

MANUSCRIPT TITLE: THE RELIABILITY AND VALIDITY OF A SOCCER-SPECIFIC NON-MOTORISED TREADMILL SIMULATION (iSPT)

BRIEF RUNNING HEAD: NON-MOTORISED TREADMILL SOCCER SIMULATION

LABORATORY: BEDFORD CAMPUS, UNIVERSITY OF BEDFORDSHIRE, BEDFORD

AUTHORS: JEFFREY W.F. ALDOUS,¹ IBRAHIM AKUBAT,² BRYNA. C.R. CHRISMAS,¹ SAMUEL L. WATKINS,¹ ALEXIS R. MAUGER,³ ADRIAN W. MIDGLEY,⁴ GRANT ABT,⁵ AND LEE. TAYLOR,^{1*}

DEPARTMENTS AND INSTITUTIONS

¹*Muscle Cellular and Molecular Physiology (MCMP) & Applied Sport and Exercise Science (ASEP) Research Groups, Institute of Sport and Physical Activity Research (ISPAR), Department of Sport Science and Physical Activity, University of Bedfordshire, Bedford, UK*

²*Newman University, Department of Physical Education and Sports Studies, Birmingham, UK*

³*Endurance Research Group, School of Sport and Exercise Sciences, University of Kent, Chatham Maritime, Kent, UK*

⁴*Department of Sport and Physical Activity, Edge Hill University, Ormskirk, UK*

⁵*Department of Sport, Health and Exercise Science, The University of Hull, Hull, UK*

CORRESPONDING AUTHOR

Dr Lee Taylor

The University of Bedfordshire – Bedford Campus

Institute of Sport and Physical Activity Research (ISPAR Bedford)

Department of Sport Science and Physical Activity

Bedford

Bedfordshire

MK41 9EA

United Kingdom

Telephone: +44 (0)1234 793043

Email: lee.taylor@beds.ac.uk

FUNDING: No Funding was received for this research

(iSPT)

ABSTRACT:

The current study investigated the reliability and validity of a novel **non-motorised treadmill (NMT)** based soccer simulation utilising a novel activity category called a ‘variable run’ to quantify fatigue during high-speed running. Twelve male University soccer players completed three familiarisation sessions and one peak speed assessment before completing the Intermittent Soccer Performance Test (iSPT) twice. The two iSPT’s were separated by 6 – 10 days. The total distance, sprint distance and high-speed running distance were 8968 ± 430 m, 980 ± 75 m and 2122 ± 140 m, respectively. No significant difference ($p > 0.05$) was found between repeated trials of the iSPT for all physiological and performance variables. Reliability measures between iSPT₁ and iSPT₂ showed good agreement (CV: $< 4.6\%$; ICC: > 0.80). Furthermore, the variable run phase showed high-speed running distance significantly decreased ($p < 0.05$) in the last 15 min (89 ± 6 m) compared to the first 15 min (85 ± 7 m), quantifying decrements in high-speed exercise compared to previous literature. The current study validates the iSPT as a NMT based soccer simulation compared to previous match-play data, and is a reliable tool for assessing and monitoring physiological and performance variables in soccer players. The iSPT could be utilised in a number of ways including player rehabilitation, understanding the efficacy of nutritional interventions, and also the quantification of environmentally mediated decrements upon soccer-specific performance.

KEY WORDS: intermittent, soccer protocol, variable run

43 INTRODUCTION

44 Soccer is a high-intensity intermittent sport, normally played over 90 min, consisting of two
45 45 min halves, with a 15 min interval. Soccer match-play activity has been quantified using
46 recent technological developments, however, the quantification of distance-based variables
47 between matches can vary considerably, demonstrated by the large variability in high-speed
48 activity between matches in elite soccer (14). Due to the large variability in game demands,
49 meaningful inferences from interventions are difficult to ascertain as match performance
50 measures show poor reliability (14).

51

52 One solution to this problem is through the development of laboratory or field based soccer
53 simulations, which replicate the demands of soccer. Control of the environment is imperative,
54 thus, laboratory treadmill based protocols are predominantly used (3, 13, 27). Field-based
55 protocols, such as the SAFT₉₀ do not utilise a treadmill, providing a multi-directional facet to
56 simulations (32). The SAFT₉₀ is a fixed distance protocol that is also useful for the
57 determination of physiological responses for a given physical output. However, fixed
58 distance and motorised treadmill-based protocols can also limit ecological validity (13, 32)
59 where, the inability to express maximal running capability is an obvious limitation (35). To
60 address some of these limitations, protocols utilising a non-motorised treadmill (NMT) have
61 been developed (3, 27, 31, 33).

62

63 Using a NMT to simulate soccer allows for decrements in performance and maximal exercise
64 performance to be quantified (27), provided a correctly formulated protocol is utilised.
65 Previous studies have found the NMT to be a valid tool for use in soccer simulations (27, 33).

However, these studies lacked reliability measures and individualised speed thresholds. Individualising speed thresholds by using each participant's peak sprint speed (PSS) facilitates specificity of the protocol to each athlete, thus, enabling the measurement of a true expression of their performance capacity, as used previously in NMT protocols (3, 31). These protocols replicated soccer match-play data with respect to average overall distance covered and the decrement in PSS (22).

High-speed running distance (HSD) is a key determinant of successful soccer-specific performance (14). Consequently, any appropriately designed simulation protocol should allow reliable quantification of this measure. However, the nature of simulations usually means that speeds are set for all activity categories and, therefore, players are not free to vary their running speed even if they are capable of running at a faster-speed. It has previously been reported that the distance covered at both high-speed ($>15 \text{ km}\cdot\text{h}^{-1}$) and sprinting appear to be meaningful measures of physical performance in soccer (22). Therefore, including measures of both sprinting, and the ability to run at 'high-speed' within a soccer simulation would be beneficial.

The current NMT Intermittent Soccer Performance Test (iSPT) contains a novel speed category referred to as a 'variable run', designed to quantify the distance covered at a self-selected speed above the second ventilatory threshold, which has previously been used to delimit a 'high-intensity' threshold (2, 20). The variable run element has been previously utilised in a NMT based soccer-specific protocol (30). However, the protocol duration was only 45 min, and large reductions in HSD have been reported to occur during the second half

(22). Potentially, increasing the simulation's duration (90 min) will allow for a more appropriate analysis of the efficacy of the variable run.

The aims of the present study were to examine the reliability and validity of a novel NMT soccer simulation (iSPT) based upon individualised speed thresholds, whilst utilising the variable run category.

METHODS

Experimental Approach to the Problem

This study used a test-retest design to determine the reliability and validity of a 90 min soccer-specific NMT simulation (iSPT), which was developed using several time-motion analysis studies of soccer match-play (1). Quantification of HSD is a key determinant of successful soccer performance and an appropriately designed protocol should be utilised to assess this measure. Soccer-specific simulations often use set activity categories meaning players are not able to vary their running speed, even if they are capable of running at a faster-speed. As distances covered at both sprinting and high speed ($>15 \text{ km}\cdot\text{h}^{-1}$) are meaningful inferences in soccer (22), it would be beneficial to include measures of both sprinting and the ability to run at 'high-speed' within a soccer simulation. Therefore, the second purpose of the study was to quantify decrements in HSD by utilising a novel self-selected speed category known as a 'variable run' within iSPT. The 'variable run' has been previously utilised in a NMT based soccer-specific protocol (30), however, the protocols duration (45 min) was not long enough to induce fatigue as soccer match-play studies have

shown large decrements in HSD occur in the second half (22). Subjects were required to attend six testing sessions to perform one maximum oxygen uptake ($\dot{V}O_{2\max}$) test, three familiarisation sessions and two full trials of iSPT separated by a minimum of 7 days.

Subjects

Twelve University level soccer players volunteered for the study (mean $\pm$ SD: age, 21 ± 2 y, body mass, 70.5 ± 9.4 kg, height, 182.0 ± 12.7 cm; $\dot{V}O_{2\max}$, 51 ± 9 ml·kg⁻¹·min⁻¹). Each participant trained at least two times per week and played at least one full 90-min match per week. Subjects standardised their food and water consumption (29), refraining from performing unaccustomed and/or additional exercise, alcohol and caffeine ingestion (21) for 72 h prior to the experimental procedures. All testing sessions were completed at the same time of day within a 3 h period to eliminate circadian influence on exercise performance. The study was approved by the Ethics Committee of the University of Bedfordshire and conformed to the declaration of Helsinki. Written informed consent was provided by all subjects.

Procedures

$\dot{V}O_{2\max}$ Test: To determine $\dot{V}O_{2\max}$ subjects completed a ramp exercise protocol performed on a motorised treadmill (Woodway, PPS51 Med-i, Cranlea). The test began at 6 km·h⁻¹, and increased by 0.1 km·h⁻¹ every 6 s until volitional exhaustion. Standardised verbal encouragement was provided throughout the test. Pulmonary gas exchange and minute ventilation were measured continuously during the test using an online gas analysis system

(Cortex, Metalyser 3B, Cranlea). $\dot{V}O_{2\max}$ was considered in line with the end-point criteria guidelines of the British Association of Sport and Exercise Sciences (36).

General Experimental Controls: All familiarisation (FAM) and protocol sessions related to iSPT were completed on the same Non-Motorised Treadmill (Woodway, Force 3.0, Cranlea, Birmingham). Subjects were secured onto the NMT using a tether belt and harness that was attached around the waist. The harness was attached to the treadmill at an angle of 8° from horizontal, as this is considered optimum (19).

Experimental Design: Visit 1 (FAM₁): FAM₁ included two short intermittent protocols lasting 9 and 13 min respectively, followed by the first 15 min of the iSPT protocol (Table 1). Between each bout of exercise subjects were rested until their heart rate returned to their previously measured resting heart rate. *Visit 2 (FAM₂, PSA):* Four days after the completion of FAM₁ a peak speed assessment (PSA) was conducted, involving a 4 min protocol completed on the NMT that consisted of four sprints lasting 6 s separated by three rest periods. For each participant, the PSS was defined as the fastest speed recorded during the PSA. Subjects then completed FAM₂, which consisted of the first 45 min of the iSPT protocol. *Visit 3 (FAM₃):* Subjects were rested for 6 – 10 days after completing FAM₂ before taking part in FAM₃, which involved the full 90 min protocol. *Visits 4 and 5 (iSPT₁ and iSPT₂):* Subjects then rested for 7 – 9 days and 6 – 10 days before taking part in iSPT₁ and iSPT₂ respectively.

#Table 1 about here#

Intermittent Soccer Performance Test (iSPT): The iSPT consisted of two 45 min halves separated by a 15 min interval. Each half consisted of three identical 15 min intermittent exercise blocks (Figure 1). During the 15 min interval subjects were seated and given 500 mL of water to drink. Whilst running the protocol, subjects interacted with a computer programme (Innervation, Pacer Performance System Software) by following a red line on the screen, which displayed their target speed and their current speed. Subjects were instructed to match their current speed with the target speed as closely as possible throughout the full protocol. Audio cues specific to each movement category (e.g. jog) were also presented. Before each change in speed, three audible tones were played, which were followed by an audible command to inform the subject of the upcoming activity (e.g. “beep”. “beep”. “beep”. “run”)

The activity pattern (e.g. mean duration of each movement category) of the iSPT was based upon previous time and motion studies of soccer (6, 37). The 15 min protocol block was developed to allow comparison of both the performance and physiological capacity between/within halves - an approach used by several previous protocols (1, 31). The iSPT consisted of seven different movement categories that were determined and classified as a percentage of PSS (Table 2). The relative speeds for most speed thresholds were modelled upon the work of Abt (1), however these were adjusted to compensate for the unorthodox movement and the inability to include modes of movement such as backwards and sideways running on the NMT (19). Four self-selected high-speed runs (variable run - 13th-14th min of

each 15 min block – see Figure 1) were included, where the participant was instructed to cover as much distance as possible without sprinting.

#Table 2 and Figure 1 about here#

Performance Variables and Physiological Responses Measured During iSPT: All performance variables were recorded from the NMT at a sampling rate of 100 Hz using the software provided by the manufacturer (Innervation, Pacer Performance System Software). The data were exported to a spreadsheet (Microsoft Excel 2010, Windows) for analysis. These data, in conjunction with physiological measures, were used to ascertain measures of external validity compared to match-play data (12, 14, 22, 23, 28) and to calculate measures of reliability. The PSS, total distance (TD), sprint distance (SD), HSD, fast run distance (FRD), variable run distance (VRD) and low speed distance (LSD) components were assessed. The HSD included the FRD, VRD and SD and the LSD included the distance covered during walking (WD), jogging (JD) and running (RD).

Heart rate (HR) was recorded beat-by-beat and averaged every 1 min using a telemetric heart rate monitor (Polar, FS1, Polar Electro, Oy). Fingertip blood samples were taken to assess blood lactate (BLa) (YSI, 2500 stat plus, YSI) during walking or standing phases of the iSPT at 12, 27 and 45 min of each half.

Statistical Analyses

Statistical analyses were conducted using IBM SPSS Statistics 19 (SPSS Inc., Chicago, IL). Statistical assumptions were checked using conventional graphic methods and were deemed plausible in all instances. Central tendency and dispersion are reported as the mean $\pm$ SD. All data were analysed using a two-way-repeated-measures ANOVA. FAM₃, iSPT₁ and iSPT₂ were compared to establish whether there was any test order effect. In the event of a statistically significant ANOVA, post-hoc pairwise-comparisons with Bonferroni-adjusted p values were performed. Reliability of all variables from consecutive pairs of trials was assessed using data from iSPT₁ and iSPT₂. The following reliability measures [change in the mean (CIM), coefficient of variation (CV), intraclass correlation coefficient (ICC) and the typical error of measurement (TE) along with ninety-five percent confidence intervals (95% CI)]. Cohen's effect sizes (ES) with qualitative interpretations (0–0.19, trivial; 0.2–0.59, small; 0.6–1.19, moderate; 1.2–1.99, large; ≥ 2.0 , very large)) are also reported (10, 16) along with ninety percent confidence intervals (90% CI) (10). The use of 90% confidence intervals was used for ES as this has been recommended by previous research (16, 17). Two-tailed significance was accepted as $p < 0.05$.

RESULTS

Overall

A repeated measures two-way ANOVA revealed that there was no significant difference ($p \geq 0.42$) for all performance and physiological variables between FAM₃, iSPT₁ and iSPT₂. Reliability statistics for all performance and physiological variables during iSPT₁ and iSPT₂, including the ICC (>0.80 ; >0.84) and CV values ($<4.5\%$; $<4.6\%$), are shown in Table 3.

#Table 3 about here#

Between Halves

All performance and physiological variables showed significant differences between halves in one or both of the iSPT₁ and iSPT₂ (Table 4). A significant decrease in TD between halves was evident in iSPT₁ (28 ± 25 m, $p = 0.002$) and iSPT₂ (142.3 ± 83.9 m, $p = 0.01$). A significant decrease in HSD between halves was observed in iSPT₁ (10.1 ± 13.2 m, $p = 0.02$) and iSPT₂ (28.5 ± 15.3 m, $p = 0.001$). Similarly, a significant decrease in SD between the first and the second half was evident in both iSPT₁ (9.3 ± 12.3 m, $p = 0.02$) and iSPT₂ (16.1 ± 12.2 m, $p = 0.01$). However, there was a significant decrease in PSS within iSPT₂ (0.7 ± 1.4 km·h⁻¹, $p = 0.02$), but not in iSPT₁ (0.2 ± 1.3 km·h⁻¹, $p = 0.55$).

A significant decrease in VRD between halves was evident (iSPT₁: 2.3 ± 4.6 m, $p = 0.04$; iSPT₂: 6.1 ± 8.8 m, $p = 0.04$). Additionally, a significant decrease in FRD was observed (iSPT₁: 2.1 ± 2.0 m, $p < 0.01$; iSPT₂: 6.0 ± 5.0 m, $p = 0.02$). A significant decrease in JD between halves was evident in both iSPT₁ (27.7 ± 42.7 m; $p = 0.04$) and iSPT₂ (34.9 ± 45.4 m; $p = 0.02$). A significant decrease in RD in the second half was evident in both trials (iSPT₁ 3.6 ± 9.9 m, $p < 0.01$; iSPT₂: 19.6 ± 24.0 m, $p = 0.02$). There was a significant decrease in WD within iSPT₂ (21.6 ± 31.7 m; $p = 0.04$), but not in iSPT₁ (13.3 ± 23.1 m; $p = 0.07$).

A significant decrease in BLa was also noted between halves (iSPT₁: 0.5 ± 1.0 mmol, $p = 0.02$; iSPT₂: 0.6 ± 1.0 mmol $p = 0.02$). HR showed no significant difference in iSPT₁ (0.6 ± 5 b·min⁻¹; $p = 0.89$), however was significantly decreased in iSPT₂ (4 ± 6 b·min⁻¹; $p = 0.02$) between halves.

#Table 4 near here#

Between 15 min Periods

#Figure 2 near here#

Figure 2 shows HSD, SD, PSS and VRD was significantly decreased in the 76-90 min period compared to the 0-15 min period in iSPT₁ (HSD: $p = 0.02$, CIM: 8.6 ± 7.1 m; 95% CI: 0.08-18.7 m, ES: 0.41(90% CI: 0.24 to 0.7); SD: $p = 0.02$, CIM: 8.6 ± 7.1 m, 95% CI: 1.0-16.2 m, ES: 0.62 (90% CI: 0.31 to 0.99); PSS: $p = 0.01$, 95% CIM: 0.8 ± 0.8 km·h⁻¹ CI: 0.22-1.9 km·h⁻¹, ES: 0.98 (90% CI: 0.63 to 1.36); VRD: $p < 0.01$, CIM: 2.2 ± 2.9 m; 95% CI: 0.73-5.72 m, ES: 0.32 (90% CI: 0.19 to 0.58)), and iSPT₂ (HSD: $p = 0.04$, CIM: 12.8 ± 9.9 m; 95% CI: 5.0-34.4 m, ES: 0.71 (90% CI: 0.36 to 0.97); SD: $p = 0.02$, CIM: 12.8 ± 10.0 m, 95% CI: 2.0-23.5 m, ES: 0.85 (90% CI: 0.41 to 1.23); PSS: $p = 0.02$, CIM: 1.5 ± 0.8 km·h⁻¹ 95% CI: 0.20-3.10 km·h⁻¹, ES: 1.08 (90% CI: 0.53 to 1.66); VRD: $p < 0.01$, CIM: 5.5 ± 3.6 m; 95% CI: 1.58-9.43 m, ES: 0.82 (90% CI: 0.47 to 1.18)).

DISCUSSION

The aim of this study was to assess the reliability and validity of a novel NMT soccer simulation (iSPT). The primary findings are that iSPT showed good reproducibility between trials and that the physiological and performance variables of iSPT are comparable to match-play data.

Reliability: The iSPT shows high test-retest reliability for performance and physiological responses. All the within-subject CV values were below 10%, regarded as an acceptable level of reliability (5). Additionally, all ICC values were between 0.80-0.97, which is considered reliable (0.80-0.90), or highly reliable (>0.90) (11). Therefore, the low test-retest error demonstrates iSPT is sensitive to detect a minimum worthwhile change not obscuring a true experimental effect.

Previously published data for TD (CV: 2.2% - (1); CV: 1.9% - (31)), when compared to iSPT (CV: 1.4%), shows comparable reliability to previous protocols. Furthermore, iSPT has been shown to be reliable with regards to other performance variables, such as SD, PSS and HSD, with previous treadmill based soccer simulations (27, 33) not reporting such strong measures of reliability for their protocols in line with statistical recommendations (15). Aside from soccer specific simulations, some reliability measures have been reported for generic team sport simulations (TSS) (18, 31). The iSPT compares favourably with the TSS (31). For example, a generic TSS (31) demonstrated that the reliability of HSD (CV: 1.5%; ICC: 0.87) was comparable to the values reported for iSPT (CV: 1.5%; ICC: 0.96). Furthermore, similar variables, such as FRD (CV: 1.7%; ICC: 0.90 - (31)) demonstrate parity with the iSPT specific data (CV: 1.8%; ICC: 0.92). However, some reliability measures specific to these

generic TSS are superior to those achieved in iSPT. For example, iSPT PSS demonstrated a CV of 4.5%, which is inferior to the CV reported (1.3%) for some generic TSS (18, 31). Despite these generic TSS having superior CV values they lack specificity due to their shorter duration with regard to movement patterns in soccer (18, 31).

To our knowledge, only one such NMT based study has assessed the reliability of physiological measures in NMT simulations, however, this was for a generic TSS (31). A generic TSS (31) assessed BLa reliability (CV: 17.6%; ICC: 0.65) post simulation and the iSPT compares favourably in this regard (CV: 4.5%; ICC: 0.98). Improved reliability for BLa in the iSPT may be due to the increased sampling frequency employed in iSPT. The CIM value reported for HR was $-2.8 \text{ b} \cdot \text{min}^{-1}$, similar to other values reported in the literature, such as the $-3.1 \text{ b} \cdot \text{min}^{-1}$ reported elsewhere (35). This demonstrates iSPT reliability is comparable to other simulations. With regard to iSPT, no significant differences between the two trials of iSPT were evident for any physiological variables.

The reliability of individual variables can have an influence upon the sample size required to detect an adequate change (7). Batterham and Atkinson (7), provided a nomogram using a variable's CV% to estimate the sample size required to detect any change associated with interventions, as also used in recent soccer-related research (14, 31). Applying this nomogram to the primary performance variables (TD: 1.4%, VRD: 1.4%, TSD: 2.2%, PSS: 4.5%) suggests that a minimum sample size of between 5 and 10 is adequate to detect a 10% change (7), in-line with previous findings (31). To detect a 5% change for the same variables a sample size between 11 and 20 would be required.

Validity: In the present study, all validity data were determined from an average of iSPT₁ and iSPT₂. Assessing the validity of a soccer simulation is difficult without utilising the same subjects within a match-play situation using expensive specialist equipment (*e.g.* GPS). Furthermore, within a match the physical performance will vary due to the impact of game factors (14). Therefore, iSPT was devised to approach the activity profile of soccer players balancing the control of a laboratory situation and the general activity pattern of soccer match-play.

Mean TD was 8968 ± 430 m in iSPT, similar to previous match-play observations (28) (8638 ± 1158 m). Evidently, when comparing TD within university standard soccer players (8968 ± 430 m) with elite European league players ($10,860 \pm 260$ m - (22)) a difference of ~ 1900 m is observed. Such differences are likely underpinned by maximal oxygen consumption, with a difference of ~ 9 ml·kg⁻¹·min⁻¹ between university players (51 ± 9 ml·kg⁻¹·min⁻¹) and highly trained (58 to 62 ml·kg⁻¹·min⁻¹) 'elite' players (22), as discussed elsewhere (34).

The mean HSD in iSPT (2122.37 ± 140.13 m) is again in line with match-play data detailed elsewhere (2116 ± 369 m - (12)), and supports the definition of HSD running as $>65\%$ of PSS, as employed in iSPT. SD covered in iSPT (980 ± 75 m) was greater than values (650 - 771 m) reported **previously** (6, 22). Mean sprint duration in soccer performance has been reported to be ~ 3.5 s shorter than in iSPT (22). However, a shorter sprint duration would have probably been less reliable due to the different running mechanics when running on a NMT and poor reliability of 3 s sprint efforts (18, 19).

333

334 It is recognised that the amount of SD, HSD and TD covered are less in the second half
335 compared to the first half of a soccer match (22, 23). Such decrements are evident between
336 the first and second halves of iSPT₁ and iSPT₂, demonstrating external validity. The
337 significantly lower TD covered in the second half compared to the first half (25-151 m) is
338 consistently reported within the literature, (12, 22) which is comparable with iSPT₁ (28 ± 25)
339 and iSPT₂ (142 ± 84). Conversely, some research has suggested that TD is not significantly
340 less in the second half, demonstrated within elite European soccer players (12), suggesting
341 that despite there being a decline in physical performance in some cases, this may not be a
342 systematic change.

343

344 A significant reduction (5.1%) in PSS was reported during iSPT₂ in the second half ($20.6 \pm$
345 $1.4 \text{ km}\cdot\text{h}^{-1}$) of the protocol compared with the first half ($21.6 \pm 1.2 \text{ km}\cdot\text{h}^{-1}$), similar with
346 reductions reported previously (3). Other soccer simulations have failed to find such a
347 substantial decrease in physical performance, where it was reported that PSS decreased by
348 2% (35). One reason why such a substantial decrease in PSS may occur is due to the duration
349 of the sprint effort used in iSPT (6 s) (35). A 6 s sprint effort was used due to the different
350 running mechanics that have been noted when sprinting on a NMT (1, 18, 19). It was
351 reported in previous studies (18, 31) that a 3 s sprint produced less reliable sprints compared
352 to using a 6 s sprint. Furthermore, the practical realities of running mechanics on a NMT
353 make a 6 s sprint more appropriate to assess physical performance (19).

354

The iSPT contains three 15 min blocks per half enabling measurement of decrements in physical performance between and within halves. The variable run element novel to iSPT details the fatigue in high-speed running performance. HSD significantly decreases in the last 15 min of match-play (23), and it was found in iSPT₁ and iSPT₂ that there was a significant decrease in VRD in the last 15 min of the second half compared to the first 15 min of match-play (Figure 2). The iSPT provides evidence that VRD can quantify, to some degree, the fatigue demonstrated by other “classic” variables of HSD, such as FR, in line with the experimental objectives. A previous NMT based soccer-specific simulation (30) reported no reduction in VRD, however, this used a 45 min protocol, which was seemingly not long enough to induce a decline in VRD.

There has been a clear emphasis on determining both the physiological and performance outputs of players by utilising a soccer-specific simulation (35). Therefore, for a simulation to be successful these physiological and performance variables must be comparable to match-play data. The performance parameters reported for the iSPT in the present study demonstrate similarities with previously reported match-play data. Furthermore, the physiological and performance parameters of the iSPT also demonstrate excellent reproducibility. Subsequently, the validity and reliability of both the performance and physiological variables suggests that the iSPT could provide a novel soccer-specific performance test. Furthermore, performance parameters, which are subject to large variance during match-play could be measured with accuracy, so that meaningful inferences can be made to inform and evaluate both training (4) and performance (33).

Experimental Limitations: Treadmill based simulations can contain certain experimental limitations (35). Due to the uni-directional nature of treadmill based protocols, they are unable to contain soccer-specific movements (e.g. backwards and sideways running) or the assessment of technical skills (e.g. passing, shooting) (32). Therefore, the use of an NMT simulation (iSPT) should not be utilised to assess these particular facets of soccer performance. Despite iSPT not containing these certain activity profiles the protocol still approaches the same internal (e.g. HR) and external (e.g. TD covered) activity load of soccer match play (4). Moreover, utilising a laboratory based simulation compared with match-play data is more advantageous for understanding the activity profiles of soccer players providing greater experimental control for performance and physiological measures whilst minimising environmental factors (14).

Sample Size Considerations: A sample size of only twelve was available for this study. Although it has been recommended for a reliability study that a sample of twenty participants should be used (5), this can prove difficult in studies such as this that are demanding on participants. However previous NMT based reliability studies have used a smaller sample size (i.e. $< n = 20$), and have still reported acceptable CV and ICC statistics (27, 31). Furthermore, 90% CI were included for all ES in place of the 95% used for other reliability measures, as this (90%) was the recommended level for assessing the precision of the data within ES (17). Utilising this approach can demonstrate that the response iSPT had upon the participants in this study compared with the general population as there would be minimal variance in 90% CI for ES between participants (16, 17). It can be reported that for variables in table 3 and the primary variables (TD covered, VRD and SD) in table 4 that the 90% CI of

ES do not cross two ES categories again showing high precision. Therefore, these points show justification for the chosen sample size for this study.

PRACTICAL APPLICATIONS

The present study demonstrates that iSPT is a valid and reliable soccer simulation, and the utilisation of the variable run phase was also shown to successfully determine decrements in high-speed running capability. Therefore, iSPT could be used in a number of ways. For example, iSPT could be utilised as a training tool to provide objective feedback to both players and coaches by quantifying the performance capability of the individual. The iSPT could also be used to assess players who are returning from injury. The iSPT could be completed by the player post-injury and compared against the pre-injury soccer-specific capacity. Therefore, utilising this approach would be useful for a coach to understand if a player is ready to play competitive soccer. Another example, iSPT could be used for player rehabilitation, as the simulation does not contain any multi-directional movements (e.g. twisting and turning) or contact of a soccer match. The iSPT may also be used when evidence is required with regard to the efficacy of a nutritional intervention (9), particularly those ergogenic aids which are reputed to delay fatigue (25). Finally, the laboratory based nature of iSPT could be used for quantifying the environmentally mediated decrement in soccer physical performance (8, 24, 26), which would be ideal for policy making for governing bodies, scientists and coaches.

REFERENCES

1. Abt, G. An attempt to assess the effect of oral creatine monohydrate supplementation on prolonged high-intensity intermittent exercise that simulates team sport play. Rockhampton: Central Queensland University, 2002.
2. Abt, G and Lovell, R. The use of individualized speed and intensity thresholds for determining the distance run at high-intensity in professional soccer. *J Sports Sci* 27: 893-898, 2009.
3. Abt, G, Raeburn, P, Holmes, M, and Gear, T. Changes in peak sprint speed during prolonged high-intensity intermittent exercise that simulates team sport play. *J Sports Sci* 21: 256 - 257, 2003.
4. Akubat, I, Barrett, S, and Abt, G. Integrating the internal and external training load in soccer. *Int J Sports Physiol Perform* (In press), 2013.
5. Atkinson, G and Nevill, AM. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Med* 26: 217-238, 1998.
6. Bangsbo, J, Norregaard, L, and Thorso, F. Activity profile of competition soccer. *Can J Sport Sci* 16: 110 -116, 1991.
7. Batterham, AM and Atkinson, G. How big does my sample need to be? A primer on the murky world of sample size estimation. *Phys Ther Sport* 6: 153-163, 2005.
8. Carling, C, Dupont, G, and Le Gall, F. The effect of a cold environment on physical activity profiles in elite soccer match-play. *Int J Sports Med* 32: 542-545, 2011.
9. Clarke, ND, Campbell, IT, Drust, B, Evans, L, Reilly, T, and Maclaren, DP. The ingestion of combined carbohydrates does not alter metabolic responses or performance capacity during soccer-specific exercise in the heat compared to ingestion of a single carbohydrate. *J Sports Sci* 30: 699-708, 2012.
10. Cohen, J. A power primer. *Psychol Bull* 112: 155-159, 1992.
11. Currell, K and Jeukendrup, AE. Validity, reliability and sensitivity of measures of sporting performance. *Sports Med* 38: 297-316, 2008.
12. Di Salvo, V, Baron, R, Tschan, H, Calderon-Montero, FJ, Bachl, N, and Pigozzi, F. Performance characteristics according to playing position in elite soccer. *Int J Sports Med* 28: 222-227, 2007.
13. Drust, B, Reilly, T, and Cable, NT. Physiological responses to laboratory-based soccer-specific intermittent and continuous exercise. *J Sports Sci* 18: 885-892, 2000.
14. Gregson, W, Drust, B, Atkinson, G, and Di Salvo, V. Match-to-match variability of high speed activities in premier league soccer. *Int J Sports Med* 31: 237-242, 2010.
15. Hopkins, WG. Measures of reliability in sports medicine and science. *Sports Med* 30: 1-15, 2000.
16. <http://www.sportsci.org/resource/stats/index.html>. Accessed 26/11/12/.
17. Hopkins, WG, Marshall, SW, Batterham, AM, and Hanin, J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc* 41: 3-13, 2009.
18. Hughes, MG, Doherty, M, Tong, RJ, Reilly, T, and Cable, NT. Reliability of repeated sprint exercise in non-motorised treadmill ergometry. *Int J Sports Med* 27: 900-904, 2006.
19. Lakomy, HKA. The use of a non-motorized treadmill for analysing sprint performance. *Ergonomics* 30: 627-637, 1987.
20. Lovell, R and Abt, G. Individualisation of time-motion analysis: A case-cohort example. *Int J Sports Physiol Perform* 8: 456-458, 2013.
21. Lu, PZ, Lai, CY, and Chan, WH. Caffeine induces cell death via activation of apoptotic signal and inactivation of survival signal in human osteoblasts. *Int J Mol Sci* 9: 698-718, 2008.
22. Mohr, M, Krstrup, P, and Bangsbo, J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci* 21: 519-528, 2003.
23. Mohr, M, Krstrup, P, and Bangsbo, J. Fatigue in soccer: A brief review. *J Sports Sci* 23: 593-599, 2005.

24. Mohr, M, Nybo, L, Grantham, J, and Racinais, S. Physiological responses and physical performance during football in the heat. *PLoS One* 7, 2012.
25. Mujika, I, Padilla, S., Ibanez, J., Izquierdo, M. & Gorostiaga, E. Creatine supplementation and sprint performance in soccer players. *Med Sci Sports Exerc* 32: 518 - 525, 2000.
26. Nassis, GP. Effect of altitude on football performance: Analysis of the 2010 FIFA World Cup data. *J Strength Cond Res* 27: 703-707, 2013.
27. Oliver, JL, Armstrong, N, and Williams, CA. Relationship between brief and prolonged repeated sprint ability. *J Sci Med Sport* 2: 137-149, 2007.
28. Rienzi, E, Drust, B, Reilly, T, Carter, JE, and Martin, A. Investigation of anthropometric and work-rate profiles of elite South American international soccer players. *J Sports Med Phys Fit* 40: 162-169, 2000.
29. Sawka, MN, Burke, LM, Eichner, ER, Maughan, RJ, Montain, SJ, and Stachenfeld, NS. Exercise and fluid replacement. *Med Sci Sports Exerc* 39: 377-390, 2007.
30. Sear, JA, Hoare, TK, Scanlan, AT, Abt, GA, and Dascombe, BJ. The effects of whole-body compression garments on prolonged high-intensity intermittent exercise. *J Strength Cond Res* 24: 1901-1910, 2010.
31. Sirotic, AC and Coutts, AJ. The reliability of physiological and performance measures during simulated team sport running on a non-motorised treadmill. *J Sci Med Sport* 11: 500-509, 2007.
32. Small, K, McNaughton, L, Greig, M, and Lovell, R. The effect of multidirectional soccer-specific fatigue on markers of hamstring injury risk. *J Sci Med Sport* 13: 120-125, 2010.
33. Thatcher, R and Batterham, AM. Development and validation of sport specific exercise protocol for elite youth soccer players. *J Sports Med Phys Fit* 44: 15-22, 2004.
34. Tonnessen, E, Hem, E, Leirstein, S, Haugen, T, and Seiler, S. VO2 max characteristics of male professional soccer players 1989-2012. *Int J Sports Physiol Perform* 8: 323-329, 2012.
35. Williams, JD, Abt, G, and Kilding, AE. Ball-Sport Endurance and Sprint Test (BEAST90): validity and reliability of a 90-minute soccer performance test. *J Strength Cond Res* 24: 3209-3218, 2010.
36. Winter, EM, Jones, AM, Davison, RC, Bromley, PD, and Mercer, TH. Sport and exercise physiology testing guidelines, in: *The British Association of Sport and Exercise Science Guidelines*. TH Mercer, ed. Oxon: Routledge, 2007.
37. Withers, RT, Maricic, Z. & Wasilewski, S. Match analysis of Australian professional soccer players. *J Hum Movement Stud* 8: 159-176, 1982.

Figure Captions

Figure 1: The 45 min activity profile of iSPT for a participant with a peak sprint speed of 23 km·h⁻¹

Figure 2: HSD, SD, PSS and VRD covered in each 15 min period throughout iSPT₁ and iSPT₂. HSD, SD, PSS and VRD were significantly less ($p < 0.05$) in the last 15 min of the second half of iSPT₁* and iSPT₂** compared to the first 15 min of the first half.

Table Captions

Table 1: Specific movements and times for each familiarisation session.

Table 2: The percentage of intensity, frequency and total time spent at each movement category during iSPT.

Table 3: Mean $\pm$ SD, significance values, change in mean (CIM), typical error (TE), intraclass correlation coefficient (ICC), coefficient of variation (CV) with 95%CI and Effect Sizes (ES) with 90%CI for all performance and physiological variables from iSPT₁ and iSPT₂. Any discrepancies between the means and the CIM are due to rounding errors.

Table 4: Mean values for the first half and second half, CIM, significance values, 95%CI values and effect size (ES) with 90%CI for all performance and physiological variables from iSPT₁ and iSPT₂. Any discrepancies between the means and the CIM are due to rounding errors.

Figure 1
[Click here to download high resolution image](#)

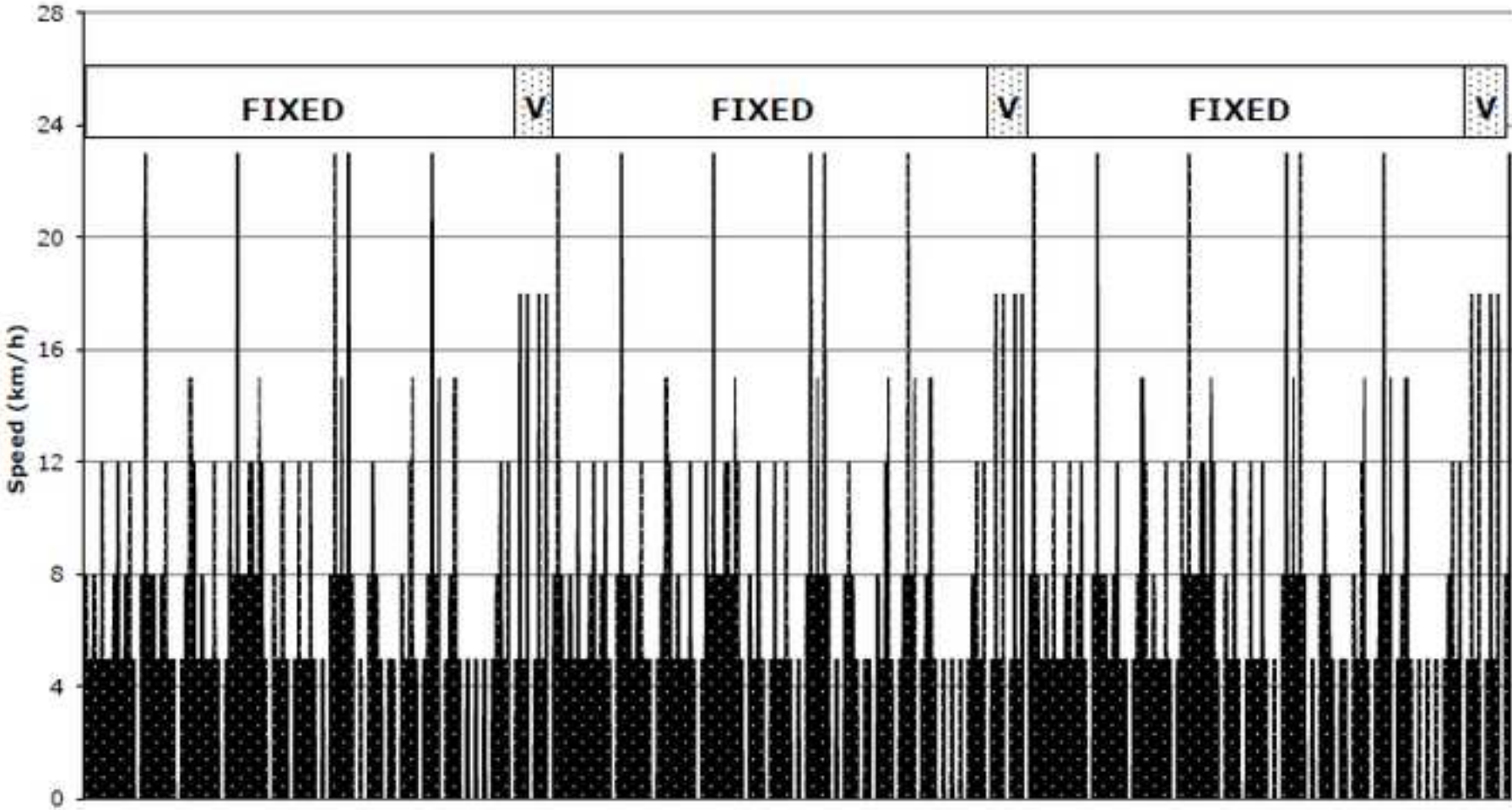


Figure 2
[Click here to download high resolution image](#)

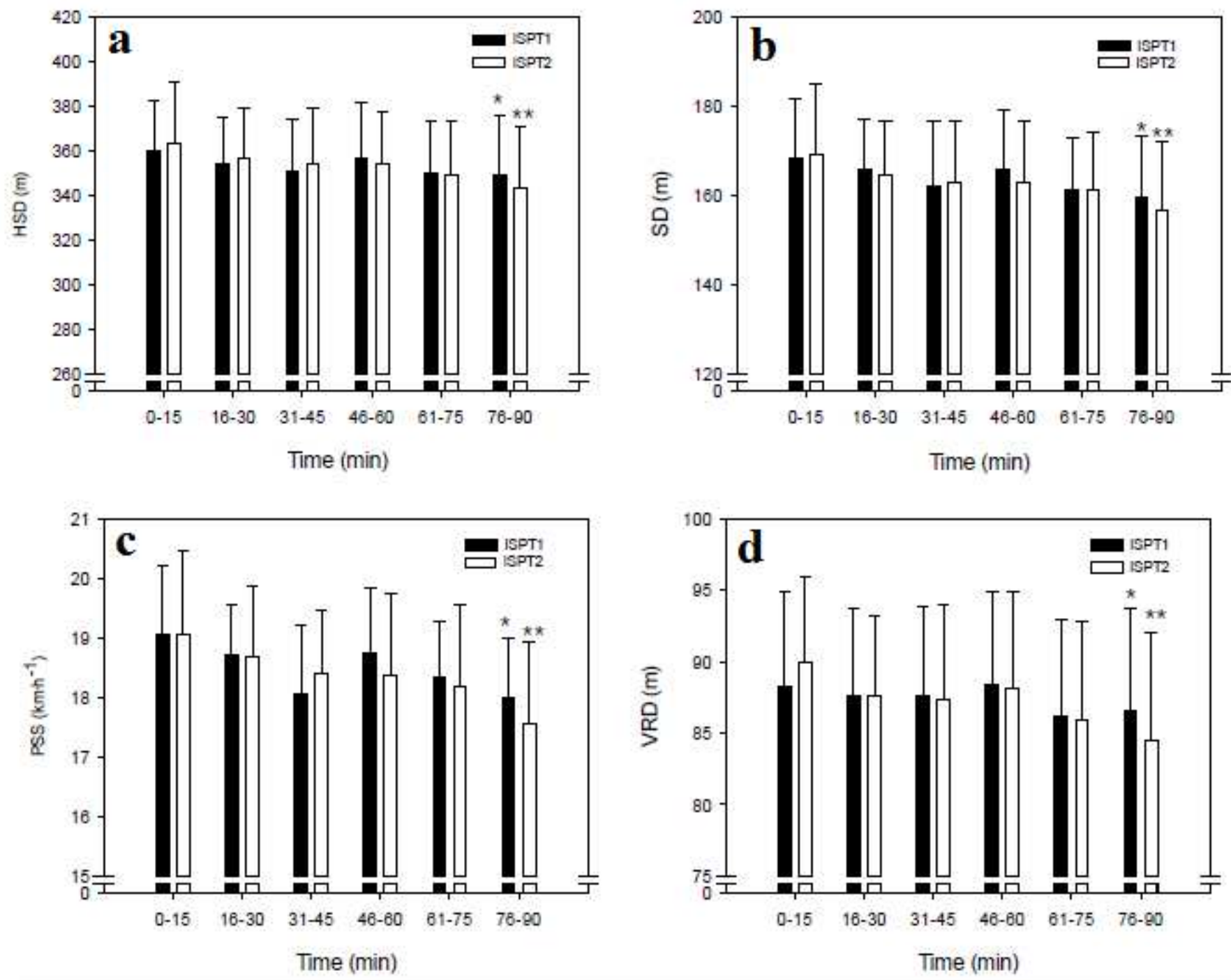


Table 1:

Familiarisation	Time (min)	Speed categories involved
1	9	Stand, walk, jog, run, fast run
	13	Stand, walk, jog, run, fast run, sprint
	15	Stand, walk, jog, run, fast run, sprint
2	45	Stand, walk, jog, run, fast run, sprint
3	90	Stand, walk, jog, run, fast run, sprint

Table 2:

Movement Category	% of PSS	Frequency	Total Time (s)	% Total Time
Stand	0	240	1920	17.8
Walk	20	456	3936	36.4
Jog	35	300	2592	24.0
Run	50	192	1248	11.6
Fast run	60	72	384	3.6
Variable run	Unset	48	288	2.7
Sprint	100	72	432	4.0
Total	---	690	5400	100

Table 3:

Variable	iSPT ₁	iSPT ₂	CIM	<i>p</i> value	ES	ICC	CV	TE
TD (m)	8965± 456	9002 ± 389	37 (-110 to 117)	1.00	0.09 (-0.27 to 0.14)	0.93 (0.79 to 0.98)	1.4 (1 to 2.5)	126.5 (89.6 to 214.8)
WD (m)	2432 ± 104	2431 ± 86	-1 (-31 to 29)	0.95	0.01 (-0.31 to 0.16)	0.89 (0.64 to 0.97)	1.4 (1 to 2.4)	33.7 (23.9 to 57.3)
JD (m)	2602 ± 159	2603 ± 160	1 (-62 to 64)	0.98	0.01 (-0.42 to 0.15)	0.81 (0.43 to 0.94)	2.8 (2 to 4.9)	70.2 (49.8 to 119.3)
RD (m)	1616 ± 98	1607 ± 93	-8 (-30 to 13)	0.42	0.09 (-0.32 to 0.12)	0.94 (0.79 to 0.98)	1.5 (1 to 2.5)	24.0 (17.0 to 40.8)
FRD (m)	617 ± 34	618 ± 40	1 (-8 to 11)	0.76	0.07 (-0.09 to 0.38)	0.92 (0.74 to 0.98)	1.8 (1.3 to 3.2)	11.1 (7.9 to 18.8)
VRD (m)	525 ± 38	524 ± 36	-1 (-7 to 6)	1.00	0.02 (-0.2 to 0.12)	0.97 (0.89 to 0.99)	1.4 (1 to 2.4)	7.5 (5.3 to 12.7)
SD (m)	983 ± 74	978 ± 79	-6 (-25 to 14)	1.00	0.07 (-0.32 to 0.17)	0.93 (0.79 to 0.98)	2.2 (1.6 to 3.9)	21.7 (15.4 to 36.9)
HSD (m)	2125 ± 138	2119 ± 146	-6 (-34 to 22)	1.00	0.04 (-0.21 to 0.16)	0.96 (0.87 to 0.99)	1.5 (1.1 to 2.6)	31.1 (22.0 to 52.8)
LSD (m)	6767 ± 387	6847 ± 310	80 (-109 to 121)	1.00	0.23 (-0.01 to 0.4)	0.88 (0.63 to 0.96)	1.9 (1.4 to 3.3)	128 (90.7 to 217.3)
PSS (km·h ⁻¹)	20.7 ± 1.2	20.7 ± 2.0	-0.04 (-0.9 to 0.8)	1.00	0.03 (-0.21 to 0.18)	0.80 (0.39 to 0.95)	4.5 (3.2 to 7.9)	0.9 (0.6 to 1.6)
HR (b·min ⁻¹)	164 ± 8	160 ± 8	-4 (-6 to -1)	0.67	0.48 (0.2 to 0.62)	0.88 (0.64 to 0.96)	1.8 (1.3 to 3.1)	3.0 (2.1 to 5.0)
Lactate (mmol)	5.0 ± 1.5	4.9 ± 1.6	-0.2 (-0.4 to 0.03)	1.00	0.02 (-0.19 to 0.13)	0.98 (0.93 to 0.99)	4.6 (3.3 to 8.1)	0.2 (0.2 to 0.4)

Total Distance = TD; Walk Distance = WD; Jog Distance = JD; Run Distance = RD; Fast Run Distance = FRD; Variable Run Distance = VRD; Sprint Distance = SD; High Speed Distance = HSD; Low Speed Distance = LSD; Peak Sprint Speed = PSS; Heart Rate = HR; Blood Lactate = Lactate; Change in Mean = CIM; Effect Size = ES; Intraclass coefficient = ICC; Coefficient of Variation = CV; and Typical Error = TE

Table 4

Table 4:

Variable	iSPT ₁						iSPT ₂					
	1 st half	2 nd half	CIM	95% CI	<i>p</i> value	ES	1 st half	2 nd half	CIM	95% CI	<i>p</i> value	ES
TD (m)	4488 ± 237	4460 ± 236	-28 ± 25	-13 to -44	0.001	0.12 (0.07 to 0.2)	4563 ± 215	4421 ± 188	-142 ± 84	-89 to -196	0.001	0.71(0.47 to 0.95)
WD (m)	1222 ± 52	1209 ± 54	-13 ± 23	-1 to -28	0.07	0.25 (0.11 to 0.59)	1226 ± 51	1204 ± 39	-22 ± 32	-2 to -42	0.04	0.48 (0.04 to 0.82)
JD (m)	1315 ± 75	1287 ± 89	-28 ± 43	-0.6 to -55	0.04	0.34 (0.02 to 0.65)	1319 ± 86	1284 ± 80	-35 ± 45	-6 to -64	0.02	0.42 (0.1 to 0.77)
RD (m)	810 ± 48	806 ± 50	-4 ± 10	-2 to -12	0.01	0.07 (0.1 to 0.25)	814 ± 53	794 ± 43	-20 ± 24	-4 to -35	0.02	0.41 (0.12 to 0.69)
FRD(m)	309 ± 17	307 ± 17	-2 ± 2	-0.8 to -3	0.001	0.12 (0.04 to 0.15)	312 ± 21	306 ± 19	-6 ± 5	-3 to -9	0.001	0.30 (0.14 to 0.44)
VRD (m)	264 ± 18	261 ± 19	-2 ± 5	-0.2 to -5	0.04	0.15 (0.05 to 0.31)	265 ± 17	259 ± 20	-6 ± 9	-0.5 to -12	0.04	0.33 (0.02 to 0.65)
TSD (m)	496 ± 37	487 ± 38	-9 ± 12	-1 to -17	0.02	0.25 (0.06 to 0.47)	497 ± 38	481 ± 41	-16 ± 12	-8 to -24	0.001	0.41 (0.25 to 0.61)
HSD (m)	1068 ± 20	1057 ± 20	10 ± 13	-2 to -18	0.02	0.14 (0.02 to 0.26)	1074 ± 72	1046 ± 75	-28 ± 15	-19 to -38	0.001	0.39 (0.27 to 0.52)
LSD (m)	3442 ± 168	3399 ± 187	-43 ± 54	-9 to -78	0.02	0.24 (0.15 to 0.32)	3468 ± 181	3379 ± 141	-89 ± 96	-28 to -150	0.01	0.55 (0.34 to 0.78)
PSS (km·h ⁻¹)	20.9 ± 0.9	20.6 ± 1.7	-0.2 ± 1.3	-0.6 to 1.2	0.55	0.19 (-1.2 to 0.59)	21.1 ± 2.5	20.3 ± 1.7	-0.7 ± 1.4	-0.3 to -2.0	0.02	0.35 (0.27 to 0.89)
HR (b·min ⁻¹)	169 ± 8	168 ± 9	-0.6 ± 5	-3 to 4	0.89	0.08 (-0.8 to 0.63)	168 ± 8	164 ± 8	-4 ± 6	-1 to -9	0.02	0.42 (0.34 to 0.74)
Lactate (mmol)	5.4 ± 1.4	4.9 ± 2.0	-0.5 ± 1.0	-0.2 to -1.6	0.02	0.29 (0.12 to 0.34)	5.3 ± 1.6	4.7 ± 1.7	-0.6 ± 1.0	-0.2 to -1.4	0.02	0.34 (0.19 to 0.51)

Total Distance = TD; Walk Distance = WD; Jog Distance = JD; Run Distance = RD; Fast Run Distance = FRD; Variable Run Distance = VRD; Sprint Distance = SD; High Speed Distance = HSD; Low Speed Distance = LSD; Peak Sprint Speed = PSS; Heart Rate = HR; Blood Lactate = Lactate; Change in Mean = CIM; Effect Size = ES; and 95% Confidence Intervals = 95% CI