

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

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

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24 **Keywords:** Youth development; training; variance; fitness testing; fitness monitoring

25 **Abstract**

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

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

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

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

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50 **Introduction**

51 Soccer-specific endurance capacity, the ability to consistently perform high
52 intensity intermittent exercise, is an essential fitness component for successful
53 performance (Wrigley et al. 2014). Regular assessment of this fitness component may
54 be used to identify individual player training requirements as well as evaluate the
55 efficacy of specific interventions (Halsen 2014; Kellam 2010). Due to the intermittent
56 nature of soccer-specific fitness, the advantages of group field-testing in team sports
57 and the need to control extraneous variables (e.g. distance covered and recovery times)
58 when conducting fitness tests, the Yo-Yo intermittent recovery (Yo-Yo IR) field tests
59 were devised as a means for assessing soccer-specific endurance (Bangsbo et al.
60 2008).

61
62 The Yo-Yo IR level 1 (Yo-Yo IR1) test is a commonly used test to assess the
63 soccer-specific endurance capacity, in both adults (Bangsbo et al. 2008; Mohr and
64 Krstrup 2014; Krstrup et al. 2003) and youth (Carvalho et al. 2014; Deprez et al.
65 2014) populations. The traditional approach to administering the Yo-Yo IR1 test
66 requires participants to exercise to their maximum (Bangsbo et al. 2008). While such
67 testing maybe incorporated into a periodized training plan, maximal testing can lead
68 to a large additional imposition on an individual's training load, which is particularly
69 impractical during intensified periods of the competitive season. As a result, sub-
70 maximal surrogates have been devised to provide a regular assessment of the players'
71 training status without imposing a large additional training load (Buchheit 2014).

72

73 The 6 min Yo-Yo IR1 test is a non-exhaustive adaptation of the traditional Yo-
74 Yo IR1 test that assesses the internal load (heart rate response) for a given external

75 load. Bangsbo et al. (2008) report unpublished data suggesting a moderate correlation
76 between an individual's relative heart rate ($\%HR_{max}$), during the 6th min of the Yo-Yo
77 IR1 test and both their maximal performance in the Yo-Yo IR1 and the volume of high
78 intensity running (>15 km/h) performed during soccer match-play ($r = 0.54$ and $r =$
79 0.48 , respectively). In addition, Krstrup et al. (2003) reported significant reductions
80 in elite male player's HR responses at the 6th min of the Yo-Yo IR1, when comparing
81 results between pre-preparation against the mid-preparation, start of the season and
82 end of the season. No changes in HR responses within the season were reported
83 though. Nevertheless, this suggests that a 6 min version of the Yo-Yo IR1 test may be
84 a useful test for tracking changes in soccer-specific endurance during intensive periods
85 of training (e.g. pre-season). Together with the fact that the reduced loading incurred
86 from the test allows for regular integration into the weekly training schedule, the
87 evidence provided supports the use of the 6 min Yo-Yo IR1 as a means for assessing
88 players' current state of soccer-specific fitness.

89

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

99 assessment into a player's current level of cardio-respiratory fitness and indication
100 towards their current training status.

101

102 While there is evidence to highlight both the relevance and application of the
103 6 min Yo-Yo IR1 test, there is a lack of information examining the reliability of the
104 measures obtained during the test. Deprez et al. (2014) reported little variance (CV's
105 between 1.1 and 4.1%) when assessing the test-retest reliability of HR measures
106 ($\%HR_{max}$) in a cohort of non-elite youth soccer players, at different levels during the
107 Yo-Yo IR1 and at 1 and 2 min post-test. Moreover, recent research by Owen, Jones
108 and Comfort (2017), reported that HR measures obtained at the end of a 6 min Yo-Yo
109 IR1 and at 30, 60, 90 and 120 sec during a 2 min passive recovery, were determined
110 to be reliable in elite youth soccer players aged 18.8 ± 0.5 years. Nevertheless, it is
111 necessary to gain population specific (i.e. age) information on the reliability of such a
112 test (Atkinson and Nevill 1998), as this information will be essential for the
113 interpretation and clinical decisiveness when examining observed changes between
114 groups and individuals (Batterham and Hopkins 2006). Particularly as younger
115 populations are more reliant upon aerobic energy provision and, therefore, heart rate
116 variability is more important to quantify (Ratel, Duche and Williams, 2006).
117 Therefore, the reliability of HR responses during the 6 min Yo-Yo IR1 test, within
118 highly trained youth soccer players requires investigation. As a result, the purpose of
119 this study was to assess the reliability of HR measures obtained during the 6 min Yo-
120 Yo IR1 test and during an additional 3 min passive recovery (10, 20, 30, 60, 120 and
121 180 sec), within a group of highly trained youth soccer players.

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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 \pm 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 °C, 70.0 % and 1010 mmHg; 13.2 °C, 72.4 % and 1012 mmHg; 12.5 °C, 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

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

182

183 For the 6 min Yo-Yo IR1 test the players were required to complete the first 6
184 min of the test (Level = 14.7; Distance = 720 m; with approximate velocities of 10 and
185 14 $km \cdot h^{-1}$ at the beginning and end of the test, respectively), at which point the test
186 was stopped and each player's absolute HR (bpm) and relative HR ($\%HR_{max}$) were
187 determined. Players' HR was recorded second-by-second (using a 10Hz GPS unit) for
188 the duration of the test, which was then downloaded after the test using Catapult Sprint
189 software (Catapult, Melbourne, Australia). Prior to analysis, each individual player's
190 HR trace was assessed for outliers. Outliers were defined as a HR data point that was
191 different to the mean of the surrounding four HR data points by more than four times
192 the standard deviation of the same surrounding four data points (Jones and Poole
193 2005), however, examination of the HR traces revealed no outliers resulting in a 100%
194 data inclusion. Once this was confirmed, an average of the final 15 sec (15 data points)
195 of the appropriate time point (3 min or 6 min during the test) was recorded. For the
196 second component of this study, a 3 min passive recovery was administered
197 immediately after the completion of the 6 min Yo-Yo IR1 test, thus providing an
198 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.

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

231

232 The intraclass correlation coefficient ($ICC_{3,1}$) was calculated as a measure of
233 relative reliability, which is the degree to which participants maintain their position
234 within a group across repeated applications of the test (Batterham and George 2003).
235 However, unlike TE and CV, the ICC value is heavily influenced by the heterogeneity
236 of the variance between participants, such that the greater the spread of the scores
237 between participants, the greater the magnitude of the ICC (Batterham & George
238 2003). Therefore, both absolute (TE and CV) and relative measures of reliability
239 ($ICC_{3,1}$) were included in this study. The calculations of change in mean, TE, CV and
240 $ICC_{3,1}$, along with their averages, and their 90% confidence intervals were all done via
241 the Excel spreadsheet developed by Hopkins (2015). All statistical analysis was
242 performed using Microsoft Excel (Microsoft Excel 2013, Microsoft, Redmond,
243 Washington).

244

245 **Results**

246 During testing, all players completed the set distance for the 6 min Yo-Yo IR1
247 at each of the testing points. Furthermore, examination of the means and standard
248 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 ($\%HR_{\text{end}}$) 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 (HRR₁₀, HRR₂₀ and HRR₃₀) presented acceptable levels of reliability (Table 3A and 3B), however, as the passive recovery increased (HRR₆₀, HRR₉₀ and HRR₁₈₀) 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

299 soccer players by Deprez et al. (2014), who reported relative HRs of 91.5, 94.1 and
300 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)
301 during the Yo-Yo IR1, thus supporting the superior trained status of the current
302 sample.

303

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

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

327

328 The current study also examined the reliability of HR measures during a 3 min
329 passive recovery phase, immediately post-test. It is suggested that measures of HRR
330 are a relevant method for assessing training-induced alterations in athletes' cardio-
331 respiratory fitness and monitoring fatigue, both of which can have direct implications
332 for training prescription and performance (Buchheit 2014). Present findings
333 demonstrated that the variance in measures of HRR (both absolute and relative)
334 increased as the passive recovery phase increased, with initial measures of HRR
335 (HRR₁₀, HRR₂₀ and HRR₃₀: Overall CVs = 1.7, 2.3 & 3.0 %, respectively)
336 demonstrating better reproducibility than those obtained later on in the recovery phase
337 (HRR₆₀, HRR₉₀ and HRR₁₈₀: Overall CVs = 8.0, 8.0 & 5.7 %, respectively).
338 Previously, both Deprez et al. (2014) and Owen et al (2017) have assessed the
339 reproducibility of HR measures obtained during a passive recovery period, following
340 a maximal and 6 min Yo-Yo IR1, respectively. Deprez et al (2014) recorded players'
341 HR at 1 and 2 min following a maximal Yo-Yo IR1 in U13, U15 and U17 youth soccer
342 players, whereas Owen et al recorded players' HR 30, 60, 90 and 120 sec following a
343 6 min Yo-Yo IR1. Both studies reported similar levels of reliability with CVs ranging
344 from 2.7 – 4.6% and ICCs ranging from 0.69 – 0.96, however unlike the present
345 results, Owen et al (2017) did not report increased levels of variance as the recovery
346 period progressed.

347

348 In any reliability study consideration towards the presence of a learning effect
349 should be given (Hopkins 2000), particularly when there are aspects of the test which
350 are novel to the participants. As can be seen in the current results, analysis of
351 variability between successive trials revealed reduced levels of variability for all HR
352 measures (absolute and relative) from trial 2 vs. trial 3, when compared to the results
353 obtained from trial 1 vs. trial 2. Although, for some of the HR measures, the initial
354 levels of reliability reported between trial 1 and trial 2 are relatively low (e.g. CV =
355 1.2 and 1.5% for 3rd and 6th min), however, it is also apparent that these measures of
356 variability are improved when an additional trial is undertaken (trial 2 vs. trial 3). This
357 is particularly evident for the HR measures obtained during the passive recovery
358 period, which is a potentially novel aspect of the test for some players. In this respect,
359 work by Owen et al. (2017) only incorporated two trials and therefore, the inclusion
360 of an additional trial may result in lower levels of variability for each of the HR
361 measures obtained during the 6 min Yo-Yo IR1 with a passive recovery period. This
362 in turn will have an impact upon the sensitivity of the test, as superior levels of
363 reproducibility will increase the possibility of detecting a 'real change'. Consequently,
364 appropriate levels of familiarisation are necessary when assessing players' HR during
365 the 6 min Yo-Yo IR1, with an additional passive recovery period. In this regard,
366 current results suggest that one additional familiarisation session reduces the levels of
367 variance within HR measures obtained during a 6 min Yo-Yo IR1 and subsequent
368 recovery period. Whether additional familiarisation to the test would enhance the
369 reproducibility of each HR measure requires further investigation, particularly with
370 regard to those HR measures obtained during the passive recovery period.

371

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

391

392 For individual sports, where athletes compete against each other to achieve the
393 best time, Smith and Hopkins (2011) suggest 0.3 of the standard deviation of a top
394 athlete’s performance provides an indication of the smallest worthwhile enhancement
395 in performance. In this regard, practitioners may wish to adopt a similar approach,
396 whereby 0.3 of the standard deviation of an individual’s performance measure within

397 a particular test (e.g. HR responses at specific points during the 6 min Yo-Yo IR1)
398 may be used to gauge whether or not there has been a ‘meaningful’ change in
399 performance. Assessing performance within team sports, however, is far more
400 complex than within individual sports (Reilly 2001). To date there is currently no
401 evidence to suggest that changes greater than any fraction of the standard deviation
402 would actually be meaningful in practice, particularly with regards to HR-derived
403 variables (Buchheit 2014). Rather, practitioners and researchers may wish to refer to
404 the work of Hopkins (2000) when looking to see if a ‘real change’ has occurred, by
405 examining if the observed changes are 1.5 to 2 times greater than the associated
406 measures of variability (TE or CV). In addition, an application and interpretation of
407 the appropriate ‘meaningful’ magnitude requires the consideration of multiple factors,
408 including the training context, proposed adaptation and the monitored variable itself.
409 Therefore, the respective magnitude may actually need to be appropriately adjusted
410 according to the training phase and the training content, however, further research is
411 required to assess this.

412

413 The aim of the current study was to examine the reliability of simple HR based
414 measures during a 6 min Yo-Yo IR1 test, in highly trained youth soccer players.
415 Consequently, the sample size employed within the current study was small due to the
416 limited availability of participants which met the study’s requirements. Nevertheless,
417 while the participants within the current study would be regarded as elite, the 6 min
418 Yo-Yo IR1 test presents a viable option for assessing levels of physical fitness and
419 heart rate responses within highly trained youth soccer players. Indeed, the non-
420 exhaustive nature of the 6 min Yo-Yo IR1 prove useful for practitioners involved in
421 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 (Gouloupoulou 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.

440

441 **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.

458

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).

468

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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 \pm Standard Deviation | 95% Confidence Intervals |
|-----------------------------|-------------------------------|--------------------------|
| Age (y) | 12.9 \pm 0.7 | 12.4 – 13.4 |
| Stature (m) | 1.53 \pm 0.55 | 149.3 – 156.9 |
| Body Mass (kg) | 42.5 \pm 6.3 | 38.2 – 46.9 |
| Maturity Offset (y) | -1.2 \pm 0.7 | -1.7 to 0.2 |
| Σ 4 Skinfolds (mm) | 29.8 \pm 5.4 | 25.7 – 33.9 |
| Tanner Stage | 3 \pm 1 | 2 - 3 |
| Training Years (y) | 6.6 \pm 1.3 | 5.7 – 7.5 |
| Training Hours (hrs.p.week) | 12.6 \pm 3.5 | 10.2 – 15.1 |

Note: Skinfolds used for the Σ 4 skinfolds were the biceps, triceps, subscapular and suprailiac (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 3A and 3B: 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 (<i>mean ± SD</i>) | 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 (<i>mean ± SD</i>) | 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 (<i>mean ± SD</i>) | 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 | | | | | | | | |
| <i>Trial 1 vs Trial 2</i> | 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) |
| <i>Trial 2 vs Trial 3</i> | 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) | | | | | | | | |
| <i>Trial 1 vs Trial 2</i> | 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) |
| <i>Trial 2 vs Trial 3</i> | 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) |
| <i>Overall</i> | 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 | | | | | | | | |
| <i>Trial 1 vs Trial 2</i> | 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) |
| <i>Trial 2 vs Trial 3</i> | 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) |
| <i>Overall</i> | 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 (%) | | | | | | | | |
| <i>Trial 1 vs Trial 2</i> | 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) |
| <i>Trial 2 vs Trial 3</i> | 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) |
| <i>Overall</i> | 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) |

| <i>B</i> | 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 (<i>mean ± SD</i>) | 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 (<i>mean ± SD</i>) | 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 (<i>mean ± SD</i>) | 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 | | | | | | | | |
| <i>Trial 1 vs Trial 2</i> | 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) |
| <i>Trial 2 vs Trial 3</i> | 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) | | | | | | | | |
| <i>Trial 1 vs Trial 2</i> | 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) |
| <i>Trial 2 vs Trial 3</i> | 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) |
| <i>Overall</i> | 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 | | | | | | | | |
| <i>Trial 1 vs Trial 2</i> | 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) |
| <i>Trial 2 vs Trial 3</i> | 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) |
| <i>Overall</i> | 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 (%) | | | | | | | | |
| <i>Trial 1 vs Trial 2</i> | 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) |
| <i>Trial 2 vs Trial 3</i> | 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) |
| <i>Overall</i> | 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.