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INTEGRATING FIELD-BASED TESTS INTO WEEKLY SOCCER TRAINING SESSIONS: A COMPARISON OF PHYSIOLOGICAL DEMANDS OF THREE PROGRESSIVE MULTISTAGE FITNESS TESTS AND REGULAR TRAINING DEMANDS

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ABSTRACT
Purpose. This study compares the physiological demands of 30-15 Intermittent Fitness Test (30-15IFT), Yo-Yo Intermittent Recovery Test level 1 (YYIRT), and VAMEVAL test as related to training and match demands among youth soccer players.
Methods. Overall, 12 under-19 male soccer players (18.21 ± 0.34 years old) were monitored over 3 consecutive weeks for heart rate (HR) responses during training sessions and matches. During this period, they were assessed with 30-15IFT, YYIRT, and VAMEVAL. The measures were taken on the same day of the week to ensure replicable conditions between the tests.
Results. The Friedman test revealed significant differences in the average HR ($p = 0.006$), time in HR zone 3 ($p < 0.001$), and time in HR zone 4 ($p = 0.039$) between the tests. Considering the representativeness of the tests in comparison with training sessions and matches, both 30-15IFT and VAMEVAL corresponded to 48% and 46% of the training session load 3 days before the match day (936 ± 447 s) and on the match day (831 ± 533 s), respectively.
Conclusions. YYIRT imposed greater time exposure to high HR intensities (in the zones of 80–100% of HR maximum) than VAMEVAL and 30-15IFT. Moreover, the multistage fitness tests corresponded to slightly more than half of the time in which a player was exposed to 80% and 100% of HR maximum during a regular training session and match day. These findings may assist coaches in understanding how to incorporate intermittent fitness tests within training in order to accurately replicate HR responses of match conditions.
Key words: football, exercise test, athletic performance, cardiorespiratory fitness

Introduction

Multistage fitness tests are used in the context of physical fitness assessment in soccer [1, 2]. These tests are proposed under the theoretical construct of soccer being an intermittent exercise in which aerobic metabolism is predominantly taxed [3]. Thus, aerobic fitness is one of the main physical fitness variables that support the match running performance of soccer players [4]. For example, soccer players with the greatest maximal oxygen uptake cover the longest distances at high intensity during a match [5, 6]. Further, performance in a multistage fitness test correlates with match running performance [7], supporting the utility of these tests to monitor changes in aerobic performance [8, 9].

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Aerobic fitness also differs between competitive levels and playing positions [10, 11]. Elite-level athletes possess greater aerobic fitness than their sub-elite and recreational counterparts [10, 11]. Additionally, midfield and full-back players exhibit higher aerobic fitness than their counterparts playing in alternate positions [10, 11]. Thus, testing aerobic fitness can distinguish player status and the ability to sustain high-intensity activities and repeated efforts over a match. The use of these test may also provide coaches with enhanced guidance for prescribing high-intensity interval training, as reported on previously [1, 2].

Although laboratory tests for determining aerobic fitness are valid and reliable [12], the reduced ecological validity and applicability supports the implementation of field-based tests that estimate the aerobic capacities of players [13]. Owing to the intermittent nature of the sport, most of the field-based tests applied in soccer are intermittent and progressive, leading players to exhaustion [14, 15]. The 2 tests most commonly used [16–19] are the Yo-Yo Intermittent Recovery Test level 1 (YYIRT) [20] and the 30-15 Intermittent Fitness Test (30-15IFT) [21]. The VAMEVAL test differs greatly as it uses continuous rather than intermittent activity. The VAMEVAL (an adaptation of the University of Montreal Track Test) [22] begins with a running speed of 8.5 km/h, with a progressive increase in pace of 0.5 km per each minute (without intermittence). In comparison, YYIRT uses 2 × 20-m shuttle runs interspaced by 10 seconds of active recovery. The test starts at 10 km/h, followed by 8 × 20-m runs at 10–13 km/h, 14 × 20-m runs at 13.5–14 km/h, proceeding stepwise 0.5 km/h speed increments after every 16 × 20-m runs until exhaustion [20]. 30-15IFT consists of 30-second shuttle runs interspaced by 15-second active recovery, starting at a pace of 8 km/h, with progressive increments of 0.5 km/h for every 30-second run until exhaustion [21]. While both 30-15IFT and YYIRT are intermittent and progressive, their design leads to significant differences in locomotor demands. For example, at a pace of 18 km/h, a player covers 150 m in 30-15IFT and 3000 m in YYIRT.

With many tests available and inherent differences between the field-based test, there is some debate about which one is best [14]. A recent narrative review suggested that the VAMEVAL test was more able to estimate maximal oxygen uptake. At the same time, 30-15IFT was more appropriate to track changes in fitness and individualize high-intensity interval training [14], and YYIRT was the best indicator of aerobic capacity and the ability to perform repeated efforts [23].

While aerobic fitness tests can identify the aerobic fitness status of players and are used to individualize the training stimulus or provide references about players' progression across the season, there are some issues related to their implementation in practical scenarios. Coaches often report difficulties including the tests in weekly training schedules [24]. This is because they are typically viewed as an addition to regular training rather than an element of the periodized training plan. However, a recent case report [25] characterized the physiological impact of 30-15IFT applied in professional players. It provided the representativeness of this impact with reference to the regular training demands of the team. 30-15IFT may represent 60–100% of the metabolic cost of a typical training session when considering the time spent at > 90% maximal HR and maximal blood lactate [25].

Before coaches can involve multistage fitness testing in regular training, it is vital to understand the effect of the tests on the total training load and their representation of usual match demands. Thus, the current study aimed to compare the physiological demands of 30-15IFT, YYIRT, and the VAMEVAL in youth soccer players and describe the physiological representativeness of these tests as related to the training session and match demands.

Material and methods

Study design, setting, and approach

This investigation used a descriptive case study design and was conducted over 3 consecutive weeks between November 21, 2021, and December 11, 2021. This corresponded to an in-season period (middle of the Turkish soccer season). A different multistage fitness test was implemented in each week: the VAMEVAL in week 1, YYIRT in week 2, and 30-15IFT in week 3. The 3 tests were performed 4 days after the last match and with 24 hours of rest from the previous training session. They were applied in the afternoon and immediately after implementing the FIFA 11+ standardized warm-up protocol (level 2), consisting in 8 minutes of low-to-moderate running, 10 minutes of strength, plyometrics, and balance exercises, and 2 minutes of running exercises. The tests started 3 minutes after the end of the standardized warm-up, approximately at 6:25 p.m. The average environmental temperature during the assessments was 22°C, with a relative humidity of 54%. The tests always took place on the same synthetic turf, except for the VAMEVAL test, which was conducted on a running track). The players used HR sensors during the testing, training sessions, and matches. For identifying the training sessions and games, the proximity to the next match day (MD) was considered. The matches always occurred on Sundays, and the training sessions on Thursday (MD-3), Friday (MD-2), and Saturday (MD-1). The researchers had no input into training other than the implementation of the multistage fitness tests.

Participants

A convenience sampling strategy was employed. The study was conducted in a single under-19 team (all participants were aged over 18 years), which competed in the national under-19 Turkish league. The following eligibility criteria were defined: (i) participation in all assessments performed over the 3 weeks; and (ii) participation in training sessions on different days (MD-3, MD-2, MD-1, and MD) at least once. From the 19 initially selected players, 12 were included in the analysis. Five players were excluded because they did not participate in the 3 tests, and 2 were excluded because they did not participate in one or more of the training sessions. The characteristics of the included athletes are presented in Table 1. The participants were informed about the study design and protocol, risks and benefits.

The VAMEVAL test

The VAMEVAL test consists in running on a 400-m athletic track. After an audio beep, the pace is increased by 0.5 km/h at each minute [26]. The test starts with a speed of 8.5 km/h, with players spaced 20 m apart. The participants are required to transition between cones (20 m apart) in time with the audio cues. The test stops when a player cannot maintain the pace or fails to reach the expected cone associated with the beep for 3 consecutive times. The primary outcome extracted from the test is the final velocity completed by the player.

The Yo-Yo Intermittent Recovery Test level 1

YYIRT consists of executing shuttle runs of 20 m, followed by a recovery period of 10 seconds. The test is intermittent and progressive. Starting at 10 km/h, the players must perform 8 runs of 20 m at a speed of 10–13 km/h, 14 runs of 20 m at 13.5–14 km/h, and 16 runs of 20 m at > 14 km/h [20]. The pace increases by 0.5 km/h at each stage [20]. The test ends when the player cannot sustain the pace imposed by an audio beep or fails to reach the expected line in 2 consecutive efforts. The main outcome of this test is the total distance completed. The final velocity is also registered.

The 30-15 Intermittent Fitness Test

The 40-m field-based 30-15IFT [21] requires athletes to run for 30 seconds, interspaced by recovery periods of 15 seconds. The test starts at 8 km/h and the pace progressively increases by 0.5 km/h after each 30-second period. An audio beep guides the participants to keep the expected pace. The test ends when a player cannot sustain the pace or fails to reach the expected line for 3 consecutive times. The primary outcome extracted from the test is the final velocity completed.

Heart rate monitoring

The heart rate (HR) responses of the players were monitored in the tests, training sessions, and matches by using the Polar Team Pro tool (Polar Electro, Kempele, Finland), which consists of a chest band with an HR sensor of a sampling frequency of 1 Hz. By applying the peak HR during the tests, it was possible to determine the maximal HR and define the following thresholds: (i) HR zone 3 (HRz3; time spent at 71–80% of the maximal HR); (ii) HR zone 4 (HRz4; time spent at 81–90% of the maximal HR); and (iii) HR zone 5 (HRz5; time spent at 91–100% of the maximal HR). The average HR (HRaverage), minimal HR (HRmin), and peak HR (HRpeak) were also collected as outcomes. Finally, Edwards' training impulse (TRIMP) [27] was calculated by multiplying the HR zones by the time spent in each of them, and the sum of all constituted the final outcome.

Statistical procedures

Descriptive statistics were presented as mean, standard deviation, and percentage of difference (V2 – V1)/V1 × 100). Variations of HR responses between 30-15IFT, YYIRT, and the VAMEVAL were tested with the Friedman test. Non-parametric tests were

Table 1. Characteristics of the included players

Age (years)	Body mass (kg)	Height (m)	30-15IFT (km/h)	YYIRT (km/h)	VAMEVAL (km/h)
18.17 ± 0.39	72.6 ± 3.5	1.78 ± 5.6	16.8 ± 1.9	17.4 ± 0.9	14.6 ± 0.8

30-15IFT – 30-15 Intermittent Fitness Test, YYIRT – Yo-Yo Intermittent Recovery Test level 1 chosen since a violation of homogeneity was found and because of the small sample ($n < 30$). The Friedman test served to examine the same population for differences on the 3 occasions. The post-hoc test was performed by using the Wilcoxon signed-rank test, which is indicated for being more conservative and exhibiting lower power [28]. Descriptive statistics were applied to describe the physiological representativeness of each test as related to the training session and match demands. The statistical procedures were executed with the Statistical Package for the Social Sciences (SPSS, version 28.0.0.0, IBM, USA). Statistical significance was assumed at the value of $p < 0.05$.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Afyon Kocatepe University ethics committee (protocol code: 2021/1166, date of approval: November 15, 2021).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

Table 2 presents the physiological demands of 30-15IFT, YYIRT, and the VAMEVAL tests performed repeatedly by the 12 players. The Friedman test revealed significant differences in HRaverage ($p = 0.006$), HRz3 ($p < 0.001$), and HRz4 ($p = 0.039$). Regarding HRaverage, YYIRT resulted in significantly lower values than 30-15IFT (–7.2%; $p = 0.013$) and the VAMEVAL (–8.0%; $p = 0.008$). Considering HRmin, YYIRT values were significantly lower than those of 30-15IFT (–14.2%; $p = 0.032$). The VAMEVAL was associated with significantly less time in HRz3 than 30-15IFT (–61.1%; $p = 0.028$) and YYIRT (–92.6%; $p = 0.002$). Additionally, time in HRz3 was shorter in 30-15IFT than in YYIRT (–80.9%; $p = 0.003$). As for HRz4, the time in the zone was significantly shorter in 30-15IFT than in YYIRT (–48.3%; $p = 0.028$). TRIMP (training time in minutes multiplied by the rating of perceived exertion) was significantly lower in the VAMEVAL than in YYIRT (–17.6%; $p = 0.038$).

The comparison of HRaverage, HRmin, and HRpeak between training and match sessions and the field-based tests can be found in Figure 1. HRpeak was lower in each of the field-based tests than on MD-3 or MD. On average, HRpeak equalled 207 (± 10 bpm) on MD-3 and 200 (± 10 bpm) on MD, while during the tests, HRpeak was 197 (± 12 bpm) in 30-15IFT, 194 (± 19 bpm) in YYIRT, and 198 (± 8 bpm) in the VAMEVAL. Regarding HRaverage, any of the field-based tests presented higher values than MD-3 (9–19%) or MD (11–20%).

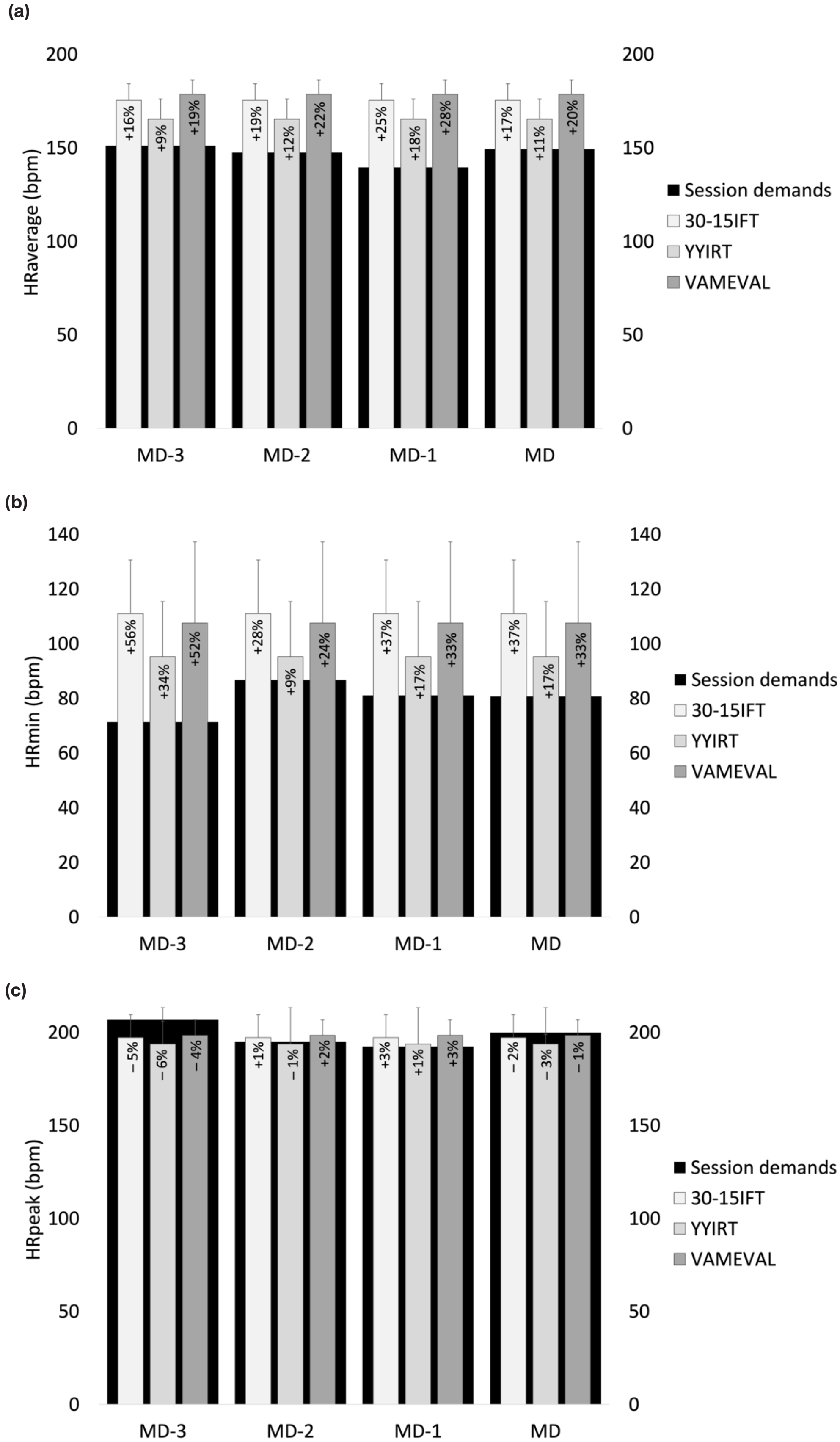
Figure 2 presents the average impact of field-based tests compared with training sessions and matches with regard to the time spent in HR zones 3–5 and TRIMP. YYIRT (the field-based test with more time spent in HRz3) corresponded to almost 72% and 52% of time spent in HRz3 on MD-3 (1501 ± 490 s) and MD (840 ± 304 s), respectively. Considering TRIMP, YYIRT corresponded to 38% and 30% of the MD-3 (272 ± 61 AU) and MD (255 ± 56 AU) demands, while the VAMEVAL and 30-15IFT corresponded to 33–34% and 34–36% of the MD-3 and MD demands. In the case of time spent in HRz5, both 30-15IFT and the VAMEVAL corresponded to 48% and 46% of the MD-3 (936 ± 447 s) and MD (831 ± 533 s) demands, respectively.

Table 2. Physiological demands of 30-15IFT, YYIRT, and VAMEVAL (n = 12)

Outcome	30-15IFT (mean ± *SD*)	YYIRT (mean ± *SD*)	VAMEVAL (mean ± *SD*)	Friedman test
HRaverage (bpm)	176.7 ± 9.0[b]	163.9 ± 11.8[a,c]	178.1 ± 7.9[b]	$p = 0.006$
HRmin (bpm)	109.5 ± 21.6[b]	94.0 ± 21.7[a]	106.2 ± 30.3	$p = 0.064$
HRpeak (bpm)	199.9 ± 11.7	195.0 ± 21.7	197.0 ± 8.9	$p = 0.368$
HRz3 (s)	74.6 ± 47.8[b,c]	390.4 ± 301.3[a,c]	29.0 ± 31.8[a,b]	$p < 0.001$
HRz4 (s)	282.5 ± 198.8[b]	546.0 ± 304.9[a]	376.7 ± 190.4	$p = 0.039$
HRz5 (s)	503.2 ± 318.0	285.7 ± 410.5	398.9 ± 218.3	$p = 0.125$
TRIMP (AU)	65.6 ± 19.0	73.5 ± 22.8[c]	60.6 ± 10.6[b]	$p = 0.212$

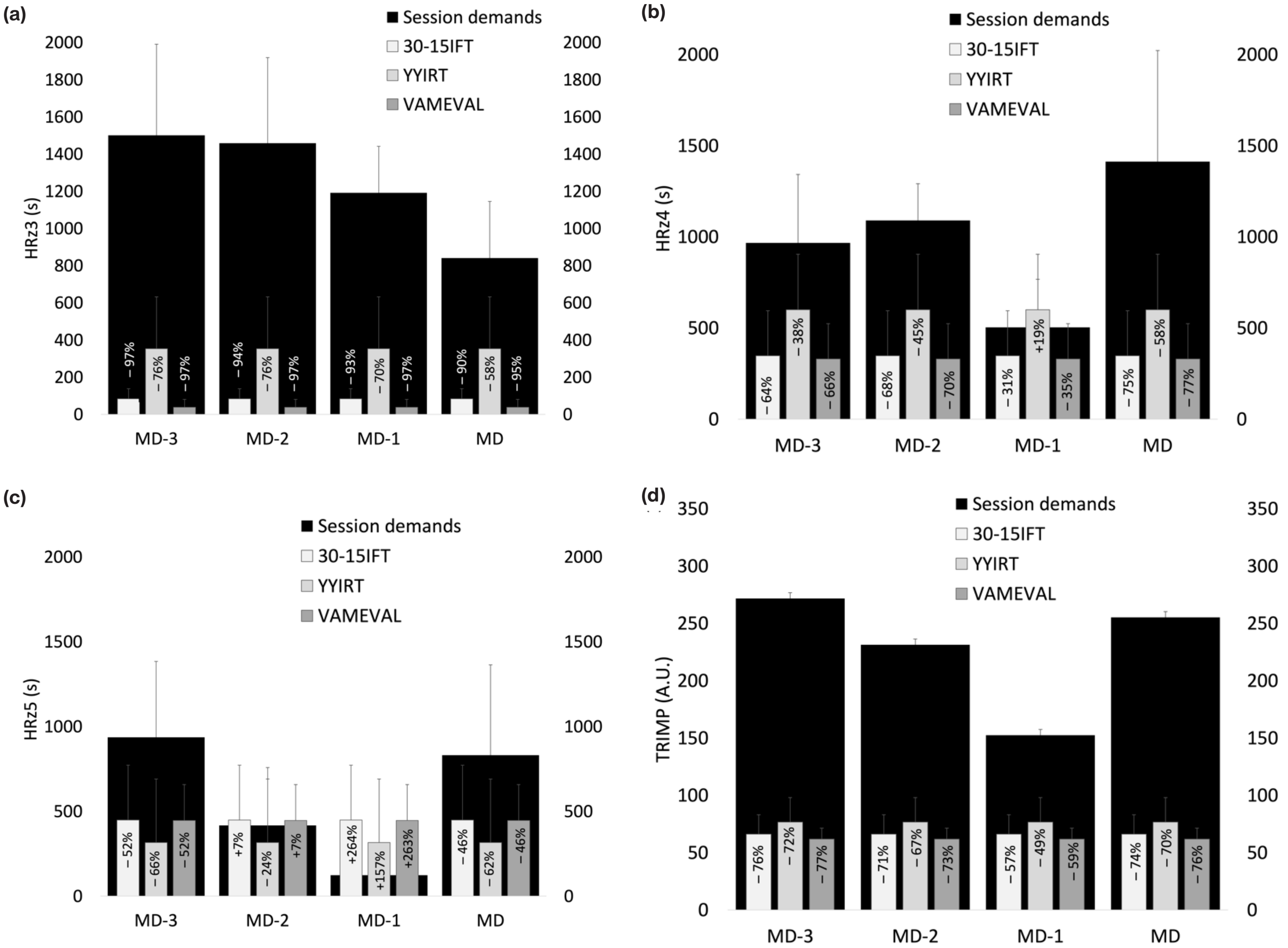
30-15IFT – 30-15 Intermittent Fitness Test, YYIRT – Yo-Yo Intermittent Recovery Test level 1, HRaverage – average heart rate, HRmin – minimal heart rate, HRpeak – peak heart rate, HRz3 – heart rate zone 3 (71–80%), HRz4 – heart rate zone 4 (81–90%), HRz5 – heart rate zone 5 (91–100%), TRIMP – Edwards' training impulse

[a] significantly different from 30-15IFT, [b] significantly different from YYIRT, [c] significantly different from VAMEVAL, at $p < 0.05$



HRaverage – average heart rate, HRmin – minimal heart rate, HRpeak – peak heart rate, MD – match day, 30-15IFT – 30-15 Intermittent Fitness Test, YYIRT – Yo-Yo Intermittent Fitness Test level 1

Figure 1. Comparison of (a) average heart rate, (b) minimal heart rate, and (c) peak heart rate between training session and match demands and field-based tests. Percentage of difference is between the field-based test and the session analysed



HRz3 – heart rate zone 3 (71–80%), HRz4 – heart rate zone 4 (81–90%), HRz5 – heart rate zone 5 (91–100%), TRIMP – Edwards' training impulse, MD – match day, 30-15IFT – 30-15 Intermittent Fitness Test, YYIRT – Yo-Yo Intermittent Fitness Test level 1

Figure 2. Comparison of (a) heart rate zone 3, (b) heart rate zone 4, (c) heart rate zone 5, and (d) TRIMP between training session and match demands and field-based tests. Percentage of difference is between the field-based test and the session analysed

Discussion

The aim of this study was to compare the physiological demands of 30-15IFT, YYIRT and the VAMEVAL in youth soccer players. Additionally, we aimed to describe the physiological representativeness of the 3 multistage tests in relation to usual training and match demands. Understanding the physiological demands of each test can guide practitioners on the best moment to integrate it into a players' overall weekly load management and progression.

A higher HRaverage and HRmin was observed for 30-15IFT and the VAMEVAL tests. In addition, the time in HRz5 was highest in 30-15IFT. 30-15IFT consists of progressive 30-second shuttle runs interspaced by 15-second active recovery periods [21], while the VAMEVAL is a continuous progressive test [22]. Thus, the time spent at HRz5 confirmed that 15 seconds of rest likely contribute to a longer time spent at the highest intensity when compared with the other 2 tests [23]. However, HRz3, HRz4, and TRIMP presented the highest values in YYIRT. Three perspectives can explain this result: (1) the characteristics of the 15-second pause in 30-15IFT; it seems that this test induced more time at a higher anaerobic component [23] and, consequently, higher HR (> 70%); (2) the continuous regime of the VAMEVAL; it seems that a higher aerobic component that is probably associated with a lower level of HR (< 70%) was more frequent in this test; and (3) a pause of 10 seconds and efforts lower than 30 seconds in YYIRT compared with 30-15IFT did not allow sufficient recovery. Therefore, the HR remaining at relative higher values (HRz3 and HRz4) is supported by a difference in the TRIMP data for each test. A possible explanation could be related to the fact that 30-15IFT is faster than YYIRT, and, for that reason, a more rapid rise in HR values (HRz5) occurred compared with lower levels (HRz3 and HRz4) [29].

Regarding the TRIMP data, it is important to mention that our study showed much higher training and match values than a previous study in under-17 soccer players, which revealed an average of 105 AU and 110 AU (Banister TRIMP) among starters and non-starters, respectively [30]. This previous finding supports the application of any test because the present TRIMP data derived from the 3 trials did not overcome TRIMP values previously reported.

Considering the representativeness of the tests compared with training sessions and matches, HRpeak falls in line with data from all training and games. However, HRaverage and HRmin were higher in all 3 tests than in the training sessions and matches. These results mean that each test presented a higher intensity than the usual training and games. However, the time spent in HRz3, HRz4, and HRz5, as well as the overall TRIMP were higher in the usual training and match sessions when compared with all tests, with the exception of MD-2 (30-15IFT and the VAMEVAL) and MD-1 (all tests) for the time spent at HRz5. This denotes that the multistage fitness tests correspond to slightly more than half of the time in which a player is exposed to 80% and 100% of HR maximum during a regular training session. This is unsurprising if one considers the maximal nature of these tests and the shorter period in which they are conducted. It also adds support to the previous work by Buchheit and Brown [25], who revealed that both the metabolic and locomotor demands of 30-15IFT were inferior to those of both matches and typical training sessions. They reported that 30-15IFT represented a load that was equivalent to 60–100% of the metabolic cost and 30–50% of the locomotor load. Their results, along with those achieved in this study, support the demanding nature of these tests from a metabolic perspective, and indicate that they may be best introduced during a technical session. This would allow the training drills that follow not to require any further metabolic loading, but rather to include 50–70% of usual session locomotor loads [25].

Owing to the varying results obtained for MD-2 and MD-1, it is also recommended that MD-3 could be the best time period in the training week to apply any of these tests, depending on the specific goal of the MD-3 session (i.e. more technical/tactical or more analytical) and the specific physical quality that needs to be trained or tested [24]. This information can help coaches and their staff in the implementation of these 3 tests to complement usual training. In addition, the application of the tests on MD-3 aligns with the recommended 48 hours of recovery before match-play [31]. Therefore, coaches only need to manage the weekly periodization to avoid exercises that have a high metabolic cost, such as excessive time spent at HR > 90%.

This study presents some limitations. First, only 12 under-19 soccer players were analysed, which may hinder generalizations of the results to other populations. Second, the study lasted for 3 weeks only and each test was employed only once. For that reason, we recommend more extensive periods of observation. Third, only weeks with 3 training sessions and one match were analysed. Weeks with more training sessions and/or matches may reveal different results owing to the influence of recovery and how that microcycle fits within the overall annual periodization plan (e.g. recovery focus or physical development focus). Fourth, physical outputs such as total distance, high-speed running distance, and accelerometry-based measures would allow further insights into the physical demands of each match and training session. Considering the aforementioned reasons, we recommend that future studies use different training schedules and, if possible, a global positioning system to address more physical output variables. Finally, we suggest conducting similar studies in other age categories and different athletic populations.

The practical application of this study suggests that despite the differences in the field tests, it appears that each could be involved in training sessions without provoking additional excessive fatigue over the usual training or match data. They may be best conducted during a technical session or in a training session where the following training drills have a lower metabolic cost with less time spent at > 90% HR maximum and include more locomotor loads in the range of 50–70% of usual sessions. Eventually, it is recommended to use greater mechanical stimulus [32] by inducing larger pitches, while decreasing the metabolic impact with a positional drill or a large-sided game [33].

When deciding on the best protocol to follow, owing to the similarities in the internal load, if the goal is to track changes in fitness and individualize high-intensity interval training, then, as per previous research [14], it would appear that 30-15IFT may be the most appropriate. Nonetheless, some caution must be taken into consideration with regard to the study limitations.

Conclusions

The current study revealed that YYIRT imposed greater time exposure to high HR intensities (namely in zones of 71–90% of HR maximum) in comparison with the VAMEVAL and 30-15IFT. In addition, 30-15IFT imposed greater time exposure at HR > 90% than the VAMEVAL and YYIRT. Moreover, it was observed that the multistage fitness tests corresponded to slightly more than half of the time in which a player was exposed to 80% and 100% of HR maximum during a regular training session (MD-3) and MD. This corroborates previous research and indicates that these tests may be best applied during sessions with lower metabolic costs and greater locomotor loads. Considering the players analysed, MD-3 appears to be the most appropriate pre-match period to apply one of these tests for cardiorespiratory assessment and/or as a training complement. The results of this study may help coaches to organize training sessions to fit the intermittent progressive multistage tests without influencing the expected training stimulus.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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