Reliability and validity of a 6 minute Yo-Yo Intermittent Endurance Test, Level 2 in sub-elite part time male soccer players.

Reliability of a submaximal intermittent running test
ABSTRACT

The aim of this study was to assess the reliability and relationship to maximal intermittent running performance of the 6 min Yo-Yo Intermittent Endurance Test Level 2 (YYIET2), amongst sub-elite part time soccer players. Twenty male soccer players (15 - 22 years) completed three 6 min YYIET2 trials with heart rate (HR), PlayerLoad™ and rating of perceived exertion assessed during the protocol and HR and blood lactate assessed during 5 min of recovery. Subjects also completed a maximal version of the YYIET2 and the maximal Yo-Yo Intermittent Recovery Test Level 1 (YYIRT1) and 2 (YYIRT2). HR at 4 and 6 min, PlayerLoad™ at 4 min and HR recovery at 2, 3, 4 and 5 min during recovery from the 6 min YYIET2 demonstrated little variance between tests. Correlations between variables measured during and after the 6 min YYIET2 and distance covered in maximal tests ranged from $r = 0.02$ to -0.72. The 6-min YYIET2 provides practitioners with a method of reliably assessing HR responses within sub-elite part time soccer players, whilst, large correlations with maximal assessments suggest it can be used as a proxy measure for maximal intermittent running performance. Given its ease of administration and low time cost, the 6 min YYIET2 offers practitioners a useful means of tracking training status and movement efficiency in players longitudinally.

Key Words:

Reliability, field test, sub-elite, soccer, monitoring
INTRODUCTION

Soccer is a sport characterized by intermittent high intensity running (7, 33). Performance during high intensity running is affected by chronological age, biological maturation, playing standard and effective training prescription. Moreover, quality of soccer performance has been shown to be related to the amount of high-intensity exercise performed during match-play (8, 33). Suitably, the assessment of soccer specific endurance capacity - the ability to consistently perform high-intensity intermittent exercise - is an important component in the design of effective training programs for soccer players (2, 40). As such it has become common place for practitioners to conduct physiological assessments at regular intervals throughout the season to assess soccer specific endurance capacity, typically using versions of the Yo-Yo Intermittent running assessment (7, 26). Whilst traditional research has focused on assessments of soccer specific endurance capacity that are maximal in nature, more recent studies have focused on submaximal protocols, that are 4-6 minutes in duration (26, 36, 38). The slower running speeds and lower intensities associated with such assessments allow for them to be employed more frequently, which may aid tracking longitudinal changes in performance. Furthermore, assessments of this nature, in both adult and young soccer players, have been shown to be reliable (7, 14, 35, 38), with submaximal protocols used in the assessment of team sport athletes to date modifying the duration (7, 14, 35) and shuttle length (38) associated with maximal soccer specific endurance capacity assessments.

Research to date has used heart rate (HR) responses to submaximal assessments to elucidate information relating to the physical status of players, both during exercise and recovery (7, 14, 35, 38). A reduction in HR at the end of a submaximal bout of exercise may suggest an improvement in physical capacity (9), with large to very large correlations shown with improvements in both high intensity exercise performance (2, 10) and cardiorespiratory fitness
Despite conjecture surrounding the most sensitive measure of HR recovery (36), its use as a method to monitor responses to training, at least from a cardiorespiratory perspective have been supported in the literature (9). If an athlete’s HR recovers to a greater extent over a specific period of time (for example the 60s following the cessation of exercise) following a standardized bout of exercise we may conclude that there has been an improvement in soccer specific endurance capacity, which is useful information when planning and scheduling future activity (9). In addition to physiological measures, movement characteristics data derived from accelerometers and ratings of perceived exertion (RPE) may also be useful in assessing training status.

PlayerLoad™ - derived from 3-dimensional measures of the instantaneous rate of change of acceleration - has been shown to be a reliable metric (3, 6) during high intensity intermittent running and is used to quantify external load during intermittent running of different intensities amongst young soccer players (17). Variations in PlayerLoad™ in response to a standardized protocol have been suggested to be indicative of altered movement strategies or compromised movement efficiency within soccer players, possibly as a result of fatigue (3). As such, assessing variations in this metric during sub-maximal assessments of soccer specific endurance capacity may provide practitioners with further information regarding the physical condition of their players. The assessment of soccer specific endurance capacity amongst players, however, should not be limited to objective measures; the use of subjective responses may provide useful information regarding the perception of the athletes to perform exercise of a high intensity nature. RPE is commonly used amongst soccer players at a range of ages and competitive levels (1, 17). It has been shown to correlate with objective markers of external training load, is reliable, and relatively easy to collect (15, 22). Despite this no studies have reported either PlayerLoad™ or RPE during submaximal assessments in sub-elite-part time...
players. Viewing physiological, perceptual and movement characteristic data in combination may yield important information regarding the physical state of soccer players exposed to a limited amount of training given their part time nature.

Physiological responses to submaximal running speeds during Yo-Yo intermittent running tests provide a valid indicator of maximal performance when the same protocol is performed to exhaustion (7, 26, 38). There may be instances, however, when the applied practitioner wishes to employ a different protocol for the assessment of maximal and submaximal training status. Indeed, some protocols, for example the Yo-Yo Intermittent Recovery Test Level 2 (YYIRT2), may need to be modified for assessments as short as 4 min for some populations (38). As such it is important to understand how responses during assessments with shorter and pre-defined lengths relate to maximal performance in a range of protocols used amongst sub-elite part time players, especially if their use enables a more time-efficient and less physically exhaustive method of assessing soccer specific endurance capacity.

Whilst the use of soccer specific endurance capacity assessments performed to volitional exhaustion provide useful data for the applied practitioner, they are also time intensive; to yield the most useable data it is likely that players will need to rest on the day prior to testing and again after the assessment. Whilst this may be applicable for full time players, scheduling such assessments for part time players is more difficult, especially when the requirement for physical capacity data is balanced against the available time to improve tactical and technical aspects of the game. For sub-elite, part time populations, it is however equally important to understand how effective specific training programs have been. As such the use of shortened assessments that are submaximal in nature and do not require modifications to pre and post training load may be an attractive option for applied practitioners. Furthermore, knowing how performance
in such assessments relate to assessments that are maximal in nature may reduce the amount of
protocols players are exposed to over the course of a season.

The aims of this study, therefore, were twofold: (1) to determine the reliability of the 6 min
version of the Yo-Yo Intermittent Endurance Test Level 2 (YYIET2), and (2) to determine the
relationships between 6 min YYIET2 responses and maximal intermittent running performance
in the YYIET2, YYIRT2 and Yo-Yo Intermittent Recovery Test Level 1 (YYIRT1) in sub-
elite part time soccer players.

**METHODS**

**Experimental approach to the problem**

A repeated measures approach was used to investigate the reliability of physiological,
perceptual and movement characteristics during the 6 min YYIET2. Subjects completed three
6 min YYIET2 trials, each separated by 3-5 days. Measures collected included HR, blood
lactate, PlayerLoad™ and RPE. Subsequently, to assess the relationship between 6 min
YYIET2 responses and maximal running performance each subject performed the YYIET2,
YYIRT1 and YYIRT2, until volitional exhaustion, with a minimum of three days between
trials and in a randomized order. Maximal running assessments commenced 3 days after the
last 6-min YYIET2 trial and all three maximal trials were performed within 10 days of the last
6 min YYIET2 trial. Data was collected in the early competitive phase of the season during a
maintenance phase. Participants completed no more than two, 90 min sessions between
successive sub-maximal trials and preceded each maximal assessment with at least 24 hours of
recovery following their last session.
**Subjects**

Twenty sub-elite part time soccer players (age: 17 ± 3 years [range: 15 – 22 years]; mass: 68.5 ± 11.3 kg; stature: 1.7 ± 0.6 m; 8 ± 2 h of soccer specific training a week; 2 ± 1 h of resistance training a week) provided written informed consent to participate in this study, with parental consent obtained for subjects under 18 years of age. All subjects had previous experience (2 ± 1 years) of physiological testing performed until volitional exhaustion, but none had previously performed the 6 min YYIET2. All testing was conducted during the season. The study was approved by the School of Science and Sport Ethics Committee at the University of the West of Scotland and conformed to the Declaration of Helsinki.

**Procedures**

Subjects attended a habituation session performed no less than 48 h prior to the first experimental trial during which anthropometry was recorded. Subjects were instructed to maintain their normal dietary habits during the study period. All testing was conducted in the early evening prior to normal squad training and on an indoor synthetic pitch (temp: 10.3 ± 2.3°C; relative humidity: 45.2 ± 8.3%; atmospheric pressure: 756.1 ± 7.7 mmHg). Each trial was preceded by 5 min of seated rest following which a resting HR was established. Subjects then performed a standardized warm-up comprising the first two shuttles (80 m) of the protocol followed by 1 min of stretching.

**Yo-Yo Intermittent running protocol**
The 6 min protocol was performed according to established guidelines described elsewhere (7). Briefly, subjects completed the initial 6 min (920 m) of the YYIET2, which involved 40 m shuttles comprising one 180° change of direction and performed at increasing speeds (11.5 km/hr and 14.5 km/hr at the beginning and end of the test, respectively). Each 40 m shuttle was interspersed by recovery intermissions of 5 s in duration whereby players had to go around a marker positioned 2.5 m behind the shuttle line. Upon completion of the 6 min protocol, subjects were required to remain stationary and seated for the duration of the recovery period.

Protocols for the maximal YYIET2 (starting speed 11.5 km/hr), YYITR1 (starting speed 10.0 km/hr) and YYIRT2 (starting speed 13.0 km/hr) were performed according to previously established guidelines (7, 26, 27). Players were afforded one warning for either failing to arrive on the line at the time indicated by the audio signal or moving from the start line prematurely. A second infringement resulted in the player being withdrawn from the test and the last completed shuttle recorded as the final score.

Heart rate

On all testing occasions HR was recorded for 5 min before, during and for 5 min after the test had finished. Following testing, data were downloaded using proprietary software (Polar Team 2, Polar Electro Oy, Kempele, Finland). HR during the 6 min YYIET2 was calculated as the average HR during the 30 s preceding the 4 and 6 min time points and expressed as both absolute (bpm) and relative (percentage HR maximum) values (10, 38). Depending on exercise intensity 3-4 mins of exercise is generally required to reach steady state (9), therefore HR at 4 min was assessed to investigate if a 4-min test could potentially be used instead of a 6 min test, which would impose a reduced training load. During maximal versions of the Yo-Yo
intermittent running tests, end HR was recorded as the average value during the 30 s preceding
exhaustion. Maximal HR was established as the highest value recorded during the three
maximal trials (2, 7, 23, 26).

Upon cessation of the 6 min YYIET2, HR was recorded for 5 min. To assess HR recovery, the
absolute difference between the average HR during the final 30s of the assessment (5:30-6:00
min) and after each minute of recovery were calculated. All HR recovery data were expressed
as a percentage of the value recorded after 6 min (38).

**Blood lactate**

Finger-tip blood samples (20 uL) were collected after 1 and 5 min of recovery for the
assessment of blood lactate concentration. All samples were analyzed using a lactate analyzer
(Biosen C-line, EKF, Diagnostics, Germany) immediately after each trial with a technical error
of measurement equal to 0.6 mmol/L.

**PlayerLoad**

Prior to each test, subjects were fitted with a global positioning system (GPS) unit (OptimEye
X4, 10 Hz GPS units, Catapult Innovations, Canberra, Australia) housed within a padded pouch
on the back of a cropped vest. The unit was positioned on the upper thoracic region of the
subject’s spine, between the scapulae. Subjects were assigned the same units on all testing
occasions to avoid inter-unit error (24). After each test, the raw data were downloaded using
a mass USB device in the charging box to the proprietary software (Openfield, Version 1.12.0,
Catapult, Melbourne, Australia) on a laptop. Total test time was applied to each individual raw
file by inserting a period equating to the duration of the test. The two warm-up shuttles and
minute of stretching, along with the 5 min recovery period were not included in data analysis.
PlayerLoad™ was reported at 4 and 6 min using arbitrary units (AU).

Rating of perceived exertion

Subjects verbally communicated their RPE after 4 and 6 min of the assessment. The CR-10 scale (5), which subjects had been habituated to through longitudinal post-training monitoring and which has been validated in the literature (22), was held up by the researcher as the subjects approached the end of each corresponding 40 m shuttle. Subjects communicated their RPE during the 5 s recovery period between shuttles.

Statistical Analyses

Descriptive statistics are reported as mean ± SD. Statistical analyses were performed using SPSS software (Version 22.0, IBM Corp., Armonk, NY, USA) and predesigned spreadsheets (20, 21). To investigate the reliability of the 6 min YYIET2, intra-class correlation coefficient (ICC3,1) and typical error (TE) expressed as a coefficient of variation (CV) were determined for all trials (i.e. trial 1 vs trial 2). An average for the three trials was also calculated (overall). All reliability statistics are expressed with 90% confidence limits. The smallest worthwhile change (SWC) in performance was considered as 0.2 multiplied by the between-subject standard deviation (4). To ascertain the performance improvement required to be 75% confident that the change was beneficial a magnitude-based inference approach was used using the SWC and TE for each variable, reported as the required change (13, 19).
Pearson correlation coefficients were used to examine the association between physiological variables, PlayerLoad™, and RPE in the third 6 min YYIET2 and distance covered during maximal tests. Where the assumption of normality was violated a Spearman Rank correlation was used. Correlation coefficient magnitudes were based on the following recommendations: trivial \((r < 0.1)\), small \((r = 0.1-0.3)\), moderate \((r = 0.31-0.5)\), large \((r = 0.51-0.7)\), very large \((r = 0.71-0.9)\), nearly perfect \((r > 0.9)\) and perfect \((r = 1)\) (19). All correlation coefficients are displayed with 90% confidence limits.

**RESULTS**

6 minute YYIET2

Physiological, PlayerLoad™, and perceptual data along with their corresponding reliability measures during and after the 6 min YYIET2 are presented in Tables 1-2. All players managed to complete the prescribed distance for each 6 min YYIET2 trial. None of the measures obtained a TE less than the SWC, although, HR measures at 4 (ICC: 0.96, CV: 1.1%; ICC: 0.94, CV: 1.1%, absolute and relative measures respectively) and 6 min (ICC: 0.96, CV: 1.1%; ICC: 0.94, CV: 1.1%, absolute and relative measures respectively) during exercise and HR measures at 3 (ICC: 0.92, CV: 4.1%) and 5 min (ICC: 0.93, CV: 3.6%) during recovery, displayed good levels of absolute reliability with a CV of less than 5% along with high relative reliability ICC \((r > 0.9)\). HR recovery at 4 min (ICC: 0.90 CV: 4.9%) and PlayerLoad™ at 4 min (ICC: 0.87, CV: 4.6%) also displayed a CV of less than 5% with moderate ICC’s \((r = 0.8 - 0.9)\), whilst, heart rate recovery at 2 min (ICC: 0.89, CV: 8.9%) displayed a moderate ICC and CV of less than 10%. In comparison, HR recovery at 1 min (ICC: 0.87, CV: 13.3%) and PlayerLoad™ at 6 min (ICC: 0.52, CV: 11.5%) demonstrated increased levels of variance,
whilst RPE and blood lactate measures demonstrated greater levels or variability. Required change for all measures with 75% confidence are presented in Tables 1-2.

***INSERT TABLES 1 AND 2 NEAR HERE***

Correlation between 6 minute YYIET2 responses and maximal intermittent running performance

Large, negative correlations were reported between total distance in the maximal YYIET2 test and absolute and relative HR at 4 \( (r = -0.54; r = -0.63, \text{ respectively}) \) and 6 min \( (r = -0.54; r = -0.57, \text{ respectively}) \) and blood lactate after 1 min recovery \( (r = -0.61) \) during the 6 min YYIET2. A very large negative correlation was also observed between blood lactate 5 min \( (r = -0.72) \) after the 6 min YYIET2 and distance covered in the maximal YYIET2. Large negative correlations were observed between distance covered in the YYIET2 and HR recovery at 1 \( (r = 0.62), 2 \ (r = 0.69), 3 \ (r = 0.61) \) and 4 min \( (r = 0.55) \) following the 6 min YYIET2.

Large negative correlations were reported between distance covered in the YYIRT1 with absolute and relative HR and RPE after 4 \( (r = -0.56, r = -0.52; r = -0.66, \text{ respectively}) \) and 6 min \( (r = -0.51, r = -0.56; r = -0.66, \text{ respectively}) \) of the 6 min YYIET2. Blood lactate measures at 1 \( (r = -0.71) \) and 5 min \( (r = -0.72) \) recovery following the 6 min YYIET2 showed very large negative correlations with distance covered in the maximal YYIRT1. A large positive correlation was also observed between HR recovery at 4 min \( (r = 0.51) \) following the 6 min YYIET2 and total distance in the YYIRT1.
A large negative correlation was observed between RPE at 4 min \((r = -0.54)\) during the 6 min YYIET2 and total distance covered in the maximal YYIRT2. All correlations are presented in Tables 3.

***INSERT TABLE 3 NEAR HERE***

**DISCUSSION**

This is the first study to document physiological, perceptual and movement characteristic data for sub-elite part time soccer players in response to a 6 min YYIET2 assessment. The first aim of this study was to determine the reliability of the 6 min YYIET2. Our data, in agreement with data previously reported during submaximal assessments demonstrated that HR responses during the 6 min YYIET2 are reliable measure and appropriate for use within sub-elite part time soccer players \((7, 14, 35, 38)\). Additionally, this study also aimed to assess the relationship between 6 min YYIET2 responses and maximal intermittent running performance in the YYIET2, YYIRT1 and YYIRT2 in sub-elite part time soccer players. Correlations between responses to the 6 min YYIET2 and total distance covered in maximal testing protocols ranged from -0.02 to -0.72, with stronger correlations demonstrated between responses during the 6 min YYIET2 and maximal YYIET2 and YYIRT1 performance. These data suggest that physiological characteristics data during non-exhaustive exercise in sub-elite part time players are valid and reliable measures of soccer specific endurance capacity, which, when used as part of a testing battery, may help practitioners make more informed decisions regarding training effectiveness.

Reliability of the 6 minute YYIET2
In the present study, HR measures obtained during the 6-min YYIET2 demonstrated small variations between trials and findings are in keeping with previously reported data in adult players (CV: 1.4%) (7). Furthermore, these data are similar to data on youth soccer players by Doncaster et al. (14) (HR at 6 min = ICC: 0.96 and 0.95, CV: 1.3% and 1.3%, absolute and relative respectively) and Owen et al. (35) (HR at 6 min = ICC: 0.96, CV: 1.6%), although in response to a 6 min YYIRT1. The present study also assessed HR recovery following the test. In keeping with previous findings (35, 38), HR recovery measures demonstrated greater variance in comparison to HR measures collected during exercise, with HR recovery at 1 min demonstrating the greatest variance of all HR measures, which is in keeping with previously research by Owen et al. (35) (ICC: 0.68, CV: 12.2%). Blood lactate measures, collected post 6 min YYIET2, also exhibited poor reliability across trials, similar to that previously reported before, during and upon completion of maximal YYIT’s (26, 27). It is acknowledge that methodological issues associated with the collection of fingertip blood samples in the field may have impacted on the present data, especially given the relatively cool ambient temperature (18). That said, whilst the reliability of HR varies depending on the protocol used, training status, age and environmental factors (9, 12, 28), our data support its use amongst soccer players during non-exhaustive exercise.

Whilst, PlayerLoad™ is typically used to detect changes in external load during soccer activities (3), our data show that this variable has acceptable reliability at 4 min, but as the 6 min YYIET2 continues, its variance increases. These data may question the standardization of the YYIET2 protocol when performed by sub-elite part time soccer players. Despite running speed being directed by the audio signal, players are able to manipulate their acceleration and deceleration profiles during each shuttle, which may impact upon PlayerLoad™ (34). We
would recommend that future studies investigate the reliability of the 6 min YYIET2 outdoors to permit the collection of movement characteristics data including running speed, acceleration and deceleration profiles. RPE has been shown to relate to external load (16) and, as such, the observed variability in PlayerLoad™ collected at 6 min may explain why RPE was not reliable in the present study. Indeed, previous research has questioned the ability of RPE to detect changes in the intensity of exercise amongst young soccer players during sub-maximal shuttle running similar to that used in this study (17).

When assessing reliability, it is also important to consider that a learning effect may occur, especially if participants, as in this study, have never performed the prescribed protocol before (19). This is meaningful as variability between trials may alter as participants gain familiarity with the protocol, subsequently impacting upon the sensitivity of the test. Suitably, some tests may require familiarization sessions, or within a soccer environment the initial test may need to be assessed with caution, when trying to assess “real change”. These data, unlike that of Doncaster et al. (14), would however suggest that no familiarization with the 6 min YYIET2 protocol is required before assessing a players HR response (e.g. trial 1 v trial 2 and trial 2 v trial 3). This finding is somewhat surprising as this test was novel to all participants, although a possible explanation for this may be that all participants had previously performed maximal YYIT’s and had therefore been exposed to the concept underpinning the test.

When assessing an individual’s response to period of training and/or competition, practitioners must consider what constitutes a “real change” in performance between tests. Changes in HR responses to a 6 min YYIET2 have been reported to be 4 bpm after a period of two weeks intensive training among international male players (7), a change greater than the TE reported in our study (HR6 = 2 bpm) and equal to the threshold for a required change (4 bpm). Moreover,
following longer training periods, greater variations in exercising HR data in response to 6 min
Yo-Yo intermittent running assessments have been observed (2, 32). These data would support
the use of the test detailed herein as a suitable tool for monitoring the effectiveness of training
interventions for soccer players. Further research is required to understand whether changes in
measures associated with HR recovery, RPE, PlayerLoad™ and blood lactate after a period of
training in sub-elite part time soccer players are greater than the required change reported in
this study.

Relationship of the 6 minute YYIET2 with maximal intermittent running performance

The strongest correlations between HR during the 6 min YYIET2 and maximal running
performance were observed for the YYIET2 and YYIRT1. This may be a result of running
speeds associated with the YYIRT2 being too fast for the young sub-elite part-time players in
the present study resulting in the players stopping or being withdrawn from the test before they
had reached their maximal exertion. This relationship was similar for HR recovery measures
and performance in the YYIET2. There was a large negative correlation between HR recovery
at 1 through 4 min and maximal YYIET2 performance, along with HR recovery at 4 min and
maximal YYIRT1 performance. The intermittent endurance versions of the Yo-Yo tests have
been suggested to be more aerobic in nature than intermittent recovery versions (39). As such,
this may explain why HR recovery, a well-established marker of enhanced aerobic capacity, is
more closely related to maximal YYIET2 test performance. Furthermore, in support of
previous findings, blood lactate measures collected after the 6 min YYIET2 were largely and
very largely negatively correlated to maximal YYIET2 and YYIRT1 performance (25, 26).
These correlations should, however, be viewed in conjunction with the high CV reported for
blood lactate. Although a potentially useful proxy-measure of maximal performance, care must be taken to ensure samples are collected in a standardized manner to reduce error.

Given time constraints associated with part time training environments, testing protocols that are time efficient should be sought (29). Non-exhaustive versions of the Yo-Yo intermittent running tests have been suggested as a potential component of squad warm-ups (38) allowing practitioners to frequently monitor physical capacity. Moreover, such protocols can limit fatigue and reduce any deleterious effects on subsequent training (37). It is, however, important to note that HR responses during the 6 min YYIET2 in the present study could not be considered submaximal (4 min average: 90.2 ± 3.9%; 6 min average 92.7 ± 3.8%) (11). Indeed, such values have been reported as being representative of the training intensity required to elicit changes in maximal aerobic capacity in youth (31) and adult players (30). Therefore, although the test is time-efficient in comparison to maximal versions, it may, for some players negatively impact subsequent training, something which may be more deleterious for those who train part time with limited opportunities to develop each component of their game. In light of this and given the reliability of HR and PlayerLoad™ data at 4 min, a shortened version may be appropriate (35). Further research is required to understand the acute effects that tests of this nature have on sub-elite part time players.

When testing sub-elite part time soccer players, who typically train in the evening, it is also important to consider that daily activities such as school and employment may impact upon cognitive and physical fatigue. Within the present study daily activities out with training were not controlled for due to the wide range of jobs and schools that players attended. Our results do, however, suggest that HR measures show little day-to-day variability. That said,
practitioners may wish to consider prior daily activities when monitoring players as such may
impact upon these data.

Practical Applications

Practitioners should consider assessing the reliability and calculating thresholds for required
change (13) when employing tests of physical capacity amongst sub-elite part time soccer
players. Our results indicate that the HR response following a 6 min YYIET2 demonstrate good
levels of reliability in sub-elite part-time soccer players, with exercising HR data the most
reliable. Furthermore, values for exercising HR from previous studies would suggest that the
YYIET2 is able to, using the values reported in this study, detect changes in performance
following an acute period of training in soccer players. As such the use of a test that is non-
exhaustive and time-efficient such as the 6 min YYIET2 may be advantageous to the
practitioner in the applied setting. Practitioners should be aware however that although non-
exhaustive, HR responses of sub-elite part time soccer players during a 6 min YYIET2 may
not be submaximal and as such consider this when scheduling its use.
REFERENCES


Table 1. Reliability of Physiological, PlayerLoad™ and perceptual responses during the 6 min YYIET2.

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<th>HR6 (bpm)</th>
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<th>HR6(%)HRmax</th>
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<td>67 ± 8</td>
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**Change in mean**

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**ICC (α, t)**

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<td>0.67 (0.40, 0.83)</td>
<td>0.33 (-0.05, 0.62)</td>
<td>0.81 (0.64, 0.91)</td>
</tr>
<tr>
<td>trial 2 vs trial 3</td>
<td>0.95 (0.89, 0.98)</td>
<td>0.95 (0.90, 0.98)</td>
<td>0.93 (0.85, 0.96)</td>
<td>0.93 (0.85, 0.97)</td>
<td>0.91 (0.82, 0.96)</td>
<td>0.36 (-0.01, 0.65)</td>
<td>0.45 (0.10, 0.70)</td>
<td>0.78 (0.58, 0.89)</td>
</tr>
<tr>
<td>trial 1 vs trial 3</td>
<td>0.95 (0.89, 0.98)</td>
<td>0.95 (0.90, 0.98)</td>
<td>0.93 (0.85, 0.97)</td>
<td>0.93 (0.85, 0.97)</td>
<td>0.84 (0.68, 0.92)</td>
<td>0.66 (0.38, 0.83)</td>
<td>0.40 (0.03, 0.67)</td>
<td>0.76 (0.54, 0.88)</td>
</tr>
<tr>
<td>overall</td>
<td>0.96 (0.92, 0.98)</td>
<td>0.96 (0.92, 0.98)</td>
<td>0.94 (0.89, 0.97)</td>
<td>0.94 (0.89, 0.97)</td>
<td>0.87 (0.78, 0.93)</td>
<td>0.52 (0.32, 0.71)</td>
<td>0.40 (0.03, 0.67)</td>
<td>0.78 (0.65, 0.88)</td>
</tr>
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**TE**

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<tbody>
<tr>
<td>trial 1 vs trial 2</td>
<td>1.72 (1.37, 2.36)</td>
<td>1.75 (1.39, 2.40)</td>
<td>0.88 (0.70, 1.21)</td>
<td>0.90 (0.71, 1.23)</td>
<td>3.59 (2.85, 4.93)</td>
<td>9.20 (7.30, 12.61)</td>
<td>0.90 (0.72, 1.24)</td>
<td>0.71 (0.56, 0.97)</td>
</tr>
<tr>
<td>trial 2 vs trial 3</td>
<td>2.08 (1.65, 2.85)</td>
<td>2.07 (1.65, 2.84)</td>
<td>1.06 (0.84, 1.45)</td>
<td>1.06 (0.84, 1.45)</td>
<td>2.64 (2.09, 3.62)</td>
<td>12.50 (9.92, 17.13)</td>
<td>0.77 (0.61, 1.06)</td>
<td>0.74 (0.59, 1.02)</td>
</tr>
<tr>
<td>trial 1 vs trial 3</td>
<td>2.11 (1.68, 2.90)</td>
<td>2.08 (1.65, 2.85)</td>
<td>1.09 (0.87, 1.50)</td>
<td>1.07 (0.85, 1.47)</td>
<td>3.44 (2.73, 4.71)</td>
<td>7.48 (5.94, 10.25)</td>
<td>0.79 (0.63, 1.08)</td>
<td>0.71 (0.56, 0.97)</td>
</tr>
<tr>
<td>overall</td>
<td>1.98 (1.70, 2.43)</td>
<td>1.98 (1.70, 2.43)</td>
<td>1.01 (0.87, 1.25)</td>
<td>1.01 (0.87, 1.24)</td>
<td>3.25 (2.79, 3.97)</td>
<td>9.95 (8.53, 12.15)</td>
<td>0.79 (0.63, 1.08)</td>
<td>0.72 (0.62, 0.88)</td>
</tr>
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</table>

**CV (%)**

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<tbody>
<tr>
<td>trial 1 vs trial 2</td>
<td>1.0 (0.8, 1.4)</td>
<td>1.0 (0.8, 1.3)</td>
<td>1.0 (0.8, 1.4)</td>
<td>1.0 (0.8, 1.3)</td>
<td>4.8 (3.8, 6.7)</td>
<td>11.6 (9.1, 16.2)</td>
<td>19.3 (15.0, 27.3)</td>
<td>11.8 (9.3, 16.6)</td>
</tr>
<tr>
<td>trial 2 vs trial 3</td>
<td>1.2 (0.9, 1.6)</td>
<td>1.2 (0.9, 1.6)</td>
<td>1.2 (0.9, 1.6)</td>
<td>1.1 (0.9, 1.6)</td>
<td>4.0 (3.1, 5.5)</td>
<td>15.3 (12.0, 21.5)</td>
<td>15.3 (12.0, 21.6)</td>
<td>13.7 (10.7, 19.2)</td>
</tr>
<tr>
<td>trial 1 vs trial 3</td>
<td>1.2 (1.0, 1.7)</td>
<td>1.2 (0.9, 1.6)</td>
<td>1.2 (1.0, 1.7)</td>
<td>1.2 (0.9, 1.6)</td>
<td>5.0 (4.0, 6.9)</td>
<td>7.5 (5.9, 10.5)</td>
<td>16.1 (12.6, 22.7)</td>
<td>12.2 (9.5, 17.0)</td>
</tr>
<tr>
<td>overall</td>
<td>1.1 (0.9, 1.5)</td>
<td>1.1 (0.9, 1.5)</td>
<td>1.1 (0.9, 1.5)</td>
<td>1.1 (0.9, 1.5)</td>
<td>4.6 (3.8, 6.4)</td>
<td>11.5 (9.0, 16.1)</td>
<td>16.9 (13.2, 23.8)</td>
<td>12.6 (9.8, 17.6)</td>
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</tbody>
</table>

**SWC**

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<td>0.8</td>
<td>2</td>
<td>3</td>
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**Required change**

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<tbody>
<tr>
<td>required change</td>
<td>-4</td>
<td>-4</td>
<td>-1.8</td>
<td>-1.8</td>
<td>-6</td>
<td>-13</td>
<td>-2</td>
<td>-2</td>
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</table>
Table 2. Reliability of Physiological responses during recovery following the 6 min YYIET2.

<table>
<thead>
<tr>
<th></th>
<th>HRR1(%)†</th>
<th>HRR2(%)†</th>
<th>HRR3(%)†</th>
<th>HRR4(%)†</th>
<th>HRR5(%)†</th>
<th>Lactate1(mmol/l)</th>
<th>Lactate5(mmol/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1 (mean ± SD)</td>
<td>30.1 ± 9.6</td>
<td>41.4 ± 9.9</td>
<td>44.9 ± 7.9</td>
<td>46.5 ± 7.1</td>
<td>45.5 ± 6.1</td>
<td>6.22 ± 3.62</td>
<td>5.74 ± 3.62</td>
</tr>
<tr>
<td>Trial 2 (mean ± SD)</td>
<td>31.4 ± 7.9</td>
<td>42.4 ± 7.4</td>
<td>45.7 ± 6.2</td>
<td>46.4 ± 5.8</td>
<td>46.3 ± 5.5</td>
<td>6.01 ± 2.48</td>
<td>5.32 ± 2.74</td>
</tr>
<tr>
<td>Trial 3 (mean ± SD)</td>
<td>32.2 ± 9.7</td>
<td>44.0 ± 9.7</td>
<td>46.2 ± 7.1</td>
<td>46.3 ± 6.2</td>
<td>46.6 ± 5.6</td>
<td>6.09 ± 2.64</td>
<td>5.47 ± 2.62</td>
</tr>
</tbody>
</table>

**Change in mean**

- trial 1 vs trial 2
  - HRR: 1.3 (-0.3, 3.0) 1.1 (-0.8, 3.0)
  - Lactate: 0.2 (-0.1, 0.6)

**ICC (3, 1)**

- trial 1 vs trial 2
  - HRR: 0.89 (0.78, 0.95) 0.86 (0.72, 0.93)
  - Lactate: 0.89 (0.78, 0.95) 0.86 (0.72, 0.93)

**TE**

- trial 1 vs trial 2
  - HRR: 3.02 (2.39, 4.13) 3.34 (2.73, 4.71)
  - Lactate: 3.21 (2.54, 3.89) 3.12 (2.54, 3.89)

**CV (%)**

- trial 1 vs trial 2
  - HRR: 11.2 (8.8, 15.6) 9.9 (7.8, 13.8)
  - Lactate: 11.3 (9.1, 14.1) 10.1 (8.3, 11.9)

**Required change**

- SWC: 1.9 1.8 1.5 1.3 1.2 0.59 0.60

*HRR1 = heart rate recovery at 1 min post-test; HRR2 = heart rate recovery at 2 min post-test; HRR3 = heart rate recovery at 3 min post-test; HRR4 = heart rate recovery at 4 min post-test; HRR5 = heart rate recovery at 5 min post-test; Lactate1 = blood lactate concentration at 1 min post-test; Lactate5 = blood lactate concentration at 5 min post-test; ICC = intra-class correlation coefficient; TE = Typical error; CV = coefficient of variation; SWC = smallest worthwhile change.

†absolute difference between heart rate at 6 min and heart rate recovery at each time point, expressed as a percentage of heart rate at 6 min.
<table>
<thead>
<tr>
<th></th>
<th>YYIET2</th>
<th>YYIRT1</th>
<th>YYIRT2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HR4 (bpm)</strong></td>
<td>-0.54† (-0.76, -0.20)</td>
<td>-0.56† (-0.78, -0.23)</td>
<td>-0.42 (-0.80, -0.04)</td>
</tr>
<tr>
<td><strong>HR6 (bpm)</strong></td>
<td>-0.54‡ (-0.76, -0.20)</td>
<td>-0.51‡ (-0.74, -0.16)</td>
<td>-0.35 (-0.74, 0.04)</td>
</tr>
<tr>
<td><strong>HR4 (%HRmax)</strong></td>
<td>-0.63† (-0.81, -0.33)</td>
<td>-0.52‡ (-0.75, -0.18)</td>
<td>-0.41 (-0.76, -0.04)</td>
</tr>
<tr>
<td><strong>HR6 (%HRmax)</strong></td>
<td>-0.57† (-0.78, -0.24)</td>
<td>-0.56† (-0.77, -0.23)</td>
<td>-0.41 (-0.80, -0.01)</td>
</tr>
<tr>
<td><strong>PlayerLoadTM4</strong></td>
<td>0.22 (-0.18, 0.55)</td>
<td>0.28 (-0.11, 0.60)</td>
<td>-0.02 (-0.48, 0.44)</td>
</tr>
<tr>
<td><strong>PlayerLoadTM6</strong></td>
<td>0.30 (-0.09, 0.61)</td>
<td>0.35 (-0.04, 0.64)</td>
<td>-0.03 (0.52, 0.46)</td>
</tr>
<tr>
<td><strong>RPE4</strong></td>
<td>-0.40 (-0.68, -0.02)</td>
<td>-0.66† (-0.83, -0.37)</td>
<td>-0.54‡ (-0.87, -0.21)</td>
</tr>
<tr>
<td><strong>RPE6</strong></td>
<td>-0.42 (-0.69, -0.05)</td>
<td>-0.66† (-0.83, -0.37)</td>
<td>-0.48‡ (-0.87, -0.09)</td>
</tr>
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<tbody>
<tr>
<td><strong>HRR1</strong></td>
<td>0.62† (0.31, 0.81)</td>
<td>0.42 (0.05, 0.69)</td>
<td>0.25 (-0.10, 0.60)</td>
</tr>
<tr>
<td><strong>HRR2</strong></td>
<td>0.69† (0.42, 0.85)</td>
<td>0.47‡ (0.11, 0.72)</td>
<td>0.34 (-0.02, 0.69)</td>
</tr>
<tr>
<td><strong>HRR3</strong></td>
<td>0.61† (0.30, 0.80)</td>
<td>0.47‡ (0.11, 0.72)</td>
<td>0.29 (-0.06, 0.64)</td>
</tr>
<tr>
<td><strong>HRR4</strong></td>
<td>0.55‡ (0.21, 0.77)</td>
<td>0.51‡ (0.17, 0.75)</td>
<td>0.14 (-0.23, 0.50)</td>
</tr>
<tr>
<td><strong>HRR5</strong></td>
<td>0.46‡ (0.10, 0.71)</td>
<td>0.46‡ (0.09, 0.71)</td>
<td>0.18 (-0.21, 0.56)</td>
</tr>
<tr>
<td><strong>Lactate1</strong></td>
<td>-0.61† (-0.80, -0.30)</td>
<td>-0.71† (-0.86, -0.45)</td>
<td>-0.30 (-0.73, 0.12)</td>
</tr>
<tr>
<td><strong>Lactate5</strong></td>
<td>-0.72‡ (-0.86, -0.45)</td>
<td>-0.72‡ (-0.86, 0.46)</td>
<td>-0.39 (-0.82, 0.04)</td>
</tr>
</tbody>
</table>

*YYIET2 = yo-yo intermittent endurance test level 2; YYIRT1 = yo-yo intermittent recovery test level 1; YYIRT2 = yo-yo intermittent recovery test level 2; HR4 = 4 min exercising heart rate; HR6 = 6 min exercising heart rate; PlayerLoadTM4 = PlayerLoadTM at 4-min; PlayerLoadTM6 = PlayerLoadTM at 6 min; RPE4 = rating of perceived exertion at 4 min; RPE6 = rating of perceived exertion at 6 min; HRR1 = heart rate recovery at 1 min post-test; HRR2 = heart rate recovery at 2 min post-test; HRR3 = heart rate recovery at 3 min post-test; HRR4 = heart rate recovery at 4 min post-test; HRR5 = heart rate recovery at 5 min post-test; Lactate1 = blood lactate concentration at 1 min post-test; Lactate5 = blood lactate concentration at 5 min post-test; bpm = beats per minute; %HRmax = percentage heart rate maximum.

†p≤0.05
‡p≤0.01