosis and sport-specific tests(36).

The different training zones help to place players in different training zones by providing guidelines for determining their endurance and fitness levels. In training zone 1, which is a low-intensity, aerobic workload, blood lactate levels do not increase. This endurance training zone helps players rebuild their bodies after intense or competitive training. Activity in training zone 2 increases fat metabolism by increasing the intensity and duration of exercise and strengthens basic endurance. In training zone 3, the intensity of activity for players remains aerobic and their lactate concentration levels do not increase. Training in this zone helps to increase and improve muscle endurance. Training zone 4, which is considered the threshold of anaerobic activity, helps to recycle lactate during high-intensity work. Zone 5, with high training intensity, improves anaerobic performance and lactate breakdown. This zone is considered the anaerobic endurance zone and the power zone(37).

Some studies have considered the training zone of SSGs, based on the heart rate recorded from the players, as Zone 4 and some Zone 5. These studies indicate that the exercise intensity is from 70 to 91% of HRmax, meaning that many SSGs are classified as "moderate intensity exercises", although these games may be classified as high intensity games in other studies(31, 32, 36). Therefore, it is very important to measure heart rate in 5 zones during training. With the above mentioned, in this study, the effects of 8 weeks of SSG training versus HIIT training in U15 soccer players were investigated.

Aim of Study

To evaluate variations of internal loads (HRV and TRIMP) based on intensity training in U-15 soccer players, associated to different SSG conditions in the 1v1 context and HIIT training.

Material and method

Participants and Study Design

This research was semi-experimental, and the research design used pre-tests and post-tests. Twenty-four U-15 male soccer players from the first division of Isfahan Province's soccer league volunteered to participate in this study and were divided into two groups: HIIT training(n=12) and SSG training(n=12). The daily training load was continuously monitored during 8-week period of the 2021–2022 competitive season. The training data corresponds to a total of 24 training sessions (3 days in week). Participants were fully briefed on the training and research methods, and data were collected using the Physical Activity Readiness Questionnaire (PAR-Q)(38).

Before the initial measurements (pre-test) began, the players' parents completed a consent form to participate in the study and a medical questionnaire to verify their child's health. The present research was conducted in accordance with the ethical standards of the Declaration of Helsinki. Table 1 presents the soccer players’characteristics.

Table 1. Characteristics of soccer players

Variable	Group	Average	Standard deviation
Age (years)	HIIT	14.63	0.48
	SSG	14.56	0.47
Height (cm)	HIIT	172	0.07
	SSG	171	0.07
Weight (kg)	HIIT (before)	64.38	6.81
	HIIT (after)	63.44	8.79
	SSG (before)	63.65	6.65
	SSG (after)	62.63	8.78

Body mass index (kg/m2)	HIIT (before)	21.67	1.24
	HIIT (after)	21.72	1.47
	SSG (before)	21.42	1.21
	SSG (after)	21.44	1.50

Eligibility Criteria for Training Data

The eligibility for training data was based on previous studies in sub-elite youth soccer(39-41) considering the following inclusion criteria: (a) Teen soccer players aged Under 15 years old; (b) healthy and free of any infectious and immune diseases, neuromuscular diseases (such as dystrophy, cachexia), inflammatory diseases, cardiovascular diseases, hormonal diseases, obesity, and blood pressure, and none of them were treated with medicine such as anabolic hormones, nutritional supplements (acid amines, creatine, antioxidants, multivitamins, and anti-inflammatory medicine, muscle damage, and colds); (c) at least 3 years of competitive experience in soccer; (d) training files containing at least 35 consecutive minutes of playing time on the pitch; (e) training data considered a competitive one-game per week schedule and complete full training sessions three times a week (~90 min). The exclusion criteria were: (a) total or partial absence from training due to data collection errors, injury events, rehabilitation sessions, individual training sessions, early withdrawal, and/or missing training; (b) soccer players aged under 14 or over 15 years; (c) the goalkeeper participated in the training session but was excluded from the analysis. The exclusion criteria resulted in the elimination of 8 observation cases.

Weekly Training Schedule

The sampled training sessions were categorized according to a specific focus, following the discussion with the coaching staff and club officials. All sampled training sessions for 2 groups started with a standard warm-up protocol with dynamic stretching condition (DSC) or dynamic stretching exercises which was used based on a similar study(42).

The DSC consisted of a 10-min warm-up with dynamic stretching. Four stretching exercises were performed, one for each muscle group of the lower body (Quadriceps, Gluteus, Hamstrings and Triceps suralis) distributed in two series of 30 s each with a rest of 45 s per exercise, dynamically executing oscillatory stretching movements with progressive increases in speed. The intensity started between 3 and 5 points, ending between 6 and 8 points of RPE. The typical weekly training schedule was categorized based on a typical training micro cycle published on youth soccer(43, 44).

Exercise Protocol and Data Acquisition

SSGs Protocols

SSG exercises, based on the study by Santos et al., included: three SSG formats composed of 2-minute play and 3-minute rest in the 1v1 context, with changes in the pitch size between SSGs.The SSGs took place with the goal objective on a 1v1 player basis, with mini training goals (2 m width signalized with training cones). Throughout the SSGs colleagues and coaches were around the pitch with soccer balls in their hands to quickly replace the ball each time it left the pitch, ensuring playing time to be completed and identical in all the games. The research team had digital stopwatches to monitor the real time of play in each SSG. During the recovery time periods of the SSGs the players could drink fluids. This protocol is shown in Figure 1.

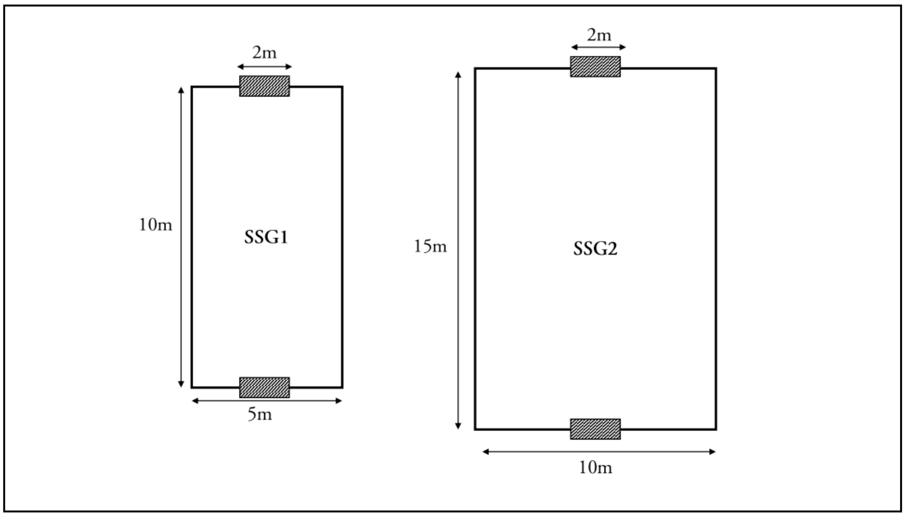

Figure 1. Schematic representation of the experimental protocol, Santos et al (2021)

High-Intensity Interval Training (HIIT) Protocol.

HIIT was performed on an outdoor field with natural grass. Players covered a predetermined distance in 15-s intervals. After each interval, players passively rested for 15 s, and then began the next 15-s interval but ran in the opposite direction(45). The distance was individualized according to the Maximal Aerobic Speed (MAS) of each player and corresponded to 110% of their MAS(46). This task was repeated for 4 bouts of 4 min with 3 min of passive rest between bouts.

Measurements of Exercise Intensity

Soccer players carried Polar H10 Heart Rate Monitor Chest Strap (Polar, Garmin, Apple, Suunto, etc.; sampling rate: 5kHz, ANT+, Polar team app, Bluetooth, Waterproof HR Sensor for Men and Women). HR was measured every 5 s during training sessions and during SSG and HIIT training, via a Polar Team Sport System. Heart rate data during training were expressed as a percentage of HRmax and grouped into three training intensities: <80%, 80–90% and >90%(46, 47). but all 5 training zones were also measured. The average measurements in the 5 zones were monitored every 5 minutes for 3 sessions over a week.

In the first step of this study, subjects were asked to measure their resting heart rate (RHR) 3 times a day in the morning and after calculating the average, they self-reported it to the trainers. RHR refers to the number of heart beats per minute when the body is at complete rest, typically measured upon waking in the morning, lying in bed, or sitting. With the development of sports medicine and training science, resting heart rate has gradually become one of the critical indicators for assessing individual cardiovascular health and training adaptation. In the training process of soccer players, monitoring training load intensity is crucial for enhancing athletic performance and preventing sports injuries. As a simple and feasible physiological indicator, RHR has unique advantages in evaluating and adjusting training load(48).

HRmax is calculated using the formula; HRmax=220-age. Based on this formula and the automatic calculation of the Polar software, the HRmax was the desired value(49).

After that, training protocols were implemented for 8 weeks (24 sessions). The players' daily Heart Rates(d.HR), including self-reported resting heart rate and maximum heart rate (MHR), Training zone Heart Rates (Tz.HR), were observed and recorded using a Polar team heart rate monitor app.

TRIMP (a.u.) was calculated using the Edwards training load method that determines the internal load by measuring the product of the accumulated training duration of five HR zones by a coefficient related to each zone (50 to 60% of HRmax × 1; 60 to 70% of HRmax × 2; 70 to 80% of HRmax × 3; 80 to 90% of HRmax × 4; and 90–100% of HRmax × 5). Edwards' TRIMP formula: duration in zone 1 × 1 + duration in zone 2 × 2 + duration in zone 3 × 3 + duration in zone 4 × 4 + duration in zone 5 × 5(50, 51).

Statistical Analyses

All statistical analyses were performed using SPSS statistical analysis software (SPSS version 27.0 for Windows, SPSS Inc., Chicago, IL, USA). Data are expressed as mean ± standard deviation. Data are expressed as mean ± standard deviation. The hypothesis of normality and the homogeneity of the variance were verified using the Kolmogorov-Smirnov. Student's paired t-tests were used to examine the differences between before and after the training program. The results were considered significant at the 95% confidence level ($p \leq 0.05$).

Results

During the 8-weeks of the experimental period, all players were able to complete the study according to the previously described study design and methodology. No injuries have been observed during the experimental period. The heart rate responses (MHR, HRR and HR reserve) during exercises measured among the two experimental groups (SSG & HIIT) before and after the training programs are illustrated in (Table2). Among SSG group, we recorded a significant improvement in RHR (P=0/001) with no significant changes in MHR (P=0/70) and HR reserve (p=0/20). However, in HIIT group we recorded significantly improved RHR (P=0/001).

Table 2. Heart rate responses during exercises measured between the two experimental groups (SSG & HIIT) before and after the training programs (N = 12)

Group	HR-Measurements	Pre-measurements	Post-measurements	P value	ES
SSG	Resting HR bpm	72.42±5.04	69.17±4.08	**0.001***	0.50
	Maximum HR bpm	191.50±0.50	190.73±0.50	0.70	0.11
	Reserve HR bpm	119.08±5.04	121.56±4.08	0.20	0.50
HIIT	Resting HR bpm	71.92±5.39	68.83±2.97	**0.001***	0.50
	Maximum HR bpm	191.75±0.72	190.25±0.50	0.20	0.50
	Reserve HR bpm	119.83±5.07	121.42±4.13	0.10	0.30

Based on the training zone, the mean heart rate and its standard deviation for the five zones are shown in Figure 1. These data indicate that at the beginning of the first week of training and recording the average heart rate in each zone until the end of the eighth week and comparing with the heart rates recorded during this period, there were no significant changes in heart rate in the two groups. Although a slight improvement in heart rate was achieved with respect to the intensity of the training, the type of training in the two groups did not change much to produce a significant improvement in heart rate.

Based on the target heart rate (THR) for each zone (Figure 2), the results of recording heart rates at 5 different times (minutes 1, 5, 10, 15, and 20) show that before and after eight weeks of HIIT training - some zones that met the training goals of the coaches - had heart rates that did not change much. While based on physiological changes, a decrease in heart rate was expected, this decrease was not very evident, and as a result, Figure 3 - which complements Figure 2 - schematically shows that HIIT training failed to produce significant changes in the players' THR.

		Very light	Light	Moderate	Hard	Maximum	
Mean and SD of Heart Rate		50%	60%	70%	80%	90%	100%
Before	HIIT Mean	138/75	151/75	165/17	178/50	191/75	205
	HIIT SD	2/65	2/05	1/72	1/12	0/72	0
After	HIIT Mean	137/85	150/14	164/24	177/25	190/25	205
	HIIT SD	3/12	3/86	2/11	1/84	0/50	0
Before	SSG Mean	72/42	151/25	164/75	178/25	191/50	205
	SSG SD	5/04	1/96	1/36	0/92	0/50	0
After	SSG Mean	71/25	150/45	163/65	177/84	190/73	205
	SSG SD	6/09	2/05	1/42	1/02	0/50	0

Figure1. The mean heart rate and its standard deviation for the five training zones

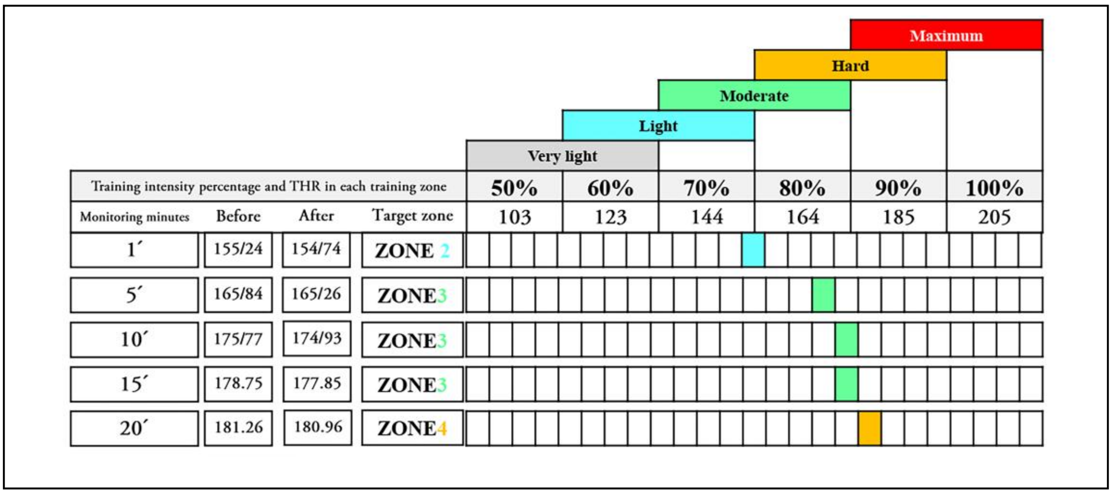

Figure2. Mean heart rate at minutes 1, 5, 10, 15, and 20 by training zone in the HIIT training protocol group

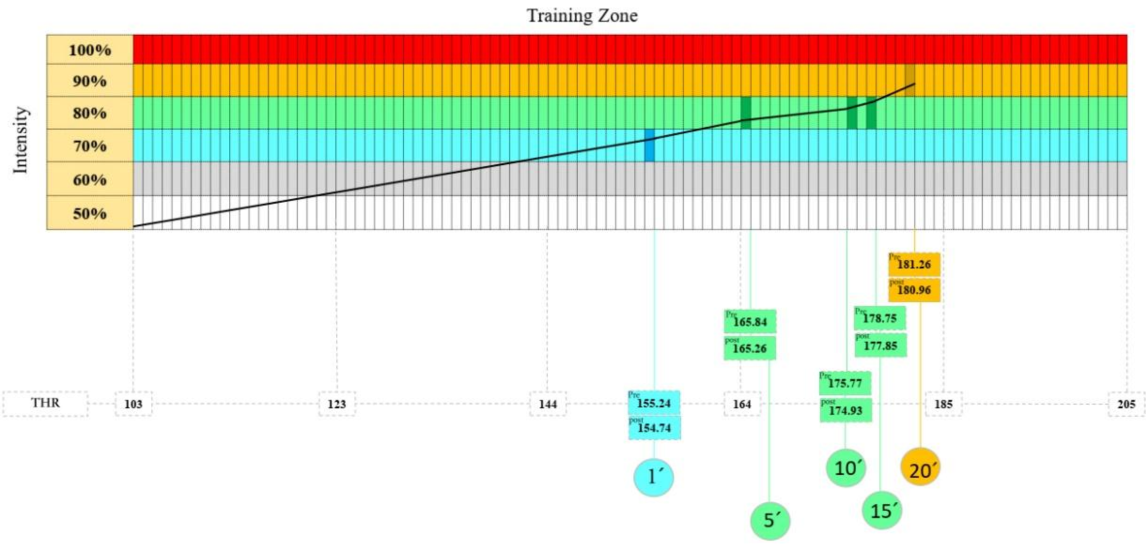

Figure3. HIIT group training zone and HR mean at 5 time points according to age group THR

Figures 4 and 5 show that in SSG training, as in HIIT training, no significant changes were achieved in THR changes based on the trainers' goals.

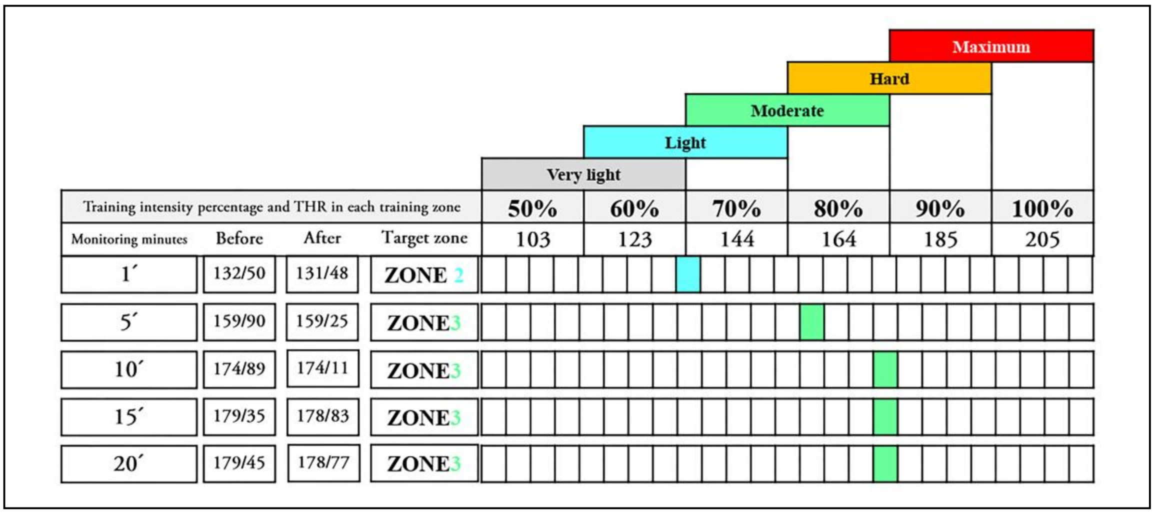

Figure4. Mean heart rate at minutes 1, 5, 10, 15, and 20 by training zone in the SSG training protocol group

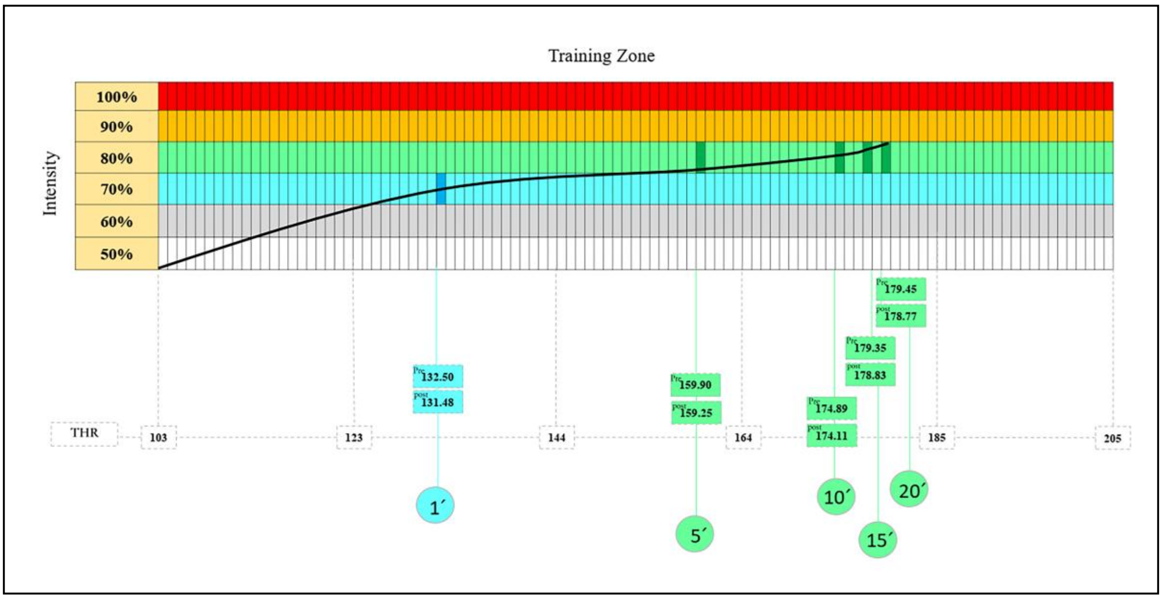

Figure5. SSG group training zone and HR mean at 5 time points according to age group THR

The THR responses during Five times of HR recording between the two experimental groups (SSG & HIIT) before and after the training programs are illustrated in (Table3). Among SSG group and HIIT group, we recorded no significant changes in HR. THR was recorded lower in all two types of SSG exercises than in the HIIT training protocol except minute 15 (1 ´: SSG=132.50<HIIT=155.24); (5 ´: SSG = 159.90 < HIIT = 165.84); (10 ´: SSG = 174.89 < HIIT =175.77); (15 ´: SSG = 179.35 > HIIT =178.75); (20 ´: SSG = 179.45 < HIIT =181.26). This situation is similar to the post-test HR recording (15 ´: SSG = 178.83 > HIIT =177.85). All these results indicated that there was no significant change in the five-point times between the two groups, and also no significant relationship was observed between the five-point times and the THR.

Table 3. THR responses during Five times of HR recording between the two experimental groups (SSG & HIIT) before and after the training programs (N = 12)

Group	Minutes of heart rate recording	Mean ± SD (Pre)	Mean ± SD (Post)	P value	ES
	1´	155.24 ± 1.13	154.74 ±1.09	0.63	0.07
	5´	165.84 ±1.48	165.26 ±1.16	0.95	0.05
HIIT	10´	175.77 ±1.41	174.93 ±1.27	0.27	0.08
	15´	178.75 ± 1.32	177.85 ± 1.21	0.31	0.06
	20´	181.26 ± 2.04	180.96 ±2.06	0.31	0.06
	1´	132.50 ± 3.24	131.48 ± 2.78	0.78	0.08

SSG	5´	159.90 ± 2.05	159.25 ±2.06	0.33	0.20
	10´	174.89 ± 3.11	174.11 ± 2.93	0.11	0.30
	15´	179.35 ± 4.08	178.83 ± 3.09	0.20	0.07
	20´	179.45 ± 0.56	178.77 ±1.02	0.22	0.06

According to Table 4, there was no significant relationship between the results before and after the HIIT and SSG training protocols in HR mean, HRmax and TRIMP-Edward indices.

Table 4. HR mean/max & TRIMP-Edwards recording between the two experimental groups (SSG & HIIT) before and after the training programs (N = 12)

Variable/ Group	HIIT		P value	ES	SSG		P value	ES
	Pre-Test	Post-Test			Pre-Test	Post-Test		
HR mean	165.18± 1.74	163.94 ± 2.28	0.11	0.10	151.63 ± 1.95	150.78 ±2.21	0.16	0.12
HR max	191.75±0.72	190.25±0.50	0.18	0.08	191.50±0.50	190.73±0.50	0.18	0.08
TRIMP-Edwards (a.u.)	11.69± 1.44	12.04 ±1.54	0.68	0.00	11.43± 1.08	11.97 ±1.11	0.63	0.00

Discussion

The objective of the present study was to evaluate the extent of agreement of HRV (MHR, RHR, HR reserve, d.HR, Tz.HR, THR and TRIMP) data obtained via the Polar H10 sensor chest strap device with that recorded for HIIT& SSG training.

HRV is most used to objectively monitor training intensity in many sports(52). Also, checking training HR calculations and THR are important for monitoring training. Among these cases is the Karvonen formula, which was also used in this study to examine MHR and other calculations(53, 54).

HR is widely used and several studies have shown that it is a valid indicator of exercise intensity in soccer(55-58). Studies that have examined HRV in the U15 age group show that these changes are of great value in monitoring training and can provide a clear indication of internal load during training(56, 59-61).

In this study, an attempt was made to use heart rate monitoring in daily training to address training goals and examine internal load, while also examining the level of players' readiness in two training protocols. Finally, this training monitoring showed results of changes in heart rate indicators.

The d.HR of the players who were given the HIIT training protocol decreased slowly and over the course of 8 weeks in each training session (d1-d24) based on the THR defined for the players' age - the same HR is also assigned to the Tz.HR in the Polar software. Based on the HIIT protocol, the HR decreased from an average of 165/18 on the first day (first session) for 12 players to an average of 163/94 on the 24th day (session 24). The RHR of the players in this training group also decreased gradually (71.92±5.39 in the pre-test) and (68.83±2.97 in the post-test). The same results were obtained for the SSG training protocol. On the first day (session 1), the players' mean and standard deviation of HR were 151.63 ± 1.95 and on the same day, their average RHR was 72.42±5.04 However, after eight weeks and on day 24 (session 24), the players' HR mean and standard deviation were 150.78 ±2.21 and the players' average RHR was 69.17±4.08. Djeddi et al.(62) in a study titled: " Effects of small-sided games and high intensity interval training on training load and physiological responses in amateur soccer players" reported that HR mean and HRmax decreased in both HIIT and SSG training samples after 8 weeks.

The importance of the role of RHR in soccer player training has been mentioned in various studies. Evaluation of training load intensity (63). Monitoring training effects(64); Adjustment of training plans(65); Application of wearable devices(66); recording the team's sleep duration, quality, and RHR levels(67); Adjusting Training Plans Reasonably(68); Application for Returning Athletes(69); are just a few examples of the importance of monitoring players' RHR during training sessions. The items stated as a set of benefits of HRH monitoring were also mentioned in Zhiyuan's study, which is consistent with this research(48).

The changes in the players' baseline HR, especially the RHR and its decrease after the end of the training protocol period, indicated the effect of the exercises on this index. On the other hand, the increase in the HR reserve in the two training groups before the full implementation of the exercises also indicated the effectiveness of the exercises.

The heart rate of the players in the HIIT training protocol was initially higher than the HR of SSG training group. The reason for this could be that HIIT training followed an ascending HR and there was a short-term decrease in the inactive RHR, but again with the continuation of the training and the training pressure on the players, the HR continued to increase. In contrast, in the SSG training, the HR at the beginning of the training was lower than the HR of the players in the HIIT and the increasing HR trend similar to the HIIT training was not observed in this group. Meanwhile, Buchheit et al. examined exercise heart rate (H Rex), recovery heart rate (HRR), and post-exercise HR variability (HRV) during and after a submaximal running test to predict changes in physical performance in U-15 soccer players. Their study showed that monitoring exercise HR and post-exercise HR was effective in tracking improvements in (the final test velocity), and that changes in HRR were also moderately correlated with changes in (repetitive) sprint performance. Buchheit et al. emphasize in this study that the present data also question the use of HRex and HRV as systematic markers of physical performance decline in young soccer players. On the other hand, there was a significant difference in the time of ball release and repositioning of players in the 2 vs 2, 3 vs 3, and 4 vs 4 training types with respect to the upward trend in HR(70, 71).

In accordance with these results, Rabbani et al. reported in their reports that the type of exercise and different physical fitness indicators act as an important factor in daily heart rate changes(72, 73). Nobari et al. also showed that simultaneous HIIT and SSG training can have a positive effect on player performance. The present study also showed the effect of both types of training on the performance of soccer players, based on heart rate measurements during 8 weeks of training and observations of the training zone(16).

Reinhardt et al. showed a strong relationship between HRR after standardizing SSG and 4 vs. 4 and endurance performance in soccer players in a laboratory setting. Therefore, in addition to the relationship with endurance capacity, it seems that some types of SSG training can be sufficient to assess the sport-specific ability to recover in soccer players. Although the current study was conducted in a field setting, the effects of SSG training are similar to those of Reinhardt(74).

The results of the present study showed that continuous monitoring of HR and examination of HR indicators during training or in order to examine the intensity of training in the Tz.HR is of particular importance. In line with our results, Atan et al.(75)by examining the HR of young soccer players and monitoring it in the RPE scale, showed that including RPE in the form of examining the HR of players during training in monitoring the training load can provide athletes, coaches and sports scientists with important information. Although Atan et al. based their study on the RPE scale and the training zones were used in the present study, the division of the training zone and the display of HR in each zone and in different time intervals can indicate visual and statistical differences in the HR of the participants. The study of HR during 20 minutes of HIIT and SSG training revealed unique characteristics of the players and obtaining average heart rates in training zones shows that the ranking of training loads in different studies should be carefully considered. In this regard, the most important point is to target training in training zones 4 and 5 with a THR of 75% and above, which is clearly not achievable throughout the entire training time. These findings in the SSG section and determination of internal load in each training zone are consistent with Teixeira et al. study(39).

For the internal load variable TRIMP, there were no significant differences, considering the increase in the playing area. There has been a slight improvement in the TRIMP index. This may be related to the fact that as time passes and the initial training is completed, players occupy the game space better, trying to restrict the spaces in the defensive process, and progress through the pass in the offensive process. These findings are consistent with the results of Espada et al. study(76). These results also have a strong resemblance to the TRIMP Edward section in the study by Gardner et al(77).

Conclusion

In conclusion, some points to be well documented in this study and are highlighted: (a) HRV can be used to monitor the physiologic load and internal training load in soccer players with good validity, especially when the analysis is considered as a function of RHR ; (b)Other important HR indicators are of great importance for training monitoring, especially when considered in the form of training zones and minutes based on the trainers' training goals; (c)Training zones 2 and 3 in SSG training and training zones 3 and 4 in HIIT training had the highest frequency in terms of players' MHR based on the coaches' training goals; (d) MHR is of particular indicator in HIIT training because at peak training intensity, zone 4 also includes the HR range of players during training; (e)In SSG training, the HR mean is lower than HIIT, because the structure and training protocol require that players have low training intensity at times during training in zones 1 and 2; (f)Since TRIMP Edwards is defined based on five training zones, it is better to use this method for heart rate monitoring to check the player's activity range based on heart rate.

Conflict of Interest: There are no conflicts of interest.

Acknowledgment: We appreciate the participants and all the colleagues that help us to do this study.

Authors' contribution:

Designing the study, data analysis: H Z

References:

Scharfen HE, & Memmert, D. (2019). The relationship between cognitive functions and sport-specific motor skills in elite youth soccer players. Frontiers in psychology, 10, 817.

Hadjicharalambous M, Zaras, N., Apostolidis, A., & Tsofliou, F. (2022). Recreational Soccer, Body Composition and Cardiometabolic Health: A Training-Intervention Study in Healthy Adolescents.International Journal of Human Movement and Sports Sciences, 10(3), 524-533.

Dolci F, Hart, N. H., Kilding, A. E., Chivers, P., Piggott, B., & Spiteri, T. (2020). Physical and energy demand of soccer: A brief review.

Nikolaos S, et al. "Physiological and fitness characteristics in well-trained adolescent soccer players: Differences between age groups and playing position." Journal of Physical Education and Sport 22.11 (2022): 2784-2792..

Varley MC DSV, Modonutti M, Gregson W, and Mendez-Villanueva A. The influence of successive matches on match-running performance during an under-23 international soccer tournament: The necessity of individual analysis. J Sports Sci 36: 585-591, 2018.

Buchheit MMtswHmDarltRP, 5, 73. [Google Scholar] [CrossRef] [Green Version].

Vesterinen VN, A.; Heikura, I.; Laine, T.; Hynynen, E.; Botella, J.; Häkkinen, K. Individual Endurance Training Prescription with Heart Rate Variability. Med. Sci. Sports Exerc. 2016, 48, 1347–1354. [Google Scholar] [CrossRef] [Green Version].

Sánchez-Sánchez JB, J.; Felipe Hernández, J.L.; León, M.; Paredes-Hernández, V.; Colino, E.; Gallardo, L.; García-Unanue, J. Heart Rate Variability and Physical Demands of In-Season Youth Elite Soccer Players. Int. J. Environ. Res. Public Health 2021, 18, 1391. https://doi.org/10.3390/ijerph18041391.

Alexandre DdS, Cristiano Diniz; Hill-Haas, Stephen; Wong, Del P.; Natali, Antonio J.; De Lima, Jorge R. P.; Filho, Mauricio G.B. Bara; Marins, Joao J.C.B.; Garcia, Emerson Silami; Karim, Chamari. Heart Rate Monitoring in Soccer: Interest and Limits During Competitive Match Play and Training, Practical Application. Journal of Strength and Conditioning Research 26(10):p 2890-2906, October 2012. | DOI: 10.1519/JSC.0b013e3182429ac7.

Capranica L, Tessitore, A, Guidetti, L, and Figura, F. Heart rate and match analysis in pre-pubescent soccer players. J Sports Sci 19: 379–384, 2001.

Tessitore A, Meeusen, R, Tiberi, M, Cortis, C, Pagano, R, and Capranica, L. Aerobic and anaerobic profiles, heart rate and match analysis in older soccer players. Ergonomics 48: 1365–1177, 2005.

Oliveira RB, J.P.; Moreno-Villanueva, A.; Nalha, M.; Rico-González, M.; Clemente, F.M. Reference Values for External and Internal Training Intensity Monitoring in Young Male Soccer Players: A Systematic Review. Healthcare 2021, 9, 1567. https://doi.org/10.3390/healthcare9111567.

Altmann S, Ruf, L., Neumann, R., Härtel, S., Woll, A., & Buchheit, M. (2022). Assessing the usefulness of submaximal exercise heart rates for monitoring cardiorespiratory fitness changes in elite youth soccer players. Science and Medicine in Football, 7(2), 177–182. https://doi.org/10.1080/24733938.2022.2060520.

Teixeira JE, et al. "Classification of recovery states in U15, U17, and U19 sub-elite football players: a machine learning approach." Frontiers in Psychology 15 (2024): 1447968..

Clemente FM, González-Fernández, F. T., Ceylan, H. I., Silva, R., Younesi, S., Chen, Y. S., et al. (2021). Blood biomarkers variations across the pre-season and interactions with training load: a study in professional soccer players. J. Clin. Med. 10:5576. doi: 10.3390/jcm10235576.

Nobari H, Fani, M., Mainer Pardos, E., and Perez-Gomez, J. (2021). Fluctuations in well-being based on position in elite young soccer players during a full season. Healthcare 9:586. doi: 10.3390/healthcare9050586.

Akenhead RH, J.; Tweddle, S. Examining the external training load of an English Premier League football team with special reference to acceleration. J. Strength Cond. Res. 2016, 30, 2424–2432. [CrossRef].

Gómez-Carmona CD, Rojas-Valverde, D., Rico-González, M., Ibáñez, S. J., and Pino-Ortega, J. (2021). What is the most suitable sampling frequency to register accelerometry-based workload? A case study in soccer. J. Sports Eng. Technol. 235, 114–121. doi: 10.1177/1754337120972516.

Oliva-Lozano JM, Rojas-Valverde, D., Gómez-Carmona, C. D., Fortes, V., and Pino-Ortega, J. (2020). Worst case scenario match analysis and contextual variables in professional soccer players: a longitudinal study. Biol. Sport 37, 429–436. doi: 10.5114/biolsport.2020.97067.

Clemente FM R-CR, Nakamura FY, et al. Effects of high-intensity interval training in men soccer player's Physical fitness: a systematic review with meta-analysis of randomized-controlled and non-controlled trials. J Sports Sci 2021;39:1202–1222.

Salazar-Martinez J, Wilder Geovanny Valencia-Sanchez, and Filipe Manuel Clemente. "Comparative impact of small-sided games and high-intensity interval training on physical performance in youth soccer players." Journal of Physical Education and Sport 23.10 (2023): 2769-2785..

Rabbani A CF, Kargarfard M, Jahangiri S. Section III-sports training combined small-sided game and high-intensity interval training in soccer players: the effect of exercise order. J Hum Kinet. 2019;69:249–57.

Nobari H GR, Martins AD, Badicu G, Oliveira R. In-season quantification and relationship of external and internal intensity, sleep quality, and psychological or physical stressors of semi-professional soccer players. Biology (Basel). 2022;11:467.

Laursen P, & Buchheit, M. (2019). Science and application of high-intensity interval training. Human kinetics.

Hostrup M GT, Fiorenza M, Mørch K, Onslev J, Pedersen KM, et al. In-season adaptations to intense intermittent training and sprint interval training in sub-elite football players. Scand J Med Sci Sport. 2019;29:669–77.

Nobari H M-PE, Denche Zamorano A, Bowman TG, Clemente FM, Pérez-Gómez J. Sprint variables are associated with the odds ratios of non-contact injuries in professional soccer players. Int J Environ Res Public Health. 2021;18:10417.

Clemente SCs-ssgar-bmAsrBoS, 38(4), 617–627. http://dx.doi.org/10.5114/biolsport.2021.102932.

Moran J, Blagrove, R. C., Drury, B., Fernandes, J. F., Paxton, K., Chaabene, H., & Ramirez-Campillo, R. (2019). Effects of small-sided games vs. Conventional endurance training on endurance performance in male youth soccer players: A meta-analytical comparison. Sports Medicine, 49(5), 731–742. http://dx.doi.org/10.1007/s40279-019-01086-w.

Sgrò F, Bracco, S., Pignato, S., & Lipoma, M. (2018). Small-sided games and technical skills in soccer training: Systematic review and implications for sport and physical education practitioners. Journal of Sports Science, 6(1), 9–19.

Sarmento H MCF, David Harper L, Teoldo da Costa I, Owen A, Figueiredo AJ. Small sided games in soccer-a systematic review. Int J Perform Anal Sport. 2018;18:693–749.

Rampinini E, Impellizzeri, F. M., Castagna, C., Abt, G., Chamari, K., Sassi, A., & Marcora, S. M. (2007). Factors influencing physiological responses to small-sided soccer games. Journal of Sports Sciences, 25(6), 659–666. http://dx.doi.org/10.1080/02640410600811858.

Hill-Haas SV DB, Impellizzeri FM, Coutts AJ. Physiology of small-sided games training in football: a systematic review. Sports Med. 2011;41:199–220.

Clemente F CM, Martins FML, Mendes R. The usefulness of small-sided games on soccer training. J Phys Educ Sport. 2012;12:93–102. 2009;31:67–74. LTOtuosdfpdSCJ.

Neufeld EV, Wadowski, J., Boland, D. M., Dolezal, B. A., & Cooper, C. B. (2019). Heart Rate Acquisition and Threshold-Based Training Increases Oxygen Uptake at Metabolic Threshold in Triathletes: A Pilot Study. International journal of exercise science, 12(2), 144–154.

Dellal. A, da Silva, C. D., Hill-Haas, S., Wong, D. P., Natali, A. J., De Lima, J. R., & Karim, C. (2012). Heart rate monitoring in soccer: interest and limits during competitive match play and training, practical application. Journal of Strength & Conditioning Research, 26(10), 2890–2906. support@sportsperformancebulletin.com. HAHrmmnbtbwtpVmamo.

Thomas S. RJ, Shephard R. J. Revision of the Physical Activity Readiness Questionnaire (PAR-Q). Can J Sport Sci. 1992 Dec;17(4):338–345. [PubMed] [Google Scholar].

Teixeira JEF, P.; Ferraz, R.; Leal, M.; Ribeiro, J.; Silva, A.J.; Barbosa, T.M.; Monteiro, A.M. Quantifying sub-elite youth football weekly training load and recovery variation. Appl. Sci. 2021, 11, 4871. [Google Scholar] [CrossRef].

Teixeira JEA, A.R.; Ferraz, R.; Forte, P.; Leal, M.; Ribeiro, J.; Silva, A.J.; Barbosa, T.M.; Monteiro, A.M. Effects of chronological age, relative age, and maturation status on accumulated training load and perceived exertion in young sub-elite football players. Front. Physiol. 2022, 13, 832202. [Google Scholar] [CrossRef].

Teixeira JEB, L.; Ferraz, R.; Leal, M.; Silva, A.J.; Barbosa, T.M.; Monteiro, A.M.; Forte, P. Weekly Training Load across a Standard Microcycle in a Sub-Elite Youth Football Academy: A Comparison between Starters and Non-Starters. Int. J. Environ. Res. Public Health 2022, 19, 11611. https://doi.org/10.3390/ijerph191811611.

Hernandez-Martinez J, et al. "Warm-up stretching exercises and physical performance of youth soccer players." Frontiers in physiology 14 (2023): 1127669..

Branquinho LF, R.; Marques, M.C. 5-a-Side Game as a Tool for the Coach in Soccer Training. Strength Cond. J. 2021, 43, 96–108. [Google Scholar] [CrossRef].

Zurutuza UC, J.; Echeazarra, I.; Guridi, I.; Casamichana, D. Selecting Training-Load Measures to Explain Variability in Football Training Games. Front. Psychol. 2019, 10, 2897. [Google Scholar] [CrossRef].

Dupont GB, N.; Berthoin, S. Performance for short intermittent runs: Active recovery vs. passive recovery. Eur. J. Appl. Physiol. 2003, 89, 548–554. [Google Scholar] [CrossRef] [PubMed].

Harrison CK, T.; Gill, N.; Kilding, A. Aerobic fitness for young athletes: Combining game-based and high-intensity interval training. Int. J. Sports Med. 2015, 94, 929–934. [Google Scholar] [CrossRef].

Los Arcos AV, J.S.; Martin, J.; Lerga, J.; Sanchez, F.; Villagra, F.; Zulueta, J.J. Effects of Small-Sided Games vs. Interval Training in Aerobic Fitness and Physical Enjoyment in Young Elite Soccer Players. PLoS ONE 2015, 10, e0137224. [Google Scholar] [CrossRef] [PubMed] [Green Version].

Tan ZAsorhrfmtliifpIMSRJ-.Robergs RA, and Roberto Landwehr. "The surprising history of the" HRmax= 220-age" equation." Journal of Exercise Physiology Online 5.2 (2002): 1-10..

Cirer-Sastre R L-AA, Corbi F, López-Laval I, PuenteLanzarote J, Hernández-González V, et al. Effect of training load on post-exercise cardiac troponin t elevations in young soccer players. International Journal of Environmental and Research in Public Health. 2019; 16: 4853.

Scott BR LR, Knight TJ, Clark AC, Janse de Jonge XAKJ. A comparison of methods to quantify the in-season training load of professional soccer players. International Journal of Sports Physiology and Performance. 2013; 8: 195–202.

Achten JJ, A. Heart rate monitoring-applications and limitations. Sports Med. 2003, 33, 517–538. [Google Scholar] [CrossRef].

Ignaszewski M, et al. "The science of exercise prescription: Martti Karvonen and his contributions." BC Med J 59.1 (2017): 38-41..

She J, et al. "Selection of suitable maximum-heart-rate formulas for use with Karvonen formula to calculate exercise intensity." International journal of automation and computing 12 (2015): 62-69..

Akubat IP, E.; Barrett, S.; Abt, G. Methods of Monitoring the Training and Match Load and Their Relationship to Changes in Fitness in Professional Youth Soccer Players. J. Sports Sci. 2012, 30, 1473–1480. [Google Scholar] [CrossRef].

Freitas CGA, M.S.; Franciscon, C.A.; Arruda, A.F.S.; Carling, C.; Moreira, A. Psychophysiological Responses to Overloading and Tapering Phases in Elite Young Soccer Players. Pediatr. Exerc. Sci. 2014, 26, 195–202. [Google Scholar] [CrossRef] [PubMed].

Los Arcos AM-V, A.; Martínez-Santos, R. In-Season Training Periodization of Professional Soccer Players. Biol. Sport 2017, 34, 149–155. [Google Scholar] [CrossRef] [PubMed].

Raya-González JN, F.Y.; Castillo, D.; Yanci, J.; Fanchini, M. Determining the Relationship between Internal Load Markers and Noncontact Injuries in Young Elite Soccer Players. Int. J. Sports Physiol. Perform. 2019, 14, 421–425. [Google Scholar] [CrossRef].

Wrigley RD, B.; Stratton, G.; Scott, M.; Gregson, W. Quantification of the Typical Weekly In-Season Training Load in Elite Junior Soccer Players. J. Sports Sci. 2012, 30, 1573–1580. [Google Scholar] [CrossRef] [PubMed].

Gjaka MT, H.; Francioni, F.M.; Tishkuaj, F.; Tessitore, A. Monitoring of Loads and Recovery Perceived during Weeks with Differente Schedule in Young Soccer Players. Kinesiol. Slov. 2016, 22, 16–26. [Google Scholar].

Cetolin TT, A.S.; Netto, A.S.; Haupenthal, A.; Nakamura, F.Y.; Guglielmo, L.G.A.; Silva, J.F. da Training Loads and RSA and Aerobic Performance Changes During the Preseason in Youth Soccer Squads. J. Hum. Kinet. 2018, 65, 235–248. [Google Scholar] [CrossRef] [Green Version].

RACHAD D, et al. ""Effects of small-sided games and high intensity interval training on training load and physiological responses in amateur soccer players"." Ovidius University Annals, Series Physical Education & Sport/Science, Movement & Health 24.2 (2024)..

Milanović Z, Pantelić, S., Čović, N., Sporiš, G., Mohr, M., Krustrup, P. (2019). Broadspectrum physical fitness benefits of recreational football: a systematic review and meta-analysis. British Journal of Sports Medicine, 53(15), 926-939. doi: 10.1136/bjsports-2017-097885. Epub 2018 Jan 25.

Gąsior JS, Gąsienica-Józkowy, M., Młyńczak, M., Rosoł, M., Makuch, R., Baranowski, R., & Werner, B. (2024). Heart rate dynamics and asymmetry during sympathetic activity stimulation and post-stimulation recovery in ski mountaineers-a pilot exploratory study. Frontiers in Sports and Active Living, 6, 1336034. https://doi.org/10.3389/fspor.2024.1336034.

Tesema G, & George, M. (2021). Associations between cardiac troponin I and cardiovascular parameters after 12-week endurance training in young moderately trained amateur athletes. BMJ Open Sport Exercise Medical, 18(1), e001065. doi: 10.1136/bmjsem- 2021-001065.

Capodilupo ER, & Miller, D. J. (2021). Changes in health promoting behavior during COVID-19 physical distancing: Utilizing wearable technology to examine trends in sleep, activity, and cardiovascular indicators of health. PloS One, 16(8), e0256063.

Javed F, Sanchez, J. C., MacLean, S., Lam, V., O'Flynn, L., Tanverdi, M., & Liu, A. H. (2023). A wireless wearable patch for remote monitoring of respiratory and cardiac rhythm in children. Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual International Conference, 2023, 1–4. https://doi.org/10.1109/EMBC40787.2023. 10340323.

Ghouili H, Farhani, Z., Amara, S., Hattabi, S., Dridi, A., Guelmami, N., Bouassida, A., Bragazzi, N., & Dergaa, I. (2023). Normative data in resting and maximum heart rates and a prediction equation for young Tunisian soccer players: a cross-sectional study. doi: 10.17179/excli2023-6215.

Chen Y, Buggy, C., & Kelly, S. (2019). Winning at all costs: a review of risk-taking behaviour and sporting injury from an occupational safety and health perspective. Sports Med Open, 5(1), 15. doi: 10.1186/s40798-019-0189-9.

Buchheit M. (2014). Monitoring training status with HR measures: do all roads lead to Rome?. Frontiers in physiology, 73. https://doi.org/10.3389/fphys.2014.00073.

Buchheit M LPH-iit, solutions to the programming puzzle: part I: cardiopulmonary emphasis. Sports Med. 2013;43:313–38.

Rabbani AK, Mehdi & Marandi, Seyed. (2009). Effects of endurance and concurrent training in combination with soccer drills on some of physiological factors in youth players.

Rabbani AC, Filipe & Kargarfard, Mehdi & Jahangiri, Saeid. (2019). Combined Small-Sided Game and High-Intensity Interval Training in Soccer Players: The Effect of Exercise Order. Journal of Human Kinetics. 69. 249-257. 10.2478/hukin-2018-0092.

Reinhardt L, Schulze, S., Kurz, E., & Schwesig, R. (2020). An Investigation into the Relationship Between Heart Rate Recovery in Small-Sided Games and Endurance Performance in Male, Semi-professional Soccer Players. Sports medicine - open, 6(1), 43. https://doi.org/10.1186/s40798-020-00273-8.

Atan Siti Azilah MFJ, Mohd Syrinaz Azli, Jorrye Jakiwa, & Mohar Kassim. (2021). The reliability of rating perceived exertion and the relationship with heart rate in young soccer players. Zulfaqar Journal of Defence Management, Social Science & Humanities, 4(1). Retrieved from https://zulfaqarjdmssh.upnm.edu.my/index.php/zjdmssh/article/view/61.

Espada MC, et al. "The effect of pitch size manipulation during small sided-games performed by different age category football players: a pilot study." (2023)..

Gardner CN, J.W.; Carrier, B.; Aguilar, C.; Perdomo Rodriguez, J. Training Impulse and Its Impact on Load Management in Collegiate and Professional Soccer Players. Technologies 2023, 11, 79. https://doi.org/10.3390/technologies11030079.