13 Heart rate-based versus speed-based high-intensity interval training in young soccer players

A. Rabbani[a] *and M. Buchheit*[a,b]

[a]Sport Science Department, Myorobie Association, Montvalezan, France
[b]Performance Department, Paris Saint Germain FC, Saint-Germain-en-Laye, France

Introduction

High-intensity interval training (HIT) is one of the most popular forms of exercise to improve athletes' cardiorespiratory fitness in (youth) soccer (Buchheit & Laursen, 2013a; Chamari et al., 2005; Helgerud et al., 2001; Hoff et al., 2002; Impellizzeri et al., 2006; McMillan et al., 2005). While appropriate HIT programming requires the consideration of up to nine variables such as exercise/rest ratio and intensities, series duration or locomotor patterns, the two most important variables are the intensity and the duration of exercise interval (Buchheit & Laursen, 2013b). There are different ways to control and prescribe the intensity of exercise intervals during HIT in soccer. Targeting a given percentage of maximal heart rate (HR, i.e. HR-based HIT) (Buchheit & Rabbani, 2014; Chamari et al., 2005; Helgerud et al., 2001; Impellizzeri et al., 2006; McMillan et al., 2005) or using a percentage of a reference running speed (i.e. speed-based HIT) are the most common approaches today (Buchheit & Laursen, 2013a).

Using HR to control the exercise intensity is very common among practitioners in the field (Achten & Jeukendrup, 2003) and is also used as a valuable tool by sport scientists to monitor match play and training intensity in soccer (Dellal et al., 2012). However, using HR as a physiological marker to individualize HIT has several limitations including i) the difficulty for practitioners to regulate running intensity during the actual workout, ii) the inability of HR to inform the intensities above the minimal running speed that elicits maximal oxygen uptake (vVO2max) and maximal HR (HRmax) and iii) the possible dissociation between HR and the actual metabolic demands during short intervals (Buchheit & Laursen, 2013a).

When it comes to the use of a reference running speed to prescribe interval intensity, the maximum speed reached at the end of 30–15 Intermittent Fitness Test (30-15IFT, VIFT) has been shown to be a relevant alternative to vVO2max, especially for short and supramaximal HIT (Buchheit, 2008). The VIFT is not only related to aerobic power, but it is also sensitive to players' anaerobic speed reserve, inter-effort recovery capacity, acceleration, deceleration and change of direction (COD) abilities (Buchheit, 2008, 2012). Practically, programming HIT using VIFT allows the equalization of exercise intensity for different players presenting with different physical capacities (Buchheit, 2008). With this approach, the between-athletes variability in cardiorespiratory responses is reduced, which simplifies the management of training load at the individual level (Buchheit, 2012).

Despite the above-mentioned theoretical evidences supporting the superiority of VIFT vs. HR as a reference method to individualize running-based HIT, whether VIFT-based HIT results in greater performance gains than a HR-based program is still unknown. Therefore, the purpose of our study was to compare, in young soccer players, the effect of VIFT-based vs. HR-based HIT on high-intensity intermittent running performance.

Methods

Data were collected over two consecutive preseason preparation periods (2012–2013 and 2013–2014) in two U16 soccer teams performing in the Premier League of Iran. The same coaches trained the players, and technical/tactical training modalities were similar each year during the preparatory phase, except the type of HIT sessions, i.e. HR-based (first year) vs. VIFT-based HIT (second year). All players were familiarized with the testing procedures before the start of the experimental phases. Training load was reduced for three days before each test to prevent excessive fatigue.

The overall training load was assessed during each training session using the rate of perceived exertion (RPE) method for the 2013–2014 group (Impellizzeri et al., 2004) (Table 13.1). Although training load was not actually monitored during the 2012–2013 season, the training load of the 2012–2013 preseason period was deemed to be similar to that reported in Table 13.1, since coaches replicated the same physical, technical and tactical sessions during the two consecutive experimental interventions.

Subjects

Players of the 2012–2013 (n=12, mean ± SD: age 15.1 ± 0.6 years; height 173 ± 4.1 cm; mass 61.4 ± 3.9 kg) and 2013–2014 (n=10, mean ± SD: age 15.2 ± 0.4 years; height 176 ± 5.7 cm; mass 61.5 ± 4.4 kg) seasons all provided informed

Table 13.1 Weekly training load (AU, mean ± SD) for the VIFT-based high-intensity interval training group

Week 5	*Week 4*	*Week 3*	*Week 2*	*Week 1*
1,935 ± 123	1,902 ± 209	1,921 ± 155	1,758 ± 189	1,714 ± 178

Note: VIFT: the maximum speed reached at 30–15 Intermittent Fitness Test, AU: arbitrary unit and SD: standard deviation.

consent prior to participating in the experiment. All procedures were approved by the local research ethics committee and the study protocol conformed to the declaration of Helsinki.

Testing

All players performed a Yo-Yo Intermittent Recovery Test Level 1 (YYIRT1) (Bangsbo et al., 2008) before undergoing the training interventions. The VIFT-based group also performed the 30-15IFT 72 hours prior to the intervention in order to assess players' VIFT. All tests were performed three days before and after the interventions on artificial turf at 10 A.M with similar temperature (31–33º C). Training hours were between 2:00 and 5:00 PM with a temperature range of 32–36º C in summer for both groups. The YYIRT1 (Bangsbo et al., 2008) and the 30-15IFT (Buchheit, 2008) tests are both incremental and intermittent in nature, but have been shown to have slight different physiological and locomotor determinants (Buchheit & Laursen, 2013a; Buchheit & Rabbani, 2014). Their respective protocols have been detailed previously (Bangsbo et al., 2008; Buchheit, 2008).

Training

The HIT interventions lasted four and five weeks for the HR-based and VIFT-based groups respectively, including six training sessions per week (i.e. two 60-min resistance-training sessions, and four 90-min outdoor technical, tactical and conditioning sessions). A description of the training programs is shown in Table 13.2. All players were very familiar with both forms of HIT; i.e. they have already performed at least four sessions of each HIT format within the previous six months.

HR-based HIT

Two sessions of HR-based HIT were performed per week prior to tactical training: three sets of 3:30 min aimed at reaching 90–95 percent of HRmax, interspersed with 3:00 min of active recovery including jogging and passing, targeting 60–70 percent of HRmax. Running intensity was individualized according to 90–95 percent of HRmax using heart rate watches for each player (Polar FT60, Finland). Players were running back and forth between two cones 25 meters apart. There were two outer players standing about 2 meters behind the cones on each side with the ball in possession. The outer players were requested to serve the ball to the middle player when this latter was reaching the side lines; the middle player had then to pass the ball back again to the outer players (two touches), then turn (180º-COD) and run back through the cones on the opposite side. The speed of running for the HR-based group was self-controlled by the players, who were requested to look at their heart rate monitor watch while running. There were also three assistant coaches looking at players' heart rate monitors randomly to assure

Table 13.2 Weekly preseason conditioning training programs

Week day	*Training contents*
Saturday and Tuesday (90 minutes)	Warm up (25 min) and cool down (15 min) HIT—three sets of 3:30 min interspersed with 3-min active recovery (25 minute) HR-based, exercise intensity @ 90–95% of HRmax running between cones (25 m) with technical actions, relief intensity @ 60–70% of HRmax. VIFT-based, exercise intensity @ 65–70 of VIFT between cones (adjusted individual distance) with technical actions, relief intensity @ self-paced jog. 25 minutes technical and tactical training (all the same for HR-based and VIFT-based groups)
Sunday and Wednesday (60 minutes)	Warm up (25 min) and cool down (15 min) Circuit resistance training including three sets of 10–15 receptions @ 40–60% of 1RM with 3-min rest between circuits Exercises: squat, bench press, leg press, pulling, leg extension, leg flexion, hip adduction, plantar flexion + three sets of maximum receptions @ body mass with 1-min rest between each sets Exercises: push down, lower back, partial curl up and crunch + balance training (single leg standing on balance board while passing the ball)
Monday and Thursday (90 minutes)	Warm up (25 min) and cool down (15 min) 20 minutes speed (acceleration, deceleration), COD and agility training Total distance covered for sprint training: 300 to 500 meters from one to five weeks 35-min technical and tactical training (all the same for HR-based and VIFT-based groups)

Note: HIT: high-intensity interval training, VIFT: the maximum speed reached at 30–15 Intermittent Fitness Test (30–15IFT), HRmax: maximal heart rate, 1RM: one repetition maximum, COD: change of direction.

the players were running in their programed HR zones. The HR-based HIT set up is illustrated in Figure 13.1; note that the distance between cones (25 meters) was similar for all players. The advantage of HR-based prescription is that exercise intensity doesn't need to be adjusted throughout the intervention; 90–95 percent of HRmax represents always the same (close to maximal) internal load, irrespective of the likely increase in players' fitness.

VIFT-based HIT

Two sessions of VIFT-based HIT were performed per week prior to tactical training: three sets of 3:30 min at 65–70 percent of VIFT for the exercise interval and with a self-paced jog for the 3-min relief intervals. The individual running pace was guided using an audio file (beep that sounded at appropriate time intervals). The same audio file was used for all players, but their running distances were set according to their individual VIFT (Figure 13.1). It is worth noting that while exercise intervals of 3 min or longer are generally performed at intensities around

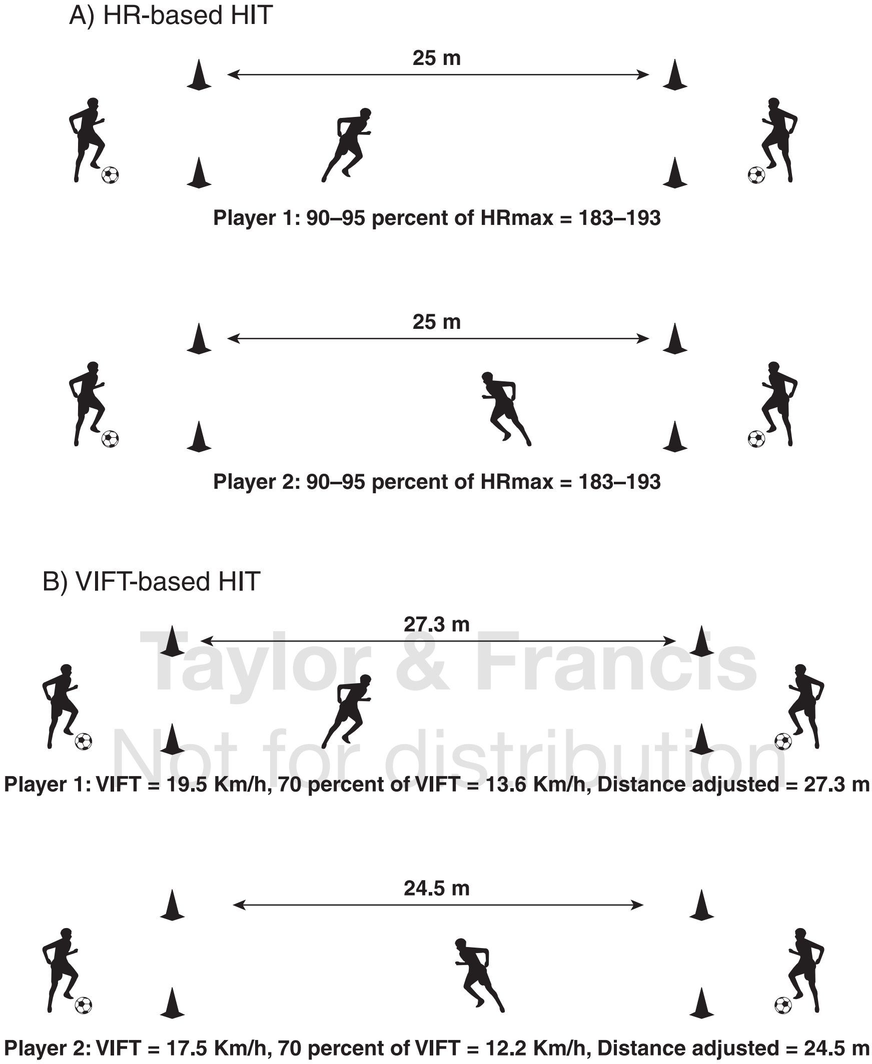

Figure 13.1 A) Heart rate (HR)-based and B) VIFT (the maximum speed reached at 30–15 Intermittent Fitness Test)-based high-intensity interval training (HIT) setup

Note: The intensity of HIT was individualized and prescribed according to 90–95 percent of maximal heart rate (HRmax) or 65–70 percent of VIFT in HR-based and VIFT-based groups, respectively.

85 percent of VIFT (Buchheit, 2012), the intensity of the exercise interval had to be decreased in the present study to account for the increased energetic running demands consecutive to ball possession and/or changing of direction (Hoff et al., 2002). This intensity adjustment was based on pilot studies and showed that 65–70 percent of VIFT allowed the players to complete the required workout

while reaching high HR values (i.e. >90–95 percent of HRmax) and similar RPEs than during the HR-based HIT. To compensate for the likely increase in players' fitness throughout the experimental phase, training intensity was increased by 2.5 percent every second week (i.e. 65 percent of VIFT during the first two weeks, 67.5 percent during weeks three and four, and 70 percent during the fifth week)

Statistical analyses

Data in the text and figures are presented as means with standard deviations (SD) and 90 percent confidence intervals (CI), respectively. All data were first log-transformed to reduce bias arising from non-uniformity error. Between-group YYIRT1 performance at baseline, within-group changes in YYIRT1 and between-groups differences in weekly changes were expressed as percentage changes and as standardized differences or effect size (ES) with 90 percent confidence limits (CL) (Hopkins et al., 2009). The comparison of the weekly changes was adjusted for baseline YYIRT1 values. Probabilities were also calculated to establish whether the true changes/differences were lower than, similar to or higher than the smallest worthwhile changes/differences (SWC, 0.2 × between-subjects SD) (Hopkins et al., 2009). These probabilities were used to make a qualitative probabilistic mechanistic inference about the true effect (Hopkins et al., 2009): if the probabilities of the effect being substantially positive and negative were both >5 percent, the effect was reported as unclear; the effect was otherwise clear and reported as the magnitude of the observed value. The scale was as follows: 25–75 percent, possible; 75–95 percent, likely; 95–99 percent, very likely; >99 percent, almost certain (Hopkins et al., 2009). Individual YYIRT1 changes were also assessed, using a specifically designed spreadsheet (Hopkins, 2000), where both the typical error of the measurement of the test derived from reliability studies (i.e. 8 percent (Bangsbo et al., 2008)) and the SWC were considered. To accurately compare the individual changes between the two groups, these were calculated using the full training duration data for the HR-based HIT group, and the estimated YYIRT1 change after four weeks in the VIFT groups (linear extrapolation). Only changes rated as at least likely (>75 percent) were considered as substantial. We then calculated the standardized odd ratio (OR, 90 percent CL) for between-training approach difference in individual responses. The magnitude of the odds ratio was interpreted using Hopkins' scale (Hopkins et al., 2009). Finally, Pearson correlation coefficients were calculated to assess possible associations between baseline YYIRT1 performance and YYIRT1 improvement within each group (Bouchard & Rankinen, 2001; Buchheit et al., 2010; Hautala et al., 2009). The magnitude of the correlation (r, 90 percent CI) was interpreted quantitatively. If the 90 percent CI overlapped small positive and negative values, the magnitude was deemed unclear (Hopkins et al., 2009).

Results

YYIRT1 performance was moderately greater for the VIFT-based (1,224 ± 227 m) than the HR-based HIT group (1,050 ± 226 m) at baseline (+17.3 percent, 90 percent

CL (1.2;36 percent), ES, 0.68 (0.05;1.31)). Within-group analyses showed that players in the HR-based group had a very likely small improvement of YYIRT1 performance after the four-week training intervention (+14.4 percent (8;21 percent). The VIFT-based group showed a most likely large improvement of YYIRT1 performance after the five-week training intervention (+28.2 percent (20;36.9 percent)) (Figure 13.2A). When comparing the weekly improvement of the two groups when adjusted for baseline performance, the VIFT-based HIT group showed a likely and moderately greater YYIRT1 improvement than the HR-based HIT group (+86 percent (1.5–240 percent); the standardized difference in the change is shown in Figure 13.2B.

When considering individual changes, while only 67 percent of the players (i.e. n = 8/12) showed a substantial improvement in YYIRT1 in the HR-based

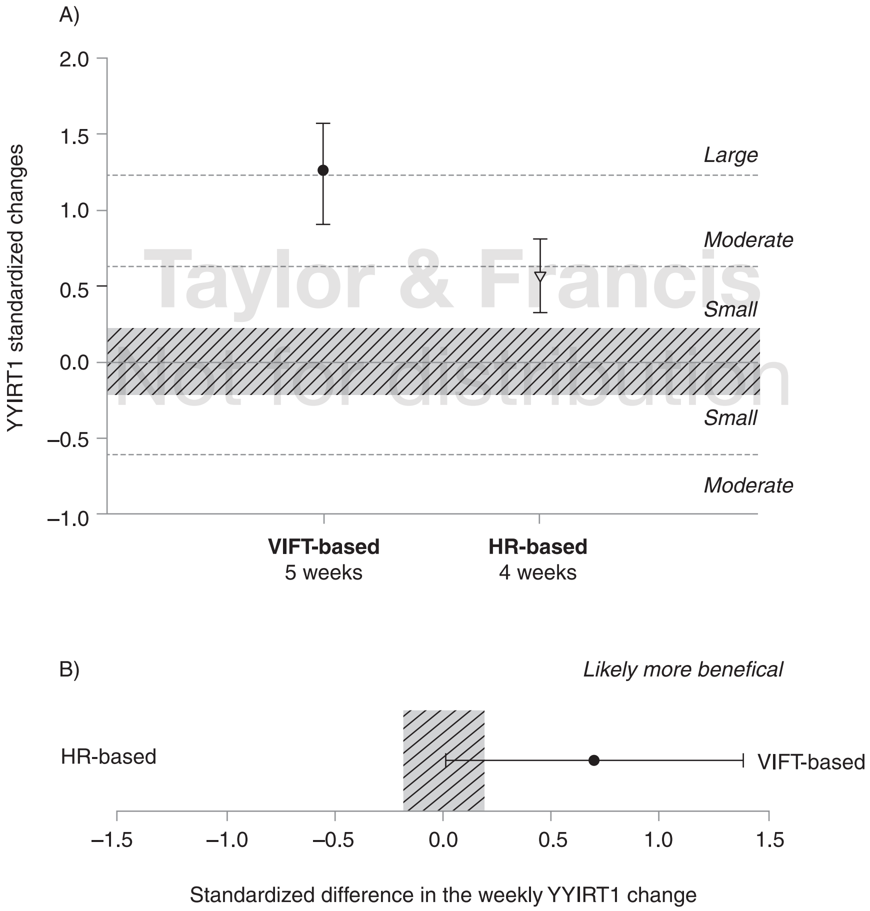

Figure 13.2 Standardized changes following the two high-intensity interval training (HIT) approaches A) within-group changes and B) difference in weekly improvements

Note: The shaded areas represent trivial changes/differences (see methods).

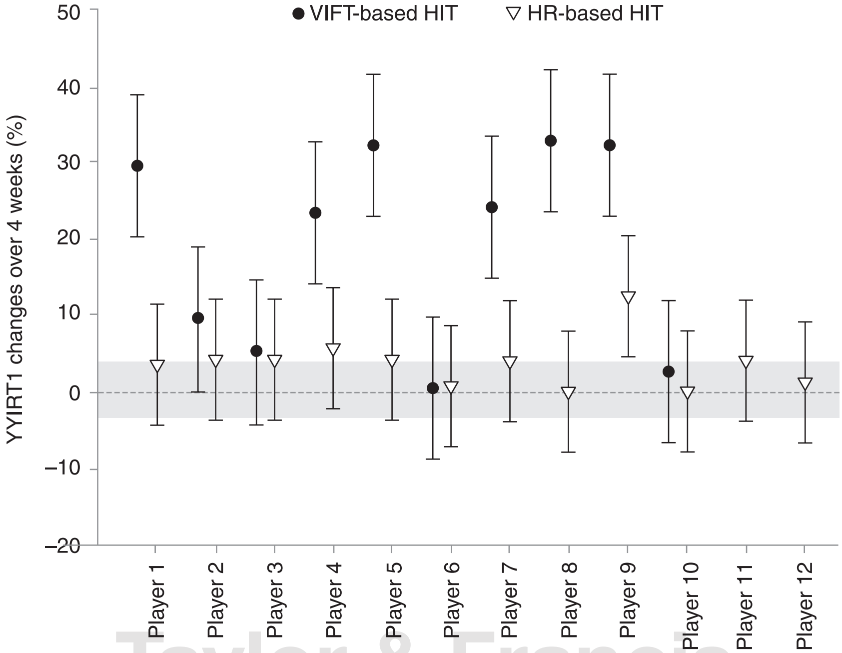

Figure 13.3 Individual changes in Yo-Yo intermittent recovery test level 1 (YYIRT1) performance over four weeks of training for both high-intensity interval training (HIT) groups

Note: The grey area represents the smallest worthwhile change (see methods). The errors bars represent the typical error of the measurement derived from reliability studies.

HIT, 80 percent of the players (i.e. n = 8/10) improved in the VIFT-based group (Figure 13.3). The OR for the chance of greater individual change with the VIFT-based vs. HR-based group was of a small but unclear magnitude (standardized OR: 0.4 (1.2;–0.6)). There was, however, no clear association between baseline YYIRT1 performance and YYIRT1 improvement within each group.

Discussion and conclusion

While HR is often used to control exercise intensity during HIT, this approach has several limitations, including the difficulty for practitioners to regulate running intensity. To overcome these limitations, using the speed reached at the end of the 30–15 Intermittent Fitness Test as the reference for running intensity has been suggested. The aim of the present study was to compare, for the first time, the respective effect of two approaches to prescribe the exercise interval intensity during running HIT on high-intensity intermittent running performance in young soccer players, i.e. using percentages of either HRmax or the maximum speed reached during the 30-15IFT as a reference marker. The main result is that while both approaches allowed for substantial gains in high-intensity intermittent running performance after four to five weeks, the VIFT-based approach produced likely and moderately greater weekly improvement in YYIRT1 compared with the HR-based approach. These results show that using the VIFT for individualizing HIT in young players is a likely more efficient strategy to program HIT in soccer (Buchheit, 2012).

The high-intensity intermittent running performance improvements observed after both the HR-based (+15 percent) and VIFT-based (+28 percent) HIT interventions were clearly greater than the SWC (Figure 13.2A), and within the 12 to 54 percent improvements previously reported after similar training preseason interventions (Bangsbo et al., 2008). However, since it is during the preseason period that the greatest changes in fitness generally occur (Bangsbo et al., 2008), performance gains of lower magnitude would likely be observed if the same training protocols were to be implemented during the season. It is also worth noting that there was also a slightly greater (but unclear) number of individual players that improved substantially their YYIRT1 in the VIFT- vs. HR-based group (i.e. 80 vs. 67 percent, Figure 13.3). While typical comparisons of training interventions generally require equated training doses or durations, the data in the present study were collected in a real life scenario with players competing in the highest league of their country, where unpredicted changes in training schedules often happen. We believe, however, that the 'real life' scenario increases the validity of the present study, and compensates somehow for the limitation of the disparate training durations. However, although the direct comparison of within-group changes is misleading because of the difference in training duration (i.e. four vs five weeks), comparing the weekly changes in high-intensity intermittent running performance allowed a proper examination of the difference between the two training approaches. Doing so, there was a 3- vs. 5-percent weekly increase in high-intensity intermittent running performance following HR- vs. VIFT-based HIT, respectively. In other words, there was a 86 percent greater weekly improvement in YYIRT1 when using VIFT compared with HRmax (Figure 13.2B). It is also important to note that if the training adaptation was to show a plateau throughout the end of the longer intervention (e.g. after the fourth week for the VIFT-based HIT), the VIFT-based HIT would have been even more efficient (i.e. reaching the same level in four and not in five weeks, which would increase further the weekly change in running performance, and suggest an even greater superiority).

While the most common method of individualizing HIT among practitioners is to use percentages (e.g. 90–95 percent) of HRmax (Buchheit & Laursen, 2013a), and despite the positive outcomes observed after HR-based HIT (Buchheit & Rabbani, 2014; Chamari et al., 2005; Helgerud et al., 2001; Hoff et al., 2002; Impellizzeri et al., 2006; McMillan et al., 2005), the comparison of HR- vs. VIFT-based HIT had never been examined yet. Importantly, also, the players subjected to the VIFT-based HIT were moderately fitter at the start of the preseason (i.e. 1,224 ± 227 vs. 1,050 ± 226 m). The comparisons of the changes between the two methods accounted statistically for these fitness differences; however, since fitter players tend generally to improve less than their less-fit counterparts (Mann et al., 2014), the 'superiority' of the VIFT-based approach may have been of even greater magnitude if the two groups had the same baseline YYIRT1 performance.

The reasons for the greater efficiency of using VIFT compared with HR to control exercise intensity during HIT are likely multiple, but the lack of physiological measures before and after the intervention (e.g. maximal oxygen uptake, cardiac output, oxidative capacity) prevent definitive conclusions on the likely adaptations. The first limitation of HR may be related to the difficulty for practitioners to tightly regulate running intensity during the actual workout. In fact, controlling HR when training a large number of athletes simultaneously during HIT is not an easy task without the use of sophisticated equipment (e.g. telemetry systems for live feedback (Dellal et al., 2012). While the lack of physiological (i.e. HR, blood lactate) and perception (RPE) measures to document the exercise intensity is a strong limitation of the present study, it is possible that players may not have spent the entire intervals at the required intensity, despite their efforts to maintain their HR in the high-intensity zone (anecdotal observations). Further comparisons of the acute cardiorespiratory responses to these two types of intervals are still required to confirm this hypothesis (Buchheit et al., 2009). The second limitation of HR-based HIT is related to the likely dissociation between HR and the actual metabolic demands during HIT (Buchheit & Laursen, 2013a), so that a high metabolic demand may not be reached despite elevated HRs (as soon as a high HR is reached, the intensity is perceived as sufficient, while players might be able to train a bit faster to reach higher and optimal levels of metabolic demands). The third limitation of using HR is, in contrast to speed-based HIT, the inability of HR to inform on running intensities above vVO2max, which represent a large proportion of the training intensities used in soccer for conditioning purposes (Buchheit & Laursen, 2013b). While this didn't apply in the present study given the submaximal running intensity, this may have to be considered for shorter and more intense types of intervals. When using a locomotor reference to prescribe running intensity, these limitations are not evident since players will be requested to complete their intervals irrespective of their HR responses (Buchheit & Laursen, 2013a).

Based on present results, it seems that the best option to control HIT intensity, particularly while implementing acceleration, deceleration, COD and technical actions simultaneously, is using VIFT and individualizing running speed accordingly with a metronome or an audio file. Including the 30-15IFT at least in preseason tests for a young athlete is therefore not only informative with respect to general fitness assessment, but it is also a very practical test for individualizing and prescribing soccer-specific HIT programs. Our study showed that 3–4 minutes of soccer-specific actions including acceleration, deceleration, COD and passing a ball at an intensity averaging 65–70 percent of VIFT was very efficient to improve high-intensity intermittent running performance in young soccer players. This intensity could be obviously modified in accordance to interval duration (i.e. higher for shorter intervals) and movement patterns (i.e. higher with less COD/ball contacts).

In conclusion, the present study showed that using VIFT as a reference for programming individualized HIT is a more likely efficient strategy to improve high-intensity running performance in young soccer players than programing intervals based on percentage of HRmax. While intensities ~85 percent of VIFT are generally used to prescribe running-based HIT with long intervals (2–3 minutes), a reduction up to 65–70 percent of VIFT may be required when implementing football-specific types of drills including COD and technical components (passes and dribbling). Future studies comparing the possible changes in various physiological markers after both interventions would help to better understand the underlying mechanisms of adaptation.

Acknowledgements

The authors thank Hamid Taghi Beigi for his help with the audio files. The authors disclose professional relationships with companies or manufacturers who will benefit from the results of the present study.

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