Original Research

Relationship between endurance field-tests and match performance in young soccer players

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Running Title: Field Endurance tests in male youth soccer

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ABSTRACT

The purpose of this study was to examine the relationship between popular endurance field tests and physical match performance in elite male youth soccer players. Eighteen male young soccer players (age 14.4±0.1 years, height 1.67±4.8 cm, body mass 53.6±1.8 kg) were randomly chosen among a population of elite-level soccer players. Players were observed during international championship games of the corresponding age categories and randomly submitted to the level 1 of the Yo-Yo intermittent recovery test (Yo-Yo IR1), the Multistage Fitness Test (MSFT) and the Hoff test on separate occasions. Physical and physiological match demands were assessed using Global Positioning System technology and short-range telemetry (GPS Elite, Canberra, Australia) respectively. Players covered 6087±582 m (5098-7019m) of which 15% (930±362 m; 442-1513) were performed at HIA. During the first and second half players attained 86.8±6.5 and 85.8±5.8% of HR_{max} ($p=0.17$) with peak HR's of 100±2 and 99.4±3.2% of $HR_{max,}$ respectively. Players' Yo-Yo IR1 and MSFT performance were significantly related (r from 0.62 to 0.76) to a number of match physical activities. However the Hoff test was only significantly related with sprint distance ($r=0.70$, $p=0.04$). The Yo-Yo IR1 showed very large association with MSFT performance ($r=0.89$, $p<0.0001$). This study's results showed that Yo-Yo IR1 and MSFT test may be regarded as valuable tests to assess match fitness and subsequently guide training prescription in youth soccer players. The very large relationship between Yo-Yo IR1 and MSFT suggests their use according to

the period of the season and the aerobic-fitness level of the players. Due to the association of the Yo-Yo IR1 and MSFT with match physical performances these tests should be considered in talent selection and development.

Key Words: association football, fitness assessment, match analysis, team sports, intermittent exercise

Running title: Endurance field-testing in youth soccer

INTRODUCTION

In youth soccer aerobic fitness has been reported to be a relevant component of the physiological make-up of the elite-level young soccer player (38-40). Indeed, scientific evidence has shown that aerobic fitness parallel the competitive development of youth soccer players (41, 43, 44).

Although laboratory aerobic fitness (32) detection is the optimal choice for the determination of reliable results, the involved procedures are time consuming and require highly trained personal (19). Furthermore, laboratory testing requires exercise-mode such us linear running that are not soccer specific (2, 5, 28, 41). Consequently the laboratory assessment of aerobic fitness may results of doubtful relevance to specific soccer-training and competition. Furthermore the protocol used may limit players' motivation to testing (2, 5, 21, 27, 41).

Field-tests are considered as a sustainable alternative of laboratory tests (26, 34, 41). Recently a number of field tests have been proposed to assess aerobic fitness in male youth soccer players (8, 9, 13, 26, 41). These tests possess different degree of logical validity as per exercise mode (i.e. continuous vs intermittent shuttle running) and for sport-specific skills (i.e. ball dribbling or passing) considered (2, 41). However despite their association with criterion physiological variables of aerobic-fitness only limited evidence was provided for their relationship with game activities (i.e. direct validity) (4). Indeed to the best of our knowledge only the Yo-Yo intermittent recovery test level 1 (Yo-Yo IR1) has been assessed for direct validity with regards to male youth soccer players (13). Information in this regard would be of interest as direct validity is considered as a necessary pre-requisite of a sport-specific field test (4, 11, 13). Furthermore knowledge about test redundancy may help

strength and conditioning coaches in endurance assessment when dealing with male youth soccer.

As a consequence of the developed reasoning the possibility to implement a soccer exercise-mode specific field-test for the determination of aerobic-fitness would be of interest for coaches and soccer strength and conditioning professionals. Therefore the aim of the present study was to examine the relationship between popular endurance based field-test performance and match physical activities in young male elite level soccer players. A second aim of the study was to evaluate the practical application of each test.

METHODS

Experimental Approach to the Problem

In this study the association between match physical performance and endurance performance of young elite-level soccer players was examined using a descriptive correlation design (12). Players' physical load, as time and distance spent in selected match activity categories, was assessed using Global Position System technology (GPS, SPElite, GPsports, Australia). Physiological stress was assessed monitoring heart rate (HR) during matches (18, 20). The endurance performance was tested using three popular field-tests: the Yo-Yo Intermittent Recovery level 1 test (Yo-Yo IR1) (2, 29), the Multistage Fitness test (MSFT) (36), and the Hoff et al. (14, 22) test (Hoff). The MSFT and Yo-Yo IR1 share the same directional running mode (i.e. shuttle running over 20m) showing difference in speed progression and exercise form (i.e. continuous vs intermittent running). Indeed the Yo-Yo IR1 protocol involves 10 s recovery every 40m and a higher starting speed (10 vs 8 $km \cdot h^{-1}$) compared to the MSFT. However after the first two stages (i.e. 12 $km \cdot h^{-1}$) the Yo-Yo IR1 considers speed increments of 0.5 $km \cdot h^{-1}$ until exhaustion like in the MSFT (2, 29).

The Hoff test was recently proposed as a valid alternative to shuttle-running tests for endurance assessment in soccer (14, 22). This test requires players to cover as much distance as possible during 10 min dribbling a ball over a purpose-built circuit (14) (Fig. 1). Recent studies have shown the Hoff test possess criterion validity and sensitivity to aerobic fitness development in youth soccer players (14). Despite this no study has evaluated the reliability and direct validity of the Hoff test and therefore the relevance of the Hoff test to soccer is mainly associated to its supposed logical validity (i.e. ball dribbling) (14). To the best of this study's authors no published study is currently available as per direct validity of the MSFT.

As the field tests considered in this study are deemed to test the same physiological variable (i.e. aerobic performance) test redundancy was assessed with multiple comparison correlation analysis (45).

Subjects

Eighteen soccer players (age 14.4±0.1 years, height 1.67±4.8 cm, body mass 53.6±1.8 kg) all members of an elite-level National Youth Soccer Academy (Federazione Sammarinese Giuoco Calcio, San Marino, N=200) were randomly selected using as stratification criteria age and playing role. The selected players (6 forwards, 6 midfield and 6 defenders) possessed at least 4 years of experience in soccer training and competition and took part in National and International championships at the time of the investigation. Players trained three times a week (~90 min per session) with a competitive match taking place at the end of the week. Training sessions consisted mainly in technical and tactical skill development (75% of the training time). Physical conditioning was performed twice a week and aimed towards anaerobic and aerobic performance development (1). Anaerobic training consisted of plyometrics and sprint training drills (1) and aerobic fitness was developed using small-sided games (35) and short or long interval running (27).

Testing procedures were performed during the last stage of the competitive season (April-May 2007). This study was conducted in accordance with the Human & Animal Experimentation Policy Statements of the American College of Sports Medicine. Written informed consent was received from all players and parents after verbal and written explanation of the experimental design and potential risks of the study. Information was presented at the time of consent in a way that was easily understood by the subjects and provided in a language in which the subjects were fluent. As a result a fair explanation of the procedures to be followed and their purposes, identification of any procedures that were experimental, and description of any and all risks attendant to the procedures was provided to each players and parent/guardian that voluntarily accepted to participate after randomised selection and prior familiarization with the testing procedures. Informed consent was obtained from each of the participants and their parents or legal guardians only after familiarization with the procedures used in this study (i.e. sub-maximal practise of the field tests and use of GPS during a trial game). In order to improve internal validity players were blinded about the work hypothesis informing the aims of this observational study. All players agreed to provide their maximum will effort in order to perform at their best during all the field tests and competitions considered in this study. Before familiarization each player and parent or legal guardian was written and verbally made aware that they were free to withdraw from the study without any penalty for an upcoming reason/s. The local Institutional Review Board approved the study.

Procedures

In this study players' activity profile was assessed using GPS technology. During competitive matches players wore a GPS device, inserted in a purpose built back-pack, that enabled speed and distance recording (1Hz). Players' accelerations were also recorded using a built-in accelerometer which operational sampling rate was of 100 Hz, in order to improve quality of

speed detection (GPS, SPElite, GPsports, Australia). Validity of the GPS system used have been reported elsewhere (3, 16, 17, 31, 33). In a recently published comparative research (37) the GPS system used in this study showed to provide distances (in match categories similar to this study) that resulted near perfectly associated (r from 0.90 to 0.94) with those detected with a semi-automatic image-recognition system (25Hz) that has been validated and it is widely used for match analysis in professional European soccer (6). Before commencing this observational research a measurement quality control was performed with this study GPS system with 10 players. No significant bias ($p>0.05$) was found between the actual vs GPS detected distances (discrete bouts of 10 to 50m) at the speed (photocells timing as criterion) considered for the match categories of this study. The magnitude of the difference was in the range of ±1-3% thus similar to that reported as acceptable for the most used match analysis system currently available (6).

Match activities were determined according to Castagna et al. (7) as follows:

1. Standing (ST; 0 to 0.4 $km \cdot h^{-1}$);
2. Walking (W; 0.4 to 3.0 $km \cdot h^{-1}$);
3. Jogging (J; 3.0 to 8.0 $km \cdot h^{-1}$));
4. Medium Intensity Running (MIR; 8.0 to 13.0 $km \cdot h^{-1}$);
5. High-intensity Running (HIR; 13.0 to 18.0 $km \cdot h^{-1}$);
6. Sprinting (SPR; >18.0 $km \cdot h^{-1}$);
7. High-Intensity Activity (HIA; HIR+SP).

Competitive matches (11 vs 11, n=4) were played at the same time of the day (15.30 pm) on a regular sized synthetic-grass soccer pitch over two halves each lasting 30 min (10 min interval). Match air temperature and relative humidity were 22.8±1.8 C° and 40±9.8% respectively. In order to avoid dehydration *"ad libitum"* drinking was allowed to players. A minimum of 5 and a maximum of 8 players were observed during the same competitive match. Each player was observed for a minimum of two and a maximum of four competitive

matches (within 15-20 days) and physical match performance categories were reported as mean of the observed games.

Heart-rates were monitored using short-range telemetry every 1 s during the matches (GPS Elite, GPSports, Australia) and every 5 s during the Yo-Yo IR1 (Polar Team-System, Kempele, Finland). Data analyses were performed with dedicated software packages (Team AMS software GPSports and Polar Team-System respectively).

The Yo-Yo IR1 and MSFT were performed according to the procedures suggested by Krustup et al. (29) and Castagna et al. (10). The Hoff test was performed following the procedures suggested by Chamari et al. (14). All test were performed in a random order and on separate occasions (i.e. at least 72 apart) within 10-15 days before or after the competitive matches on a grass football pitch. Peak HR attained during the Yo-Yo IR1 was considered as the players' maximal heart rate (HR_{max}) as per Krustrup et al. (29). Reliability of Yo-Yo IR1 was established in 18 players tested one week apart resulting in a coefficient of variation (CV) of 3.8% with a Intra-class coefficient of correlation (ICC) of 0.92. The CV and ICC for the MSFT (3.6% and 0.92) and Hoff (18.2% and 0.68) test were assessed in 16 players 1 week apart. Field-test procedures were carried out with air temperature and relative humidity of 21.5±1.2 C° and 45±4.3% respectively.

Statistical analyses

Results are presented as mean±standard deviation (range). Data sets were checked for normality using the Shapiro-Wilk normality test and visual inspection. Differences between two variables were analysed using paired t-tests. The effect size (ES) of the difference between variables was assessed using Cohen's *"d"* (15). Value of *d* lower than 0.1, from 0.1 to 0.20, from 0.20 to 0.50, from 0.50 to 0.80 and higher than 0.80 were considered as trivial, small, moderate, large and very large, respectively. Relationships between variables were

assessed using Pearson's product moment correlation. According to Hopkins (24) magnitude for correlation coefficients were considered as trivial ($r < 0.1$), small ($0.1 < r < 0.3$) moderate ($0.3 < r < 0.5$), large ($0.5 < r < 0.7$), very large ($0.7 < r < 0.9$) and nearly perfect ($r > 0.9$) and perfect ($r = 1$). Confidence intervals at 95% (95%CI) were provided for the correlation between variables. Significance was set at 0.05. A pilot study performed before this investigation, showed that to obtain a power of 0.80 twelve players were necessary.

-------Figure 1 about here-------

RESULTS

During the match players covered 6087±582 m (5098-7019m) of which 15% (930±362 m, 442-1513) were performed at HIA. During the second half players covered significantly less total distance (-3.8%, p=0.04) and distance at MIR (11%, p=0.04). No difference between halves was observed for HIA (p=0.96) and SPR (p=0.18). Details of match activities are presented in table 1. During the first and second half players attained the 86.8±6.5 and 85.8±5.8% of HR_{max} (p=0.17) respectively. Peak HR during the first and second half was 100±2 and 99.4±3.2% of HR_{max}, respectively.

Total distance covered during the Yo-Yo IR1, MSFT and Hoff test was 760±283m (400-1320m), 1653±367m (1040-2120m) and 1059±191m (666-1280m) respectively. Association between field tests and match activities are reported in table 2. The TD was associated (large) with MSFT only. However the Yo-Yo IR1 and MSFT performances were significantly related (large to very large) to HIA (figure 2), HIR and SPR. The Hoff test performance was only related (large) to SPR. The Yo-Yo IR1 performance was significantly correlated (very large) with MSFT performance ($r=0.89$, $p<0.0001$, 95%CI 0.78-0.93). No significant relationship was found between Hoff test with either Yo-Yo IR1 or MSFT performances.

----------Table 1 about here ----------

----------Figure 2 about here ----------

DISCUSSION

This is the first study to test three popular field-tests (Yo-Yo IR1, MSFT and Hoff test) for direct validity in male youth soccer players within the same research design.

In this study Yo-Yo IR1 and MSFT showed large to very-large association (see table 2) with several physical match activities that have been demonstrated to be soccer-specific dependent variable (24, 25). Thus supporting the direct validity of the Yo-Yo IR1 and MSFT for male youth soccer. However, the Hoff test demonstrated a large association with only the distance covered whilst sprinting ($r=0.70$, $p=0.04$, 95%CI 0.63-0.77).

This study's results are in-line with previous studies that examined the direct validity of the Yo-Yo IR1 in male and female soccer players (2). Also the very large correlation ($r=0.73$, $p=0.003$ 95%CI 0.68-0.83) found between HIA and Yo-Yo IR1 performance is similar to that reported by Castagna et al. (13) for male young soccer players ($r=0.77$, $p<0.001$) and by Krustrup et al. (29, 30) for adult male ($r=0.71$, $p<0.05$) and female ($r=0.76$, $p<0.05$) soccer players. However in contrast to previous studies no significant relationship was observed between TD and Yo-Yo IR1 ($r=0.42$, $p=0.14$ CI95% 0.31-0.53) (13, 29, 30).

This study addressed for the first time the direct validity of MSFT and Hoff in male young soccer players. The MSFT was significantly related to distances covered in several speed zones/match activity categories showing a magnitude of effects ranging from large to very-large (24) (see table 2). In contrast to the Yo-Yo IR1, MSFT performance showed to be largely related to TD ($r=0.62$, $p=0.02$, 95%CI 0.52-0.72). However no significant difference ($p>0.05$) was found between correlation coefficients of Yo-Yo IR1 and MSFT for the total distance covered. This findings may be considered as a consequence of the almost nearly

perfect correlation (r=0.89, p< 0.0001, 95%CI 0.78-0.93) found between MSFT and Yo-Yo IR1 performance in this study.

In light of this study finding the MSFT and Yo-Yo IR1 may be considered as similar tests (i.e. 79% common variance) for young elite male soccer players of the age here considered (14-15 years). Consequently the MSFT and Yo-Yo IR1 may be used interchangeably to track the soccer-specific fitness of male young players in field conditions.

Despite having potential for a higher logical validity as it involves ball dribbling throughout the test, the Hoff test showed only a limited association with match activities when compared to MSFT and Yo-Yo IR1. Indeed the Hoff test was only related to the distance covered during the match with sprinting (r=0.70, p=0.04, 95%CI 0.68-0.72), with the magnitude of the correlation coefficient being consistent with those reported for the same match activity in the MSFT and Yo-Yo IR1 comparisons. The reason for that limited relevance for soccer showed by the Hoff is difficult to be explained with this research design. However the low relative (ICC=0.68) and absolute (CV= 18.2) reliability reported in this study may suggest a limited application of the Hoff test for male young soccer players aerobic-fitness performance assessment.

The main problem with correlation studies is that the value of the correlation is sensitive to the population addressed if not well designed (23). However the generalisation of this study findings may be warranted by the stratified random sampling undertaken for determining the players group. Furthermore the data reported here for Yo-Yo IR1 and MSFT are in line with those found by Castagna et al. (13) and Williford et al. (46) in soccer players of similar competitive level and age respectively. Additionally the average match distance covered by players was similar to that previously reported in studies addressing male youth soccer players of similar characteristics (i.e. age, experience and competitive level) (7, 13). Furthermore similarity with previously published studies on male youth soccer were found for cardiovascular stress (i.e. mean HR) (41). Conservation of HIA between halves was found

despite a significant decrement of TD and MIR across halves, a finding in-line with previously published papers (7, 13), thus further supporting the suggested competitive "sparing behaviour" reported originally by Castagna et al. (7). As a consequence of these similarities, in terms of physical match performance and field-test performance, the population of male youth soccer players employed in this study may be considered as representative of age, training and competitive level matched soccer players. Consequently the external validity of this study finding is warranted (11).

This study findings clearly demonstrate that aerobic performance, as determined by commonly used field-tests is related to physical match performance in young male soccer players. This provide further evidence to the relevance of aerobic fitness *per se* in male youth soccer (38, 39). Consequently aerobic fitness should be collated in the training strategies attempting to develop the physical preparedness of young soccer players (13, 27, 41).

The resulting associations between field-test performance and match physical performance demonstrate that the Yo-Yo IR1 and MSFT may be regarded as relevant test to evaluate endurance in young soccer. However the magnitude of the effect although ranging between large to very large according to the definition provided by Hopkins (24) the corresponding effect size of the relationship, assumed as coefficient of determination (r^2), was above the critical value of 0.50 only in 4 out of the 8 significant pre-planned correlations (42). Furthermore the highest value did not reached the 60% of shared variance. Although the specificity of this test should be admitted with caution (i.e. r^2 from 0.38 to 0.58) the direct validity was warranted by this study findings (42). It could be speculated that new soccer specific tests are to be estabilished in order to more closely describe match physical demands. In this regard field tests should more closely mimic match activity pattern and thus based on sound match and time motion analysis procedures (6). Due to the interest and relevance of this issue future studies are warranted.

PRACTICAL APPLICATIONS

The results of this study showed that Yo-Yo IR1 and MSFT being strongly associated (i.e. $r=0.89$, $p<0.0001$) and similarly related to match physical performance (see table 2) may be considered as interchangeable. This peculiarity may suggest the use of these "beep tests" (i.e. audio cue guided tests) in accordance of the preparation moment of the season. Coaches and strength conditioning professional may use the MSFT in the first stages of their fitness training program as its protocol involves lower starting speeds (10). On the other hand the Yo-Yo IR1 may be implemented when players are more aerobically fit as it considers starting speeds, although repeated for a limited number of bouts and with frequent recovery time (i.e. 10s every 40m), that correspond very often to the maximal speed attained at exhaustion during the MSFT. An added value of the Yo-Yo IR1 lies in the limited amount of time that usually requires (i.e. 6.21 min) in this population of male young soccer players (13). This suggests the Yo-Yo IR1 to be a field test that is easy implement when a limited time can be devoted to testing (i.e. during the competitive season) (2, 29).

Interestingly the Hoff test, although involving an exercise mode relevant to soccer (i.e. ball-dribbling) possessed only a limited association with physical match performance (i.e. sprinting) and no significant relationship with the other field tests. However the emerged association with match sprinting distance was similar to those showed by Yo-Yo IR1 and MSFT ($p>0.05$). As a consequence of the required labour time necessary to set-up the Hoff test track, the limited number of players that may be reasonably tested with this course at a time and the poor reliability showed by this test in this study, the use of the Hoff is discouraged.

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LEGENDS of TABLES and FIGURES

Table 1. Match analysis data (n=18).

Table 2. Correlation matrix of the relationship between field tests and match activities (n=18). Only statistically significant relationships are reported ($p \leq 0.05$).

Figure 1. Testing course of the Hoff test (1 lap=290m).

Figure 2. Correlation plots of the relationships HIA vs MSFT (black dots) and HIA vs Yo-Yo IR1 (open dots), six data overlapped.

Table 1

Variable (m)	First Half	Second Half	Effect Size (*d*)	Total
Walking	240±48	245±54	0.12	486±93
Jogging	1531±117	1499±183	0.26	3029±274
MIR	862±224**	768±212	0.59	1630±405
HIR	346±139	367±134	0.23	713±258
Sprinting	120±81	97±60	0.40	217±129
HIA	466±201	464±181	0.02	930±362
TD	3102±299**	2986±312	0.62	6087±582

TD= Total Distance; HIA= High Intensity Activities; HIR= High Intensity Running; MIR= Medium Intentisity Running. *= $p \leq 0.05$; **=$p < 0.01$.

Table 2. Correlation matrix of the relationship between field tests and match activities. Only statistically significant relationships are reported ($p \leq 0.05$).

Match Activity	Yo-Yo IR1	MSFT	Hoff
TD		0.62* (0.52-0.72)	
HIA	0.73**(0.68-0.83)	0.75**(0.58-0.72)	
HIR	0.65**(0.58-0.72)	0.70**(0.68-0.72)	
Sprinting	0.76**(0.69-0.83)	0.72**(0.67-0.77)	0.70*(0.63-0.77)

TD= total distance; HIA= High Intensity Activities; HIR= High Intensity Running. * $p \leq 0.05$; **$p < 0.01$. (95%CI).

Figure 1.

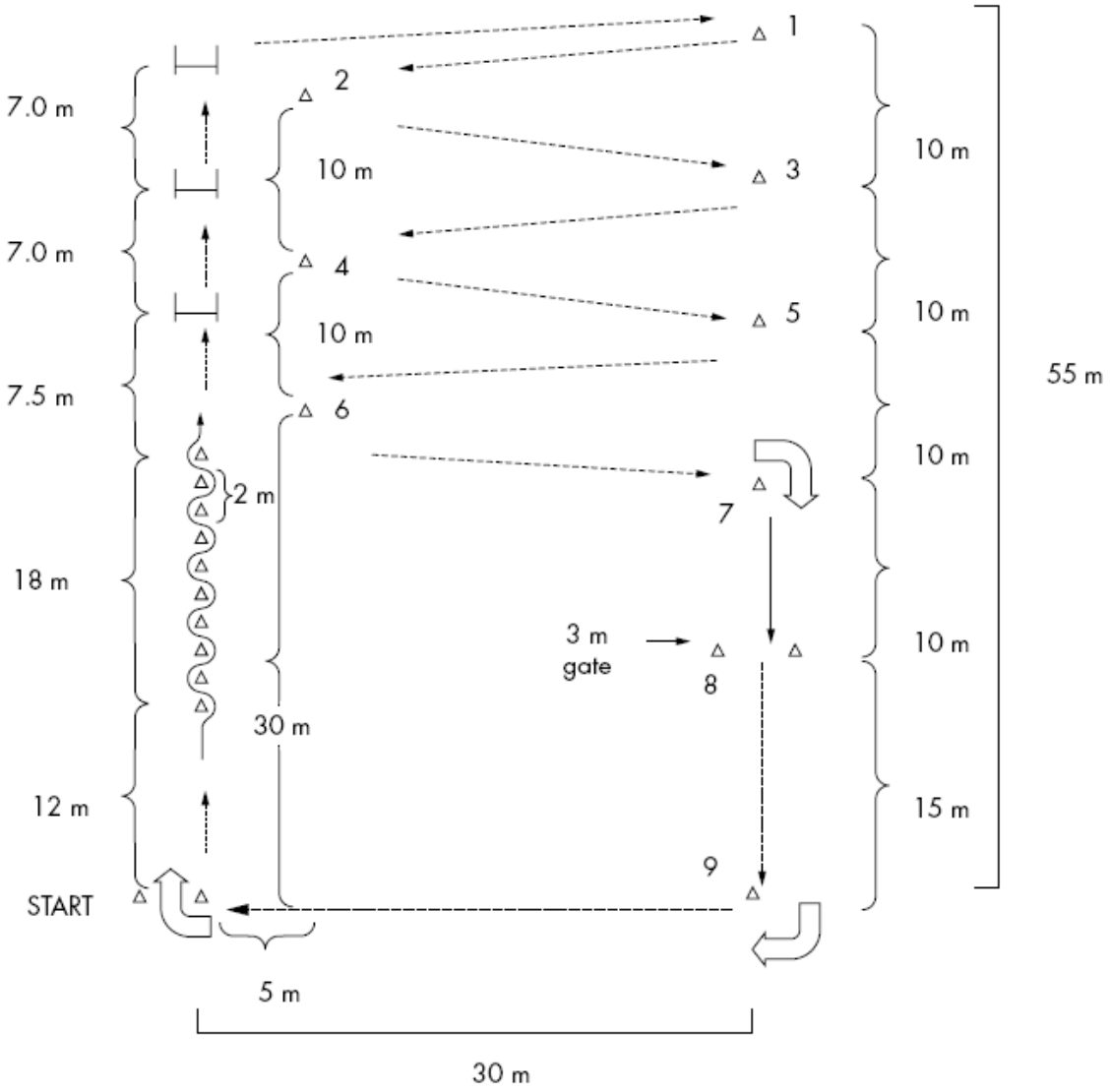
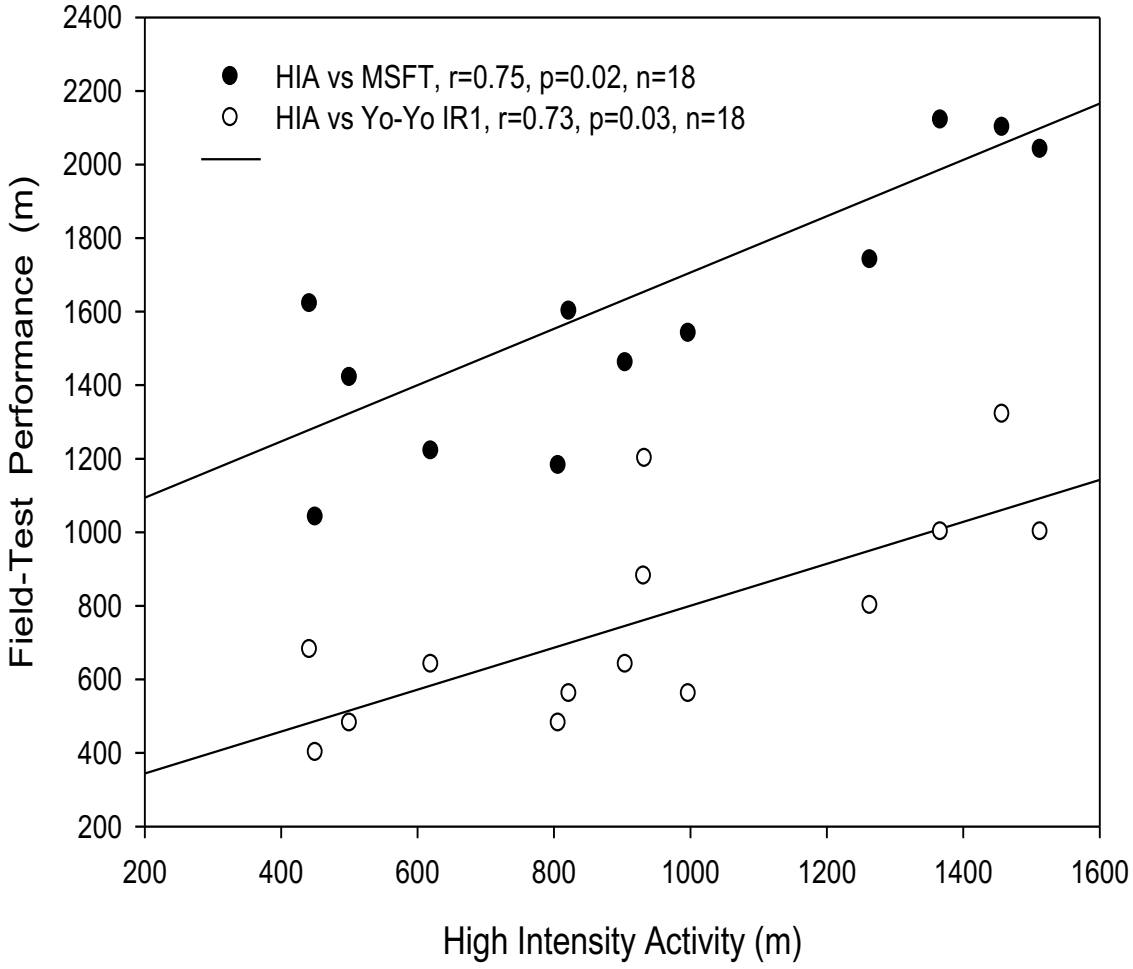

1
2
3
4
5
6
7
8
9
START
7.0 m
7.0 m
7.5 m
18 m
12 m
10 m
10 m
2 m
30 m
3 m
gate
10 m
10 m
10 m
10 m
15 m
55 m
5 m
30 m

Figure 2.


HIA vs MSFT, r=0.75, p=0.02, n=18
HIA vs Yo-Yo IR1, r=0.73, p=0.03, n=18
Field-Test Performance (m)
High Intensity Activity (m)
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
200
400
600
800
1000
1200
1400
1600