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The NIE Intermittent High-Intensity Running Test: A Reliable and Valid Test for Assessment of Soccer-Specific Fitness

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ABSTRACT

The overall activity pattern of soccer is that of intermittent high-intensity (Int-HINT) type and elite players have a greater repeated high-intensity running capability. Since soccer involves rapidly changing work intensities in an unpredictable manner, tests simulating overall activity pattern in a cyclical sequence have limited practical usefulness in testing of soccer fitness. The primary aim of this study was to develop a laboratory-based protocol to specifically assess the Int-HINT running capability in soccer players.

University team games athletes (n=8, Mean ± SD; age 22.30 ± 1.65 years, stature 1.73 ± 0.04 m, body mass 69.36 ± 6.04 kg) participated in the reliability study and male youth professional soccer players (n=20, Mean ± SD age, 17.5 ± 0.3 yrs; stature, 1.73 ± 0.04 m; body mass, 67.2 ± 7.5 kg) participated in the validity study. The players performed on the NIE Intermittent High-intensity (NIE Int-HINT) Running Test during the pre-season, early in-season and end mid-season phases of the soccer season. Performance was measured as total distance covered on the treadmill. The participants also performed the YoYo Intermittent Recovery Test Level 2 (YoYo IRT L2) during each phase of the competition season.

The NIE Int-HINT test was found to be of high reliability (ICC, 0.98; CV, 2.1%; ratio limits of agreement (rLOA) 0.99 ×/÷ 1.03). A positive and significant correlation ($p < 0.05$) was found between the performance in the NIE Int-HINT test and the YoYo IRT L2 performance ($r = 0.68$-0.77) during different phases of the soccer season.

The NIE Int-HINT test provided a reliable measure of intermittent high-intensity running capability and a valid and sensitive method of estimating soccer-specific fitness in youth professional soccer players. Further studies are needed to evaluate the applicability of this test in adult elite soccer players and other intermittent team game athletes.

Key words: Association Football, Intermittent High-Intensity Exercise, Repeated Sprint Ability Test, Soccer, Youth Sport

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Mike Lambert (University of Cape Town, South Africa)

INTRODUCTION

The overall activity pattern of soccer is that of an intermittent high-intensity type, and this characteristic of the game is independent of player and position-based differences [1-3]. The ratio of rest-to-high and rest-to-low intensity period may vary to some extent depending on the individual style of play, but all outfield players show a similar intermittent high-intensity exercise pattern [1]. Moreover, the higher the level of soccer, the greater is the amount of high-intensity running performed by the players. The total distance covered may vary from game to game for a player, but the amount of high-intensity exercise appears to be a more constant measure of performance [4]. Hence, soccer at higher standards is characterised by the players' capability to perform high-intensity work repeatedly and this fitness attribute constitutes the most consistent, discriminatory, decisive and valid measure of performance in modern soccer. Therefore, it is important that soccer players should possess the fitness capability to perform repeated high-intensity running in quick succession. Further, it will be of practical significance for soccer coaches, trainers and sports scientists to gain information on the performance indicators that characterise the repeated high-intensity running capability.

Determining the capability in the players to perform repeated high-intensity efforts provides a worthwhile applied performance measure [5]. While several attempts have been made by the researchers to develop soccer-specific tests [6-10], no single test can be absolutely accepted as a measure of soccer-specific fitness, especially with regard to the intermittent high-intensity exercise pattern of the game. Various protocols have been developed to simulate the different work-intensities of soccer play on the cycle ergometer [11] as well as on a motorised treadmill [7, 8]. While cycle ergometer-based protocols have questionable validity for running-based activity [12-14] like in soccer, treadmill-based protocols essentially simulate only forward movements. Movements like sideward and backward running, games skills like heading, shooting and dribbling sudden starts and stops and other unorthodox movements like throws, turns and tackles cannot possibly be included in the protocol. Given that these activities have their own energy consequences [15], their non-inclusion will inevitably underestimate the physiological responses elicited by such protocols.

Another soccer-related protocol, constructed with a purpose of determining the aerobic capacity and the time to exhaustion (TTE), and to correlate these measures to the performance on a field test (YoYo IRT level-1) was found to be valid for assessing repeated high-intensity running in soccer players and the high-intensity exercise performance during a game [8]. However, the drawback of this protocol was that it lasted for approximately 40-46 minutes which may be a deterrent for testing elite athletes in the laboratory. Therefore, a need is evident for a suitable protocol for the assessment of the most discriminatory and valid performance quality of modern soccer; i.e., the capability to perform repeated high-intensity running. Since the overall game pattern is highly variable and unpredictable, the extent to which the performance of the players in such 'fixed pattern' tests are applicable to continuously changing activity patterns of the game is uncertain. Rather, it would be of greater practical relevance to specifically assess the intermittent high-intensity running capability that has been established to be the more consistent and valid measure of soccer performance.

The objective of this study was to develop a laboratory-based test protocol to specifically assess the intermittent high-intensity running capability in soccer players. The next objective was to determine its validity by comparing the performance on the developed protocol with the performance in the YoYo Intermittent Recovery Test Level 2 (YoYo IRT L2) which has already been established to be the valid measure of soccer-specific fitness in terms of intermittent high-intensity running capability in elite soccer players [8, 16].

METHOD

This study was conducted in two parts. The first part involved the test protocol development and the determination of reliability while the second part was to determine the validity and sensitivity of the protocol wherein the performance of the participants in the developed protocol was compared with the YoYo IRT L2 during different phases of the entire soccer season.

Singapore national combined university team games players (soccer, n=6; rugby, n=4) volunteered to participate in the reliability study. However, owing to the academic commitments of the participants and that each test had to be conducted twice on the participants within a stipulated time-interval, eventually eight of the ten recruited participants (soccer, n=6; rugby, n=2) completed the requirements of the pilot study. The physical characteristics of the participants (n=8) were (Mean ± SD) age 22.30 ± 1.65 years, stature 1.73 ± 0.04 m and body mass 69.36 ± 6.04 kg respectively.

Following explanation of the experimental procedural details, the participants gave a written informed consent for their voluntary participation in the study. Following two familiarisation sessions separated by four days, the participants completed the NIE Intermittent High-intensity (NIE Int-HINT) test on the programmable motorised treadmill (H/P/COSMOS Pulsar, Germany). The participants repeated the test after three days during the same time of the day (9-11 am) for the determination of reproducibility of the performance on the test protocol.

The validity study was conducted on male youth professional soccer players, excluding goalkeepers. The participants were the members of the National Football Academy under-18 team, the best soccer talent in the country in that age group. The team represented the Singapore National Youth Soccer team and also played in a local professional soccer league. The physical characteristics of the participants (n=20) at the time of initial recruitment were (Mean ± SD) age 17.5 ± 0.3 years, stature 1.73 ± 0.04 m and body mass 67.2 ± 7.5 kg, respectively. Institutional ethical clearance was obtained and parental consent and subject assent was sought for voluntary participation in the study.

The validity study spanned nine months of the ten-month soccer season. The soccer season was broadly divided into the pre-season and the in-season phases. The in-season season phase was further sub-divided into early in-season, mid-season and the end-season phases, respectively. Following two familiarisation sessions separated by a week, the players performed on the NIE Int-HINT test thrice during the pre-season, early in-season and the end mid-season, respectively. Each test performance was separated by thirteen weeks. In addition, the players also performed the YoYo IRT L2 on the three occasions during each phase of the season.

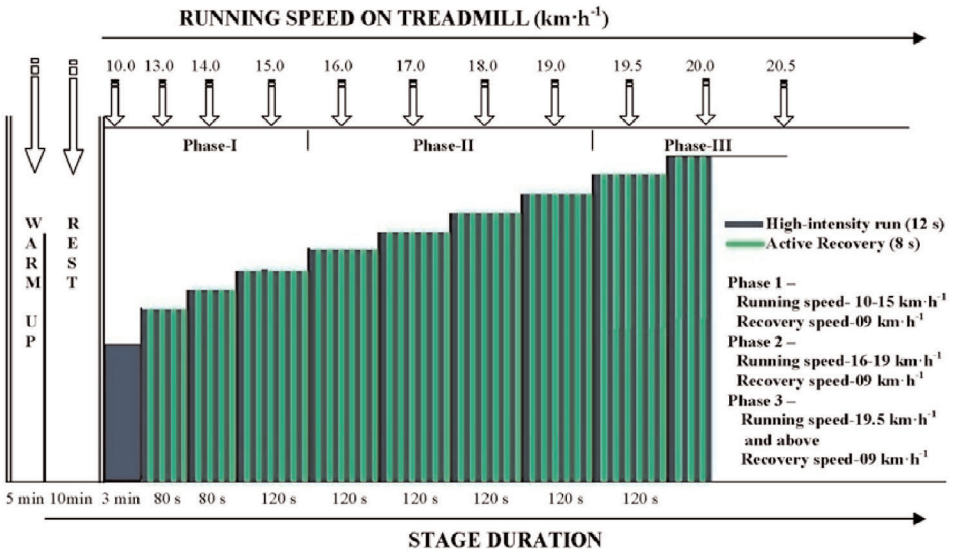
THE NIE INT-HINT TEST

The NIE Int-HINT test was developed to assess the intermittent high-intensity running capability in soccer players. This test was conducted on the programmable motorised treadmill (H/P/COSMOS Pulsar, Germany). Telemetric metabolic analyser (Cosmed K4b^2, COSMED s.r.l., Italy) was used for the estimation of oxygen uptake during the test protocol. Heart rate estimation was done using telemetric heart rate monitor (Polar Sports tester, Polar Electro OY, Finland). A pre- and post-exercise finger-prick blood test was done under asepsis for the estimation of resting blood lactate using whole blood lactate analyser (YSI, 2300 STAT Plus^{TM}, YSI Inc. Ohio, USA).

The participants warmed up doing light jogging and stretching exercises, followed by a 3-min alternate walk and jog on the treadmill at speeds alternating every 15 s between

6 km·h^{-1} and 9 km·h^{-1}. This was followed by a 10-15 min rest period during which the metabolic analyser was fastened on the participant's chest and the face mask fixed.

The protocol consisted of three phases, each of which has different stages (Figure 1).



Note: km·h^{-1} – kilometre per hour; min- minute; s- second

Figure 1. Schematic Representation of the NIE Int-HINT Test

The different phases and stages of the test protocol were pre-fed into the software application programme of the motorised treadmill. Essentially, the protocol involved alternate high-intensity running lasting 12 s followed by 8 seconds of low-intensity running. The different phases were based on the speed of the high-intensity running (Table 1). Phase-1 comprised of running speeds starting at 10 km·h^{-1} for 3 minutes which formed the stage-1 of Phase-1. The high-intensity runs started at the speed 13 km·h^{-1} through 15 km·h^{-1} which constituted the stages 2-4 of the Phase-1. The stages-2 (speed 13 km·h^{-1}) and 3 (speed 14 km·h^{-1}) had four repetitions each while stage-4 (speed 15 km·h^{-1}) onwards had six repetitions. Phase-2 involved speed levels starting from 16.0 km·h^{-1} to 19.0 km·h^{-1} which constituted stages 1-4 of Phase-2. Thereafter, in the Phase-3, the speed increases by 0.5 km.h^{-1} starting from 19·5 km.h^{-1} onwards until the participant was no longer able to sustain the effort.

Table 1. The Phases and Stages of the NIE Int-HINT Test

Phase 1				**Phase 2**				**Phase 3**
Stage 1	**Stage 2**	**Stage 3**	**Stage 4**	**Stage 1**	**Stage 2**	**Stage 3**	**Stage 4**	**≥19.5 km·h^{-1}**
10 km·h^{-1} for 3 min	13 km·h^{-1} (12 s) 9 km·h^{-1} (8 s) Four repetitions	14 km·h^{-1} (12 s) 9 km·h^{-1} (8 s) Four repetitions	15 km·h^{-1} (12 s) 9 km·h^{-1} (8 s) Six repetitions	16 km·h^{-1} (12 s) 9 km·h^{-1} (8 s) Six repetitions	17 km·h^{-1} (12 s) 9 km·h^{-1} (8 s) Six repetitions	18 km·h^{-1} (12 s) 9 km·h^{-1} (8 s) Six repetitions	19 km·h^{-1} (12 s) 9 km·h^{-1} (8 s) Six repetitions	19.5 km·h^{-1} (12 s) 9 km·h^{-1} (8 s) Six repetitions

During the test, the participants were provided verbal signals of the changes in speed using reverse countdown by the laboratory assistant. The participants were verbally and visually encouraged by the researcher to perform at their maximum effort. The sign indication for volitional exhaustion was pre-decided between the participant and the researcher. The performance was measured as the distance covered in metres on the treadmill by the participant. The mean time taken by the participants to volitional exhaustion was 17.2 minutes (range 14.6 – 20.4 min).

STATISTICAL METHODS

The reliability of the performance measures in the NIE Int-HINT test was assessed using the intra-class correlation (ICC), coefficient of variation (CV), change in the mean, limits of agreement (LOA) [17] and in the event of detection of heteroscedasticity, ratio limits of agreement (rLOA). Further, the usefulness or the ratings of the tests were evaluated using the smallest worthwhile change [18-19] and the typical error [20]. The methodological design in the present study involved measurement of correlated variables repeatedly (three times during the season) on the same group of participants. This required a multivariate analysis of variance (MANOVA) approach to the repeated-measures data. Further, since there were two dependent variables, the performance measure on the NIE Int-HINT test and the YoYo IRT L2 characterising the same performance quality - the capability to perform repeated high-intensity running, a correlational structure was expected within each measure and a different correlational structure across the measures. Such a structure of the study entailed a 'doubly multivariate approach to repeated-measures ANOVA' [21-23] to determine the time effect; i.e., if the measures of repeated high-intensity running capability in soccer players changed through the season. A Bonferroni post hoc test was done to determine the level of significance. The homogeneity of variance was evaluated using a Mauchly test of sphericity, and if the assumptions of sphericity were violated, the Greenhouse Geisser correction was used. The strength of relationship between the NIE Int-HINT test performance and the YoYo IRT L2 was assessed using the Pearson correlation coefficient. The level of significance was set at $p < 0.05$.

RESULTS

RELIABILITY

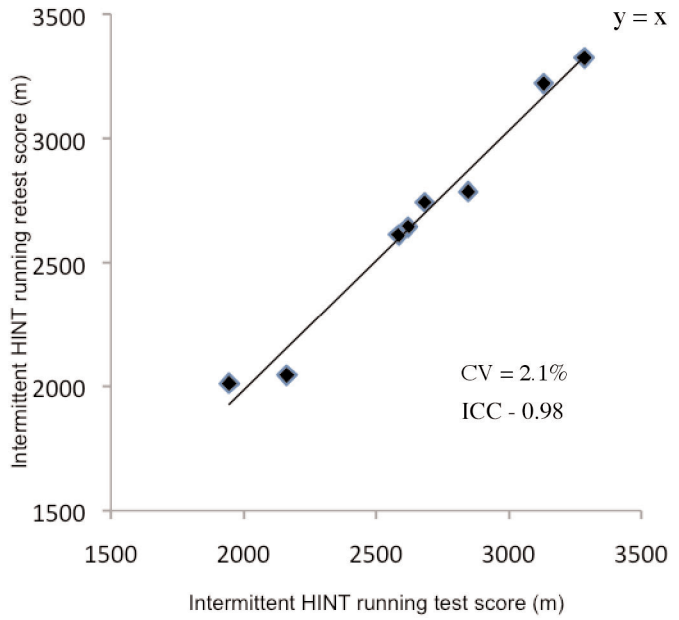
The performance measures recorded in the test for intermittent high-intensity running ability on the motorised treadmill are presented in Table 2.

Table 2. NIE Int-HINT Test Performance Data (Mean ± SD); n=8

Measure	Test	Retest	Interval
Distance covered (m)	2658.12 ± 449.15	2672.75 ± 474.76	3 days
Resting BLa (mmol·l^{-1})	1.19 ± 0.36	1.08 ± 0.11	
Post-exercise BLa	4.74 ± 0.93	4.87 ± 0.64	
Max VO2 (ml·kg-1·min^{-1})	52.84 ± 3.46	54.15 ± 3.95	
HRmax	188.6 ± 5.4	188.7 ± 4.8	
RPE	19.6 ± 0.5	19.2 ± 0.4	

Note: m-metre; $\dot{V}O_2$- oxygen uptake; BLa- blood lactate; HR_{max}- maximum heart rate; RPE- rating of perceived exertion

No significant difference ($t_{(7)} = -0.58$, $p > 0.05$) was found between test-retest measurements (Mean ± SD, 2658.1 ± 449.1 and 2672.7 ± 474.7 m) for the distance covered suggesting no statistically significant test-retest bias. Furthermore, achieving similar maximal heart rates (Mean ± SD, 188.6 ± 5.4 and 188.7 ± 4.8) and RPE ratings (Mean ± SD, 19.6 ± 0.5 and 19.2 ± 0.4) suggested that the participants exerted equivalence of maximum effort in both the sessions. The test-retest reproducibility for the distance covered in the intermittent high-intensity running test is presented in Figure 2.



Note. HINT- high-intensity; m-metre; CV – coefficient of variation; ICC – intraclass correlation coefficient

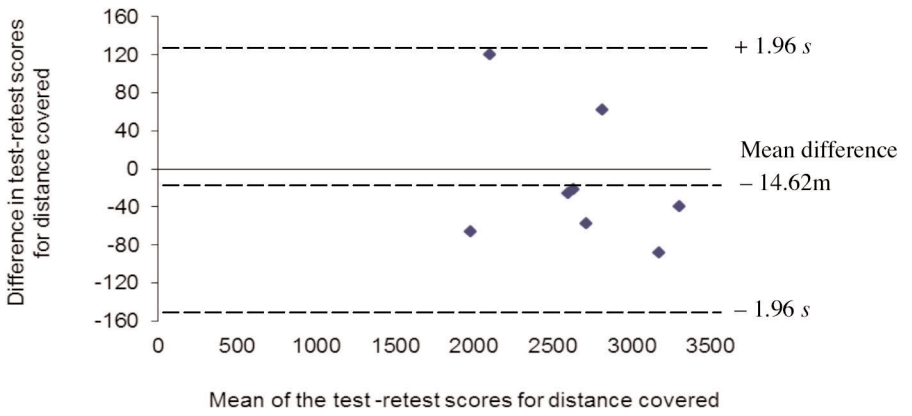
Figure 2. Test-Retest Reproducibility of the NIE Int-HINT (n=8) The full line is the identity line (x = y).

The reliability statistics for the NIE Int-HINT test were intraclass correlation coefficient (ICC), 0.98 (95% CL, 0.93 - 0.99); coefficient of variation (CV), 2.1% (95% CL, 1.4 - 4.4%); change in mean, 14.63 m; limits of agreement (LOA), –14.62 ± 137.94 and the ratio limits of agreement (rLOA) 0.99 ×/÷ 1.03 respectively.

The plot of differences in distance covered during the NIE Int-HINT test against their respective mean for the test-retest sessions is presented in Figure 3. The random error lines defining the limits of agreement are also presented on the Bland-Altman plots.

RATING/USEFULNESS OF THE NIE INT-HINT TEST

The 'typical error' (TE) for the distance covered in the intermittent high-intensity running test was 49.77 m (95% CI, 32.91-101.29) and in terms of percentage, the TE was 1.86%. The smallest worthwhile change [18, 19] for the distance covered was calculated to be 92.4 m and in terms of percentage was 3.46%. The smallest worthwhile change for the distance covered being greater than the typical error indicates the rating/usefulness of the test as 'good'.



Note. HINT – high-intensity; s - standard deviation of the test-retest difference scores

Figure 3. Bland-Altman Plot for the NIE Int- HINT Test-Retest Scores

Validity

Significant correlations ($p<0.05$) were observed between the performance in the NIE Int-HINT test performance and the YoYo IRT L2 test performance during the pre-season, early in-season and the end mid-season (Figures 4-6). The individual data points, the regression line and the 95% confidence limits for the regression lines are also shown in the figures.

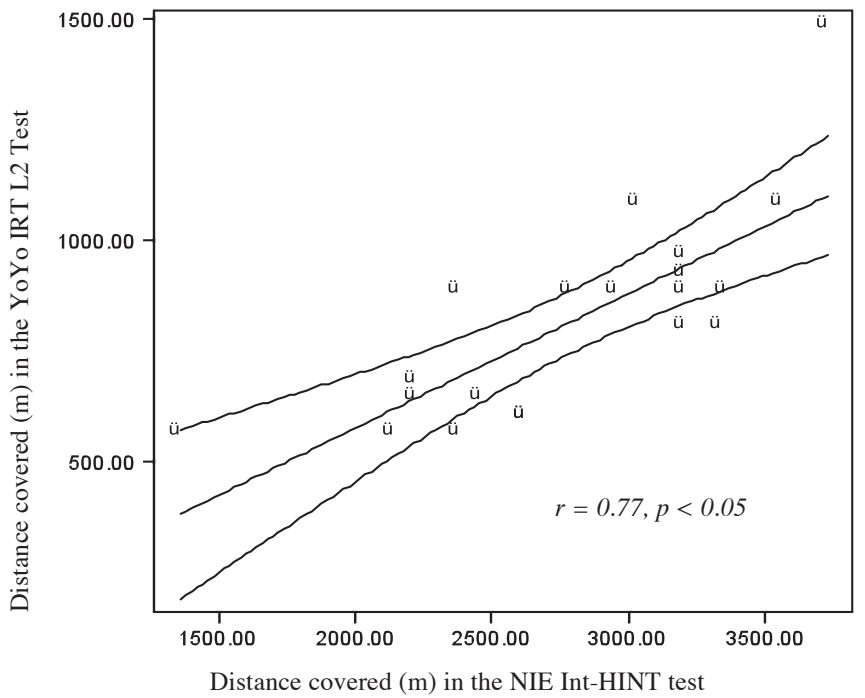


Figure 4. Pre-Season Correlation

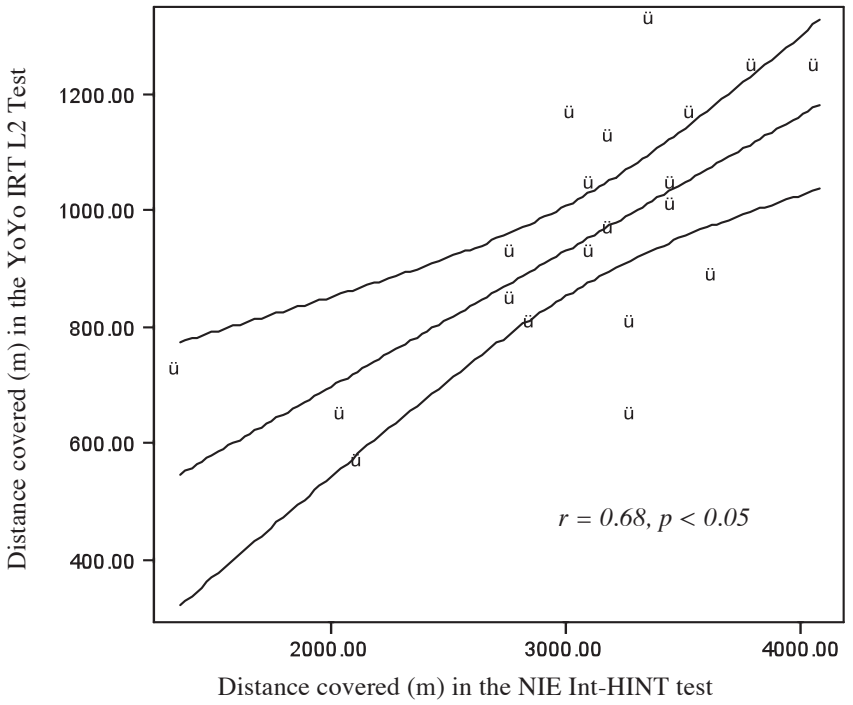


Figure 5. Early In-Season Correlation

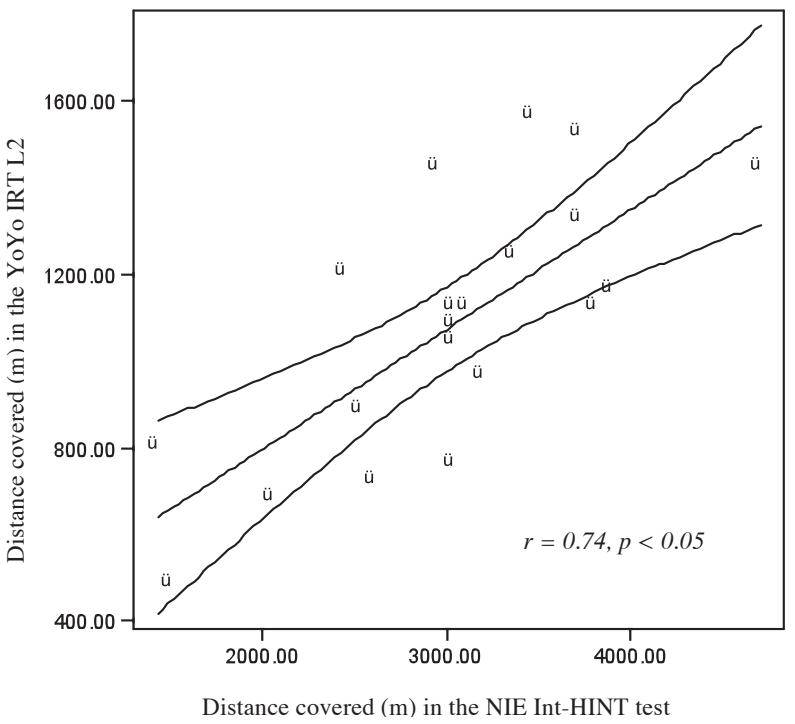
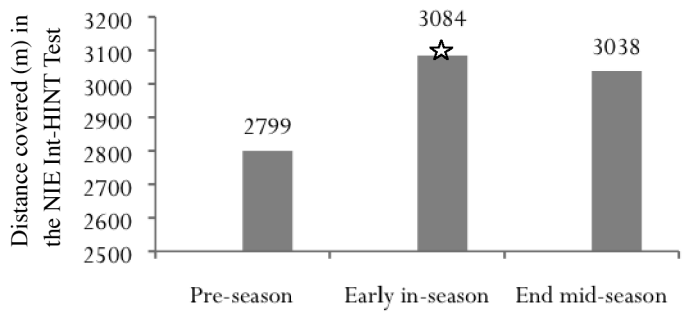


Figure 6. End Mid-Season Correlation

The structure of the present study entailed a doubly multivariate approach to repeated-measures ANOVA to determine if the measures of repeated high-intensity running capability in soccer players changed through the season. The results of the omnibus F test indicated a significant time effect, Wilk's $\lambda = 0.17$, $F_{(8, 12)} = 7.51$, $p < 0.05$, $\eta^2 = 0.83$.

The follow-up step-down univariate analysis showed that both the dependent variables, namely the distance covered in the NIE Int-HINT test ($F_{(1.5, 28.8)} = 6.32$, $p < 0.05$) and distance covered in the YoYo IRT L2 ($F_{(1.9, 36.3)}$, $p < 0.05$) contributed to the significant results in the omnibus multivariate test. This was possibly because both measures characterised the same performance quality; i.e., the capability to perform repeated high-intensity running.

Post hoc pairwise comparison using Bonferroni correction was performed for each dependent variable. For the measure of the distance covered in the NIE Int-HINT test, results of the pairwise comparison revealed that the change in the performance score was significant ($p < 0.05$) between phase-1 and phase-2, but was non-significant between phase-2 and phase-3 and between phase-1 and phase-3 (Figure 7). Post hoc pairwise comparison for the distance covered in the YoYo IRT L2 revealed a significant difference ($p < 0.05$) between phase-1 and phase-2, but the difference between phase-2 and phase-3 was non-significant ($p > 0.05$).



Note: ☆ indicates significant difference from the previous phase

Figure 7. The NIE Int-HINT Test Performance Through the Soccer Season

DISCUSSION

This study developed a laboratory-based test protocol to specifically assess the intermittent high-intensity running capability in soccer players. This was based on the rationale that as soccer involves activities of frequently changing intensities in an unpredictable pattern [1, 2, 16, 24], it would be highly improbable to incorporate every possible work-intensity and activity pattern in a test protocol. Therefore, specifically assessing the more consistent and valid performance measure of repeated high-intensity running ability would be a more practical approach. The major finding of this study was that the NIE Int-HINT test was a reliable and valid measure of intermittent high-intensity running capability in soccer players. In addition, this test protocol was sensitive to the changes in the intermittent high-intensity running capability through different phases of the soccer season.

The reliability of sports and performance-specific systems and protocols must be assessed prior to using them as measurement tools in sports and exercise science [25]. Reliability refers to the reproducibility of the values of a test, assay or any other measurement in

repeated trials on the same individuals [20]. Several tests with different modes have been devised in the past for measurement of different physiological capacities and various statistical techniques have been applied to assess the reliability of these tests. However, owing to the recommendation that certain reliability measures although applicable, should not be employed as a sole statistic [26], this study used multiple measures of reliability. The NIE Int-HINT test proved to be of high reliability on the all the measures used in the study.

While interpreting a change in performance in a fitness test, there are three fundamental issues. Firstly, to determine how good is the test of choice in identifying changes in highly-trained players. Secondly, whether the observed change is 'real' or merely an error or noise in the test and thirdly, is the magnitude of the observed change in fitness greater than a pre-determined threshold for a 'worthwhile' change or improvement in test performance. The two key criteria in establishing the usefulness of a test are the TE (noise or error in the test) and the smallest worthwhile change in the performance terms. Estimation of the smallest worthwhile change helps to determine if a real change has occurred between tests [18, 19]. This is important to establish the usefulness of a test. In team sports the relationship between the performance in the fitness tests and the team performance is not clear cut. Therefore it has been suggested that the smallest worthwhile change for elite athletes can be calculated as 0.2 × between-subject standard deviation of that test, based on the Cohen's principle of 'effect size' [19]. If the TE is less than the smallest worthwhile change, the test is rated as 'good'. If the TE is approximately the same as the smallest worthwhile change, the test is rated as 'OK' and if the TE is considerably greater than the smallest worthwhile change, the test rating is 'marginal' [19]. The TE for the distance covered in the NIE Int-HINT test was less (49.77m; 1.86%) than the smallest worthwhile change for the distance covered (92.4 m; 3.46%) indicating the rating/usefulness of the test was 'good'. However, it is important to remember that these ratings primarily reflect the reliability of the tests and not directly to the importance of the tests to game performance [19].

The question of whether the observed change in fitness between two tests is 'real' or is an error can be answered by the simple approach of comparing the magnitude of the observed changed score value with the typical error. This method identifies if the real change in the test scores is greater than the biological or technological error. An observed positive change being greater than the TE signifies 'real improvement' and in case of an observed negative change, a 'real decline'. If the observed change, whether positive or negative, is less than the TE, the test is rated as 'stable' [19]. The mean distance covered by the youth soccer players during the different phases of the soccer season were 2799, 3084 and 3038 m, respectively. This suggests that there was a worthwhile and real improvement (285 m) in the repeated high-intensity running capability of the participants from pre-season to the early in-season phase while the performance from early in-season to end mid-season (46 m) was 'stable'.

The ability to perform repeated high-intensity running is fuelled by both aerobic and anaerobic energy sources. This makes it imperative to examine the indicators of both the energy systems to gain information on repeated high-intensity running capability. The YoYo IRT L2 has been established to valid measure of soccer performance in terms of the capability to perform high-intensity intermittent exercise with a large anaerobic component with a significant degree of aerobic contribution [16]. The performance in NIE Int-HINT test showed consistently significant correlations ($p < 0.05$) with the performance in the YoYo IRT L2 through the entire soccer season. Moreover, the results of the doubly multivariate RM ANOVA showed that both the NIE Int-HINT test and the YoYo IRT L2 showed a significant time effect. These findings strongly supported the criterion validity and sensitivity of the NIE Int-HINT test with respect to the assessment of repeated high-intensity running capability in

youth elite soccer players. Additionally, this being a laboratory-based test protocol provides the option of conducting different physiological measurements like oxygen uptake, heart rate monitoring and blood lactate estimation in a controlled testing environment.

CONCLUSION

The present study developed the NIE Int-HINT test for the assessment of intermittent high-intensity running capability in youth professional soccer players. The results showed that the NIE Int-HINT test was a reliable and valid measure of intermittent high-intensity performance in soccer players. In addition, this test was also sensitive to the changes in the repeated high-intensity performance capability through the soccer season. Furthermore, the developed test being a laboratory-based protocol provides the option of additional physiological and metabolic measurements during the test performance. Such information can provide further insights into the physiological mechanisms underlying repeated high-intensity performance capability in soccer players.

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