Title: Reliability of heart rate responses both during and following a 6 min Yo-Yo IR1 test, in highly trained youth soccer players.

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Running Head: Reliability of HR during 6 min Yo-Yo IR1

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Abstract

Purpose: To examine the reliability of HR measures obtained during the 6 min Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IR1), and following a 3 min passive recovery, within a group of highly trained youth soccer players.

Methods: Eight players, completed three separate 6 min Yo-Yo IR1 tests, with a passive recovery, over a two week period. Measures of absolute heart rate (bpm) and relative HR (%HR_{max}) were obtained at the 3rd and 6th min of the test, with measures relative to the end HR (%HR_{end}) 10, 20, 30, 60, 90 and 180 seconds, during the 3 min passive recovery. Variability in HR measures were assessed across successive trials (trial 1 vs. 2 and trial 2 vs. 3) and across all 3 trials, using the intraclass correlation coefficient (ICC), coefficient of variation (CV) and typical error (TE).

Results: HR measures obtained during the 6 min Yo-Yo IR1 test displayed good levels of reliability (ICC: 0.95-0.98, CV: 1.1-1.3% and TE: 0.96-2.44). Results, display a potential learning effect, with lower levels of variability between trial 2 vs. trial 3. Examination of %HR_{end} obtained during the passive 3 min recovery demonstrated an increased variance, as the passive recovery period progressed.

Conclusion: The 6 min Yo-Yo IR1 test presents a novel and potentially practical approach to regularly assessing youth soccer players' physical response to intermittent exercise. Practitioners and researchers should however, consider the need for appropriate familiarisation when undertaking this test.

Introduction

Soccer-specific endurance capacity, the ability to consistently perform high intensity intermittent exercise, is an essential fitness component for successful performance (Wrigley et al. 2014). Regular assessment of this fitness component may be used to identify individual player training requirements as well as evaluate the efficacy of specific interventions (Halson 2014; Kellam 2010). Due to the intermittent nature of soccer-specific fitness, the advantages of group field-testing in team sports and the need to control extraneous variables (e.g. distance covered and recovery times) when conducting fitness tests, the Yo-Yo intermittent recovery (Yo-Yo IR) field tests were devised as a means for assessing soccer-specific endurance (Bangsbo et al. 2008).

The Yo-Yo IR level 1 (Yo-Yo IR1) test is a commonly used test to assess the soccer-specific endurance capacity, in both adults (Bangsbo et al. 2008; Mohr and Krustrup 2014; Krustrup et al. 2003) and youth (Carvalho et al. 2014; Deprez et al. 2014) populations. The traditional approach to administering the Yo-Yo IR1 test requires participants to exercise to their maximum (Bangsbo et al. 2008). While such testing maybe incorporated into a periodized training plan, maximal testing can lead to a large additional imposition on an individual’s training load, which is particularly impractical during intensified periods of the competitive season. As a result, sub-maximal surrogates have been devised to provide a regular assessment of the players’ training status without imposing a large additional training load (Buchheit 2014).

The 6 min Yo-Yo IR1 test is a non-exhaustive adaptation of the traditional Yo-Yo IR1 test that assesses the internal load (heart rate response) for a given external load. Bangsbo et al. (2008) report unpublished data suggesting a moderate correlation between an individual's relative heart rate (%HR_{max}), during the 6th min of the Yo-Yo IR1 test and both their maximal performance in the Yo-Yo IR1 and the volume of high intensity running (>15 km/h) performed during soccer match-play (r = 0.54 and r = 0.48, respectively). In addition, Krustrup et al. (2003) reported significant reductions in elite male player's HR responses at the 6th min of the Yo-Yo IR1, when comparing results between pre-preparation against the mid-preparation, start of the season and end of the season. No changes in HR responses within the season were reported though. Nevertheless, this suggests that a 6 min version of the Yo-Yo IR1 test may be a useful test for tracking changes in soccer-specific endurance during intensive periods of training (e.g. pre-season). Together with the fact that the reduced loading incurred from the test allows for regular integration into the weekly training schedule, the evidence provided supports the use of the 6 min Yo-Yo IR1 as a means for assessing players' current state of soccer-specific fitness.

Previous research has predominantly focused on players' HR during the 6 min Yo-Yo IR1 and not the players' HR during an additional recovery component. This is surprising considering that Buchheit et al. (2007) demonstrated that parasympathetic activity is highly impaired following repeated high intensity exercise, a form of exercise which is common among soccer training. Consequently, improved measures (faster recovery) of heart rate recovery (HRR) can be used as an indicator of training status and readiness to train or compete (Buchheit et al. 2010). The addition of a 3 min recovery phase to the 6 min Yo-Yo IR1 will provide an opportunity to assess players' HRR following a standardised external load. Therefore, providing a more detailed assessment into a player's current level of cardio-respiratory fitness and indication towards their current training status.

While there is evidence to highlight both the relevance and application of the 6 min Yo-Yo IR1 test, there is a lack of information examining the reliability of the measures obtained during the test. Deprez et al. (2014) reported little variance (CV's between 1.1 and 4.1%) when assessing the test-retest reliability of HR measures (%HR_{max}) in a cohort of non-elite youth soccer players, at different levels during the Yo-Yo IR1 and at 1 and 2 min post-test. Moreover, recent research by Owen, Jones and Comfort (2017), reported that HR measures obtained at the end of a 6 min Yo-Yo IR1 and at 30, 60, 90 and 120 sec during a 2 min passive recovery, were determined to be reliable in elite youth soccer players aged 18.8 ± 0.5 years. Nevertheless, it is necessary to gain population specific (i.e. age) information on the reliability of such a test (Atkinson and Nevill 1998), as this information will be essential for the interpretation and clinical decisiveness when examining observed changes between groups and individuals (Batterham and Hopkins 2006). Particularly as younger populations are more reliant upon aerobic energy provision and, therefore, heart rate variability is more important to quantify (Ratel, Duche and Williams, 2006). Therefore, the reliability of HR responses during the 6 min Yo-Yo IR1 test, within highly trained youth soccer players requires investigation. As a result, the purpose of this study was to assess the reliability of HR measures obtained during the 6 min Yo-Yo IR1 test and during an additional 3 min passive recovery (10, 20, 30, 60, 120 and 180 sec), within a group of highly trained youth soccer players.

Methods

Subjects

Eight highly trained academy youth soccer players volunteered to participate in the present study. All participants were outfield players, aged between 12 and 14 years and from the same Category One Premier League Football Academy. Table 1 displays all anthropometric and descriptive characteristics of the players. Maturity status was quantified using self-assessment, Tanner Stage method (Tanner 1962) and maturity offset (Mirwald et al. 2002). Players and their parents were informed about all procedures and requirements involved before providing written informed consent and assent from parents and participants, respectively. Ethical approval was granted from the local university ethics committee.

***** Table 1 near here *****

Study Design

To assess the reliability of heart rate measures obtained during the 6 min Yo-Yo IR1 test, with an additional 3 min passive recovery, the same 8 players completed the test on 3 separate occasions over a two week period. Testing was conducted during the final two weeks of a 6 week end of season training meso-cycle, in which participants were undertaking 3 field based training sessions, 2 strength and conditioning sessions and one competitive match per week. Participants wore the same heart rate monitor (Polar Electro, Kempele, Finland) and 10 Hz GPS unit (Catapult, Melbourne, Australia) for each test. A minimum of 48 hr recovery was provided between tests and all tests were completed at the same time of day ± 1 hr and all participants were familiar with the Yo-Yo IR1 protocol. Specifically, all players had been at the club for the previous two years, in which they had completed the Yo-Yo IR1 a minimum of 6 times (pre, mid and end of season). In addition, all participants had previously undertaken the 6 min Yo-Yo IR1, with a 3 min passive recovery, on one previous occasion prior to partaking in this study.

All tests were preceded by a 10 min warm-up, consisting of low intensity running, dynamic exercises (bilateral and unilateral) and then moderate intensity running, which incorporated appropriate 180 degree changes of direction similar to that which are undertaken in the 6 min Yo-Yo IR1 test. Prior to starting the test, a 5 min recovery period was implemented in which all participants HR returned to <100 bpm. Following all tests, including the 3 min recovery period, a 5 min cool down, consisting of low intensity running and static stretching, was conducted. All field testing and matches were conducted on third generation artificial pitch in clear and dry conditions with minimal wind. Temperature, humidity and pressure on testing days one, two and three corresponded to 11.0 ºC, 70.0 % and 1010 mmHg; 13.2 ºC, 72.4 % and 1012 mmHg; 12.5 ºC, 62.8 % and 1011 mmHg, respectively. Participants were instructed to refrain from exercise on the days preceding each test and to maintain a normal diet throughout testing. Players were also informed to refrain from consuming any drinks containing sugar or caffeine as well as the consumption of any food in the two hours preceding any test.

Yo-Yo Intermittent Recovery Test Level 1: Maximal & 6 Min Versions

To accurately assess players' relative HR (%HR_{max}), Players' maximal HR were obtained from an end of season maximal Yo-Yo IR1 test, performed in the week prior to the testing period. For the Yo-Yo IR1 test, cones were placed 20 m apart, with a 5 m recovery zone marked out at one end. The Yo-Yo IR1 test requires participants to run 2 x 20 m shuttle runs at increasing speeds, interspersed with 10 seconds of active recovery. The pace of the test was controlled by audio signals emitted from a CD player (Sony CFD-V7, Sony, Tokyo, Japan). For the maximal Yo-Yo IR1 test players were required to run until volitional termination of the test or, when they have twice failed to meet the designated cones in time with the audio signal, at which point they are removed from the test. The highest HR obtained during this test was recorded as each participant's maximal heart rate (HR_{max}).

For the 6 min Yo-Yo IR1 test the players were required to complete the first 6 min of the test (Level = 14.7; Distance = 720 m; with approximate velocities of 10 and 14 $km \cdot h^{-1}$ at the beginning and end of the test, respectively), at which point the test was stopped and each player's absolute HR (bpm) and relative HR ($\%HR_{max}$) were determined. Players' HR was recorded second-by-second (using a 10Hz GPS unit) for the duration of the test, which was then downloaded after the test using Catapult Sprint software (Catapult, Melbourne, Australia). Prior to analysis, each individual player's HR trace was assessed for outliers. Outliers were defined as a HR data point that was different to the mean of the surrounding four HR data points by more than four times the standard deviation of the same surrounding four data points (Jones and Poole 2005), however, examination of the HR traces revealed no outliers resulting in a 100% data inclusion. Once this was confirmed, an average of the final 15 sec (15 data points) of the appropriate time point (3 min or 6 min during the test) was recorded. For the second component of this study, a 3 min passive recovery was administered immediately after the completion of the 6 min Yo-Yo IR1 test, thus providing an indirect estimate of cardiac autonomic modulation of the players (Buchheit et al.

2007). On completion, participants were asked to stop, stand still and refrain from communicating for 3 minutes. During this period, HR was continually recorded, enabling relative measures of HRR to be maintained at discrete time points: 10, 20, 30, 60, 90 and 180 seconds (HRR_{10}, HRR_{20}, HRR_{30}, HRR_{60}, HRR_{90} and HRR_{180}, respectively), for both absolute HR measures (bpm) and relative HR measures. Relative measures of HRR were assessed in relation to respective players HR at the end of the 6 min Yo-Yo IR1 ($\%HR_{end}$), with $\%HR_{end}$ always equating to 100%.

Statistical Analysis

To assess the reliability of the 6 min Yo-Yo IR1 test, with an additional 3 min passive recovery the change between means, typical error (TE), coefficient of variation of typical error (CV) and intraclass correlation of coefficient ($ICC_{3,1}$) were all determined for successive trials (i.e., trial 1 vs. trial 2 and trial 2 vs. trial 3). An average for the three trials (overall) was also calculated for the TE, CV and ICC (see Hopkins 2015). To indicate the precision of each of these values their 90% confidence intervals were also determined.

The TE was calculated using the standard deviation of the differences between two trials divided by square root of 2. In order to calculate the CV, the same calculations were performed on the log transformed data which was multiplied by 100 prior to transforming. Heteroscedasticity was assessed by performing individual Pearson correlations on the absolute deviations between trials and their means for both trial comparisons at each time point (Atkinson and Nevill 1998; Hopkins 2000). The correlation values were shown to be variable (see table 2). This was likely to be a result of the small sample size, with individual values having a strong effect in some cases.

It was not possible to pool the data across all time points to generally assess the heteroscedasticity as there was a strong relationship between the time point at which the data was recorded and the size of the difference, as the recovery period within the test protocol progressed the differences within the HR measures became larger. Consequently, the absolute (TE) and relative values (CV) for typical error are reported. Also, reporting the typical error as a CV facilitates the comparison of reliability measures across different studies (Hopkins 2000).

The intraclass correlation coefficient ($ICC_{3,1}$) was calculated as a measure of relative reliability, which is the degree to which participants maintain their position within a group across repeated applications of the test (Batterham and George 2003). However, unlike TE and CV, the ICC value is heavily influenced by the heterogeneity of the variance between participants, such that the greater the spread of the scores between participants, the greater the magnitude of the ICC (Batterham & George 2003). Therefore, both absolute (TE and CV) and relative measures of reliability ($ICC_{3,1}$) were included in this study.The calculations of change in mean, TE, CV and $ICC_{3,1,}$ along with their averages, and their 90% confidence intervals were all done via the Excel spreadsheet developed by Hopkins (2015). All statistical analysis was performed using Microsoft Excel (Microsoft Excel 2013, Microsoft, Redmond, Washington).

<u>Results</u>

During testing, all players completed the set distance for the 6 min Yo-Yo IR1 at each of the testing points. Furthermore, examination of the means and standard deviations across the three trials did not reveal any signs of systematic bias across the three trials. Nevertheless, to assess for any potential learning effects, results are reported for successive trials (Trial 1 vs. Trial 2 and Trial 2 vs. Trial 3) and across all three trials (overall) (Table 3).

Measures of absolute HR (bpm) and relative HR (%HR_{max}) during the 3rd min and 6th min of the 6 min Yo-Yo IR1 were shown to have minimal levels of variance between trials and good levels of relative reliability (ICC: 0.95 – 0.98), with little differences between absolute and relative heart rate measures (Table 3A and 3B). Examination of the reliability of HR measures obtained during the passive 3 min recovery demonstrated an increased level of variance as the passive recovery period progressed, for both absolute (bpm) and relative (%HR_{end}) HR measures. Absolute and relative HR measures obtained 10 seconds into the passive recovery (HRR_{10}) were shown to have the least amount of variability, with regards to TE and CV. Heart rate measures obtained at 60, 90 and 180 seconds, however displayed increased levels of variance (Table 3A and 3B), with the highest levels of variance being reported at HRR_{60} and HRR_{90}. Measures of ICC revealed moderate to good levels of relative reliability (ICC: 0.74 – 0.93) for HR measures obtained during the passive recovery. In addition, analysis and comparisons of the variability between successive trials demonstrated reduced levels of variability between trial 2 and trial 3, when compared to the levels of variability between trial 1 and trial 2.

***** Table 3A and 3B near here *****

Discussion

The aim of the present study was to assess the reliability of HR measures obtained during the 6 min Yo-Yo IR1 test, with an additional 3 min passive recovery (heart rate measures obtained during passive recovery at 10, 20, 30, 60, 120 and 180 sec), within a group of highly trained academy youth soccer players. Results revealed that HR measures (relative and absolute) obtained during the 6 min Yo-Yo IR1 (3 and 6 min) show good levels of reliability (CV: 1.1 – 1.3). Similarly, both absolute (bpm) and relative (%HR_{end}) HR measures obtained during the initial stages of a passive recovery, at 10, 20 and 30 sec (HRR_{10}, HRR_{20} and HRR_{30}) presented acceptable levels of reliability (Table 3A and 3B), however, as the passive recovery increased (HRR_{60}, HRR_{90} and HRR_{180}) so did the level of variance within measures of absolute and relative HR.

In the present study, HR measures (relative and absolute) obtained at 3 and 6 min during the 6 min Yo-Yo IR1 were shown to have little variance between trials. Deprez et al. (2014) also examined the reproducibility of relative HR measures obtained at level 13.1, 14.1 and 15.1 during a maximal Yo-Yo IR1 test in groups of U13, U15 and U17 sub-elite youth soccer players. In their study, the CVs ranged from 1.9 - 2.3, 1.5 - 2.2 and 1.0 – 1.3% for levels 13.1, 14.1 and 15.1 of the Yo-Yo IR1 test, thus demonstrating similar results to the present study, which involved highly trained academy youth soccer players. As expected, heart rates increased progressively during the 6 min Yo-Yo IR1, reflecting an increase in the oxygen demand (Bangsbo et al. 2008). Mean heart rates at minute 3 and 6 of the Yo-Yo IR1 ranged from 88.3 – 89.0 and 92.4 – 93.8 %HR_{max}, respectively. In the present study, relative HR measures obtained during the 6 min Yo-Yo IR1 were lower than those reported for sub-elite soccer players by Deprez et al. (2014), who reported relative HRs of 91.5, 94.1 and 96.7 $\%HR_{max}$ at level 13.1 (2 min 25 sec), 14.1 (3 min 40 sec) and 15.1 (6 min 20 sec) during the Yo-Yo IR1, thus supporting the superior trained status of the current sample.

Evidence from Krustrup et al. (2003) has shown that the 6 min Yo-Yo IR1 test can detect seasonal changes in players' soccer-specific endurance capacity, with players demonstrating a reduced $\%HR_{max}$ (internal load) for the same external load as a season progressed (pre-season vs. mid-season), providing support for the sensitivity of the test to training. Research from Fanchini et al. (2014) and Fanchini et al. (2015), however, question the sensitivity of the 6 min Yo-Yo IR1 male soccer players, stating that the maximal version of the Yo-Yo IR1 is more sensitive to training than the 6 min version. Despite the reduced levels of sensitivity, within the 6 min Yo-Yo IR1, the HR obtained at the 6^{th} min was shown to have reduced levels of variability (CV = 2.2%) when compared to the metres covered during the maximal Yo-Yo IR1 (CV = 7.3%) (Fanchini et al., 2014). Therefore, the higher levels of sensitivity associated with the maximal Yo-Yo IR1 are due to the greater changes evident, between tests, in response to training. The regular implementation of a maximal Yo-Yo IR1 test into the weekly training schedule is highly unlikely, due to the associated increases in training load that would accompany the inclusion of this maximal test. However, within the current study, improved levels of reliability were evident for absolute and relative HR measures at minute 6 of Yo-Yo-IR1 (Table 3). Indeed, TE for relative HR measures for the 6^{th} min were below 1% between trial 2 and trial 3, which is half that presented by Fanchini et al., 2014). In this regard, and in accordance with Hopkins (2000), when monitoring an individual, a realistic threshold for a 'real change' should be about 1.5

to 2 times the TE. Therefore, a difference of 2% in an individual's $\%HR_{max}$ between tests, when participants are appropriately familiarised, would indicate that a 'real change' is likely to have occurred.

The current study also examined the reliability of HR measures during a 3 min passive recovery phase, immediately post-test. It is suggested that measures of HRR are a relevant method for assessing training-induced alterations in athletes' cardio-respiratory fitness and monitoring fatigue, both of which can have direct implications for training prescription and performance (Buchheit 2014). Present findings demonstrated that the variance in measures of HRR (both absolute and relative) increased as the passive recovery phase increased, with initial measures of HRR (HRR_{10}, HRR_{20} and HRR_{30}: Overall CVs = 1.7, 2.3 & 3.0 %, respectively) demonstrating better reproducibility than those obtained later on in the recovery phase (HRR_{60}, HRR_{90} and HRR_{180}: Overall CVs = 8.0, 8.0 & 5.7 %, respectively). Previously, both Deprez et al. (2014) and Owen et al (2017) have assessed the reproducibility of HR measures obtained during a passive recovery period, following a maximal and 6 min Yo-Yo IR1, respectively. Deprez et al (2014) recorded players' HR at 1 and 2 min following a maximal Yo-Yo IR1 in U13, U15 and U17 youth soccer players, whereas Owen et al recorded players' HR 30, 60, 90 and 120 sec following a 6 min Yo-Yo IR1. Both studies reported similar levels of reliability with CVs ranging from 2.7 – 4.6% and ICCs ranging from 0.69 – 0.96, however unlike the present results, Owen et al (2017) did not report increased levels of variance as the recovery period progressed.

In any reliability study consideration towards the presence of a learning effect should be given (Hopkins 2000), particularly when there are aspects of the test which are novel to the participants. As can be seen in the current results, analysis of variability between successive trials revealed reduced levels of variability for all HR measures (absolute and relative) from trial 2 vs. trial 3, when compared to the results obtained from trial 1 vs. trial 2. Although, for some of the HR measures, the initial levels of reliability reported between trial 1 and trial 2 are relatively low (e.g. CV = 1.2 and 1.5% for 3rd and 6th min), however, it is also apparent that these measures of variability are improved when an additional trial is undertaken (trial 2 vs. trial 3). This is particularly evident for the HR measures obtained during the passive recovery period, which is a potentially novel aspect of the test for some players. In this respect, work by Owen et al. (2017) only incorporated two trials and therefore, the inclusion of an additional trial may result in lower levels of variability for each of the HR measures obtained during the 6 min Yo-Yo IR1 with a passive recovery period. This in turn will have an impact upon the sensitivity of the test, as superior levels of reproducibility will increase the possibility of detecting a 'real change'. Consequently, appropriate levels of familiarisation are necessary when assessing players' HR during the 6 min Yo-Yo IR1, with an additional passive recovery period. In this regard, current results suggest that one additional familiarisation session reduces the levels of variance within HR measures obtained during a 6 min Yo-Yo IR1 and subsequent recovery period. Whether additional familiarisation to the test would enhance the reproducibility of each HR measure requires further investigation, particularly with regard to those HR measures obtained during the passive recovery period.

The measurement error (TE or CV), however, should not be considered in isolation, rather the magnitude of the measurement error (noise) should be assessed in comparison to 1) the usually observed changes (signal) and 2) the changes that may be regarded as a practical effect (Hopkins 2004). As highlighted by Buchheit (2014), in practice, players need to be monitored on an individual basis, thus allowing for the appropriate individualisation of training. In practice, however, significant changes in physiological based measures (e.g. HR measures) may not be of practical importance and likewise, non-significant changes may have meaningful implications for performance (Hopkins 2002). Therefore, an understanding of what constitutes a 'real change' between tests is necessary, particularly if such measures are going to be used to make informed decisions. This can be achieved via calculating an individual's change in a HR variable and considering it in relation to what would be regarded as a smallest important performance enhancement (Smith and Hopkins 2011). Future research and those working in practice, should look to examine the sensitivity of each of the different HR measures in relation to the respective TE or CVs. This will highlight which variables present the greatest signal-to-noise ratios and subsequently the most sensitive measure for monitoring a team or an individual's readiness to train or assessing a player's response to a training stimulus (Buchheit 2014; Smith and Hopkins 2011).

For individual sports, where athletes compete against each other to achieve the best time, Smith and Hopkins (2011) suggest 0.3 of the standard deviation of a top athlete's performance provides an indication of the smallest worthwhile enhancement in performance. In this regard, practitioners may wish to adopt a similar approach, whereby 0.3 of the standard deviation of an individual's performance measure within a particular test (e.g. HR responses at specific points during the 6 min Yo-Yo IR1) may be used to gauge whether or not there has been a 'meaningful' change in performance. Assessing performance within team sports, however, is far more complex than within individual sports (Reilly 2001). To date there is currently no evidence to suggest that changes greater than any fraction of the standard deviation would actually be meaningful in practice, particularly with regards to HR-derived variables (Buchheit 2014). Rather, practitioners and researchers may wish to refer to the work of Hopkins (2000) when looking to see if a 'real change' has occurred, by examining if the observed changes are 1.5 to 2 times greater than the associated measures of variability (TE or CV). In addition, an application and interpretation of the appropriate 'meaningful' magnitude requires the consideration of multiple factors, including the training context, proposed adaptation and the monitored variable itself. Therefore, the respective magnitude may actually need to be appropriately adjusted according to the training phase and the training content, however, further research is required to assess this.

The aim of the current study was to examine the reliability of simple HR based measures during a 6 min Yo-Yo IR1 test, in highly trained youth soccer players. Consequently, the sample size employed within the current study was small due to the limited availability of participants which met the study's requirements. Nevertheless, while the participants within the current study would be regarded as elite, the 6 min Yo-Yo IR1 test presents a viable option for assessing levels of physical fitness and heart rate responses within highly trained youth soccer players. Indeed, the non-exhaustive nature of the 6 min Yo-Yo IR1 prove useful for practitioners involved in high level performance, where the regular assessment of players' soccer-specific endurance capacity as well as the design, prescription and management of training loads is a problematic but necessary concern (Weston 2013). The current approach (i.e 6 min Yo-Yo IR1 with 3 min passive recovery) may still be viewed as time-consuming, particularly if a 10 min warm-up is undertaken prior to the test. In practice however, this test would not be used excessively, rather it would be implemented in the initial stages of a training week (or microcycle). A further limitation of the current study is that it only assessed the reliability of simple HR measures (absolute and relative) during exercise and recovery of the Yo-Yo IR1 6 minute test. With the increasing accessibility of advanced HR equipment, more and more studies and practitioners are assessing players' heart rate variability (HRV) as a means for monitoring training load (Buchheit 2014). Heart rate variability, is a reflection of cardiac sympathetic and parasympathetic autonomic control and has the potential to underpin players' HRR. As a result, future research should look to examine the variance within HRV measures during and following the 6 min Yo-Yo IR1 test. Furthermore, as HRV, following maximal intensity exercise, has been shown to be affected by maturation (Goulopoulou et al. 2005), an exploration of these responses, and the variance within these responses, with respect to maturity status in youth soccer players is also warranted.

Conclusion

Present results suggest that the HR measures (absolute and relative) obtained during a 6 min Yo-Yo IR1 test, with a 3 min passive recovery period, demonstrate good levels of reliability, in a cohort of highly trained academy youth soccer players. However, HR measures obtained during the passive 3 min recovery demonstrated an increased level of variance as the passive recovery period progressed, for both absolute (bpm) and relative (%HR_{end}) HR measures. Nevertheless, further consideration toward what constitutes a 'real change', when monitoring players over time, is required. Incidentally, practitioners should look to assess the reliability of these measures within their own cohort of players and in relation to a performance measure. This will allow them to calculate the impact of the sensitivity of each HR measure during the 6 min Yo-Yo IR1, in line with the player's current level of performance and training content. The present findings, coupled with the advantages of administering such a test on a regular basis provide support for the application of the 6 min Yo-Yo IR1, within highly trained youth soccer players. In doing so, however, consideration toward the process of familiarisation and the subsequent impact upon the reproducibility of the test is required.

Practical Implications

An improved understanding and ability to monitor youth soccer players' physical response, via a standardized 6 min Yo-Yo IR1, will enable practitioners to provide appropriate training programs that are in line with youth players' development. This is even more pertinent given the periods of volatile growth, and the resultant physical and physiological adaptations, which occur in youth populations. In addition to the practical implications of these findings, the reporting of reliability estimates facilitates the estimation of sample sizes in subsequent experiments that utilize repeated measures designs (see Hopkins 2000).

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Disclosure of Interest

The authors report no conflicts of interest to report.

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Table 1: Anthropometric and screening measures of the players (*n*=8).

Variable	Mean ± Standard Deviation	95% Confidence Intervals
Age (y)	12.9 ± 0.7	12.4 – 13.4
Stature (m)	1.53 ± 0.55	149.3 – 156.9
Body Mass (kg)	42.5 ± 6.3	38.2 – 46.9
Maturity Offset (y)	-1.2 ± 0.7	-1.7 to 0.2
Σ4 Skinfolds (mm)	29.8 ± 5.4	25.7 – 33.9
Tanner Stage	3 ± 1	2 - 3
Training Years (y)	6.6 ± 1.3	5.7 – 7.5
Training Hours (hrs.p.week)	12.6 ± 3.5	10.2 – 15.1

Note: Skinfolds used for the Σ 4 skinfolds were the biceps, triceps, subscapular and suprailliac (Durnin and Womersley, 1974).

Table 2: Pearson correlations (*r* value) assessing levels of heteroscedascity between successive trials for each time point.

Time point	Relative		Absolute	
	Trial 1 vs Trial 2	**Trial 2 vs Trial 3**	**Trial 1 vs Trial 2**	**Trial 2 vs Trial 3**
3 min	-0.25	0.49	-0.13	0.24
6 min	-0.37	-0.08	0.36	0.54
10 sec	-0.86	0.12	-0.03	-0.36
20 sec	-0.06	0.24	-0.04	-0.20
30 sec	0.09	-0.17	0.24	0.17
1 min	-0.14	-0.25	-0.26	-0.21
90 sec	-0.09	-0.64	0.03	-0.75
3 min	-0.14	0.46	-0.03	0.08

Table 3*A* and 3*B*: Reproducibility of HR measures (90% Confidence Intervals) obtained during a 6 minute Yo-Yo IR1 with a 3 min passive recovery for (A) absolute and (B) relative HR measures.

A	**6 min Yo-Yo IR1**		**3 min Passive Recovery**					
	3min (bpm)	**6min** (bpm)	**10 sec** (bpm)	**20 sec** (bpm)	**30 sec** (bpm)	**60 sec** (bpm)	**90 sec** (bpm)	**180 sec** (bpm)
Trial 1 (*mean ± SD*)	176.4 ± 10.1	184.4 ± 8.4	179.4 ± 8.1	169.5 ± 9.4	153.6 ± 14.2	122.3 ± 21.2	106.9 ± 17.1	102.3 ± 12.3
Trial 2 (*mean ± SD*)	176.8 ± 9.7	186.5 ± 10.2	183.4 ± 8.1	170.9 ± 8.8	157.5± 10.9	125.1 ± 15.9	106.1 ± 15.8	101.6 ± 12.4
Trial 3 (*mean ± SD*)	177.8 ± 9.7	187.3 ± 9.3	183.9 ± 7.6	173.8 ± 8.7	157.0 ± 9.6	128.4 ± 12.4	112.6 ± 7.4	102.3 ± 10.1
Change in the mean								
Trial 1 vs Trial 2	0.4 (-1.7 – 2.4)	2.1 (-0.5 – 4.8)	4.0 (0.7 – 7.3)	1.4 (-1.7 – 4.5)	3.9 (-0.8 – 8.5)	2.9 (-6.1 – 11.8)	-0.8 (-8.3 – 6.81)	-0.6 (-6.7 – 5.4)
Trial 2 vs Trial 3	1.0 (-0.5 – 2.5)	0.8 (-1.1 – 2.6)	0.5 (-0.3 – 1.3)	2.9 (0.1 – 5.7)	-0.5 (-2.6 – 1.6)	3.3 (-3.3 – 9.8)	6.5 (-0.3 – 13.3)	0.6 (-3.1 – 4.3)
ICC $_{(3,1)}$								
Trial 1 vs Trial 2	0.97 (0.89 – 0.99)	0.94 (0.79 – 0.98)	0.87 (0.58 – 0.96)	0.91 (0.70 – 0.98)	0.90 (0.66 – 0.97)	0.81 (0.44 – 0.95)	0.83 (0.48 – 0.95)	0.80 (0.41 – 0.94)
Trial 2 vs Trial 3	0.98 (0.94 – 1.00)	0.98 (0.91 – 0.99)	0.99 (0.97 – 1.00)	0.92 (0.74 – 0.98)	0.97 (0.90 – 0.99)	0.83 (0.48 – 0.95)	0.73 (0.27 – 0.92)	0.92 (0.73 – 0.98)
Overall	0.98 (0.93 – 0.99)	0.96 (0.87 – 0.99)	0.93 (0.80 – 0.98)	0.92 (0.77 – 0.98)	0.93 (0.80 – 0.98)	0.82 (0.55 – 0.95)	0.78 (0.46 – 0.93)	0.85 (0.61 – 0.96)
TE								
Trial 1 vs Trial 2	2.17 (1.53 – 3.90)	2.84 (2.00 – 5.10)	3.51 (2.47 – 6.30)	3.29 (2.32 – 5.92)	4.89 (3.45 – 8.79)	9.43 (6.65 – 16.95)	7.98 (5.63 – 14.34)	6.39 (4.51 – 11.49)
Trial 2 vs Trial 3	1.60 (1.13 – 2.88)	1.95 (1.38 – 3.51)	0.85 (0.60 – 1.52)	2.99 (2.11 – 5.37)	2.17 (1.53 – 3.90)	6.90 (4.87 – 12.41)	7.19 (5.07 – 12.92)	3.89 (2.74 – 6.99)
Overall	1.91 (1.4 – 3.18)	2.44 (1.88 – 4.06)	2.55 (1.9 – 4.24)	3.14 (2.43 – 5.23)	3.78 (2.92 – 6.30)	8.26 (6.38 – 13.76)	7.60 (5.87 – 12.65)	5.29 (4.09 – 8.81)
CV (%)								
Trial 1 vs Trial 2	1.2 (0.9 – 2.3)	1.5 (1.0 – 2.7)	2.0 (1.4 – 3.6)	2.0 (1.4 – 3.5)	3.1 (2.2 – 5.7)	8.5 (5.9 – 15.8)	7.7 (5.4 – 14.3)	6.6 (4.6 – 12.2)
Trial 2 vs Trial 3	0.9 (0.6 – 1.6)	1.0 (0.7 – 1.8)	0.5 (0.3 – 0.8)	1.8 (1.2 – 3.2)	1.4 (1.0 – 2.5)	6.2 (4.3 – 11.4)	7.7 (5.4 – 14.3)	3.9 (2.7 – 7.1)
Overall	1.1 (0.8 – 1.8)	1.3 (1.0 – 2.1)	1.4 (1.1 – 2.4)	1.9 (1.4 – 3.1)	2.4 (1.9 – 4.0)	7.4 (5.7 – 12.6)	7.7 (5.9 – 13.2)	5.4 (4.1 – 9.2)

B	6 min Yo-Yo IR1		3 min Passive Recovery					
	3min ($\%HR_{max}$)	**6min** ($\%HR_{max}$)	**10 sec** ($\%HR_{end}$)	**20 sec** ($\%HR_{end}$)	**30 sec** ($\%HR_{end}$)	**60 sec** ($\%HR_{end}$)	**90 sec** ($\%HR_{end}$)	**180 sec** ($\%HR_{end}$)
Trial 1 (*mean ± SD*)	88.3 ± 3.3	92.4 ± 4.2	97.4 ± 4.1	92.0 ± 4.9	83.4 ± 6.9	66.4 ± 11.3	58.0 ± 8.9	55.6 ± 7.4
Trial 2 (*mean ± SD*)	88.5 ± 3.8	93.4 ± 3.9	98.4 ± 2.2	91.7 ± 2.6	84.5 ± 3.5	67.2 ± 8.4	56.9 ± 8.0	54.5 ± 6.4
Trial 3 (*mean ± SD*)	89.0 ± 3.4	93.8 ± 4.0	98.2 ± 1.6	92.9 ± 4.2	83.9 ± 3.5	68.7 ± 7.2	60.2 ± 4.1	54.7 ± 5.6
Change in the mean								
Trial 1 vs Trial 2	0.2 (-0.8 – 1.2)	1.0 (-0.2 – 2.3)	1.0 (-0.8 – 2.9)	-0.3 (-2.4 – 1.7)	1.1 (-2.1 – 4.3)	0.8 (-4.6 – 6.2)	-1.1 (-5.5 – 3.3)	-1.1 (-4.5 – 2.4)
Trial 2 vs Trial 3	0.5 (-0.3 – 1.3)	0.4 (-0.5 – 1.3)	-0.2 (-1.1 – 0.7)	1.2 (-0.6 – 3.0)	-0.6 (-1.8 – 0.6)	1.5 (-2.2 – 5.2)	3.3 (-0.3 – 6.9)	0.1 (-1.8 – 2.1)
ICC $_{(3,1)}$								
Trial 1 vs Trial 2	0.94 (0.79 – 0.98)	0.93 (0.75 – 0.98)	0.72 (0.23 – 0.92)	0.76 (0.32 – 0.93)	0.69 (0.18 – 0.91)	0.74 (0.28 – 0.93)	0.77 (0.34 – 0.93)	0.78 (0.37 – 0.94)
Trial 2 vs Trial 3	0.97 (0.8 – 0.99)	0.96 (0.87 – 0.99)	0.82 (0.45 – 0.95)	0.78 (0.36 – 0.94)	0.92 (0.71 – 0.98)	0.82 (0.44 – 0.95)	0.71 (0.23 – 0.92)	0.92 (0.73 – 0.98)
Overall	0.95 (0.86 – 0.99)	0.95 (0.84 – 0.99)	0.77 (0.45 – 0.93)	0.81 (0.36 – 0.94)	0.79 (0.49 – 0.94)	0.78 (0.47 – 0.93)	0.74 (0.38 – 0.92)	0.85 (0.60 – 0.96)
TE								
Trial 1 vs Trial 2	1.08 (0.77 – 1.95)	1.33 (0.94 – 2.39)	1.95 (1.38 – 3.51)	2.20 (1.55 – 3.96)	3.39 (2.39 – 6.10)	5.72 (4.03 – 10.27)	4.64 (3.27 – 8.34)	3.69 (2.60 – 6.63)
Trial 2 vs Trial 3	0.81 (0.57 – 1.46)	0.94 (0.66 – 1.68)	0.94 (0.67 – 1.70)	1.88 (1.32 – 3.38)	1.22 (0.86 – 2.20)	3.91 (2.76 – 7.03)	3.81 (2.69 – 6.85)	2.06 (1.45 – 3.70)
Overall	0.96 (0.74 – 1.60)	1.15 (0.89 – 1.91)	1.53 (1.19 – 2.56)	2.05 (1.58 – 3.41)	2.55 (1.97 – 4.25)	4.90 (3.78 – 8.15)	4.25 (3.28 – 7.07)	2.99 (2.31 – 4.98)
CV (%)								
Trial 1 vs Trial 2	1.2 (0.9 – 2.3)	1.5 (1.0 – 2.7)	2.1 (1.5 – 3.9)	2.4 (1.7 – 4.4)	4.0 (2.8 – 7.4)	9.4 (6.5 – 17.5)	8.5 (5.9 – 15.7)	7.2 (5.0 – 13.2)
Trial 2 vs Trial 3	0.9 (0.6 – 1.6)	1.0 (0.7 – 1.8)	1.0 (0.7 – 1.7)	2.1 (1.4 – 3.7)	1.5 (1.0 – 2.7)	6.4 (4.5 – 11.8)	7.5 (5.2 – 13.9)	3.7 (2.6 – 6.8)
Overall	1.1 (0.8 - 1.8)	1.3 (1.0 – 2.1)	1.7 (1.3 – 2.8)	2.3 (1.7 – 3.8)	3.0 (2.3 – 5.1)	8.0 (6.1 – 13.7)	8.0 (6.1 – 13.7)	5.7 (4.4 – 9.6)

Note: ICC = Intraclass Correlation Coefficient, TE = Typical Error, CV = Coefficient of Variation, $\%HR_{max}$ = percentage of maximum heart rate, $\%HR_{end}$ = percentage of heart rate at end of 6min Yo-Yo IR1.