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

BRIEF RUNNING HEAD: NON-MOTORISED TREADMILL SOCCER SIMULATION

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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 $iSPT_1$ and $iSPT_2$ 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 (89.24 ± 6.16 m) compared to the first 15 min (85.38 ± 7.28 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, reproducibility, variable run, testing

INTRODUCTION

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

One solution to this problem is through the development of laboratory or field based soccer simulations, which replicate the demands of soccer. Control of the environment is imperative, thus, laboratory treadmill based protocols are predominantly used (3, 13, 27). Field-based protocols, such as the $SAFT_{90}$ do not utilise a treadmill, providing a multi-directional facet to simulations (32). The $SAFT_{90}$ is a fixed distance protocol that is also useful for the determination of physiological responses for a given physical output. However, fixed distance and motorised treadmill-based protocols can also limit ecological validity (13, 32) where, the inability to express maximal running capability is an obvious limitation (35). To address some of these limitations, protocols utilising a non-motorised treadmill (NMT) have been developed (3, 27, 31, 33).

Using a NMT to simulate soccer allows for decrements in performance and maximal exercise performance to be quantified (27), provided a correctly formulated protocol is utilised. 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 $km \cdot h^{-1}$) 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 $km \cdot h^{-1}$) 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 ($\dot{V}O_{2max}$) 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 ± SD: age, 21 ± 2 y, body mass, 70.5 ± 9.4 kg, height, 182.0 ± 12.7 cm; $\dot{V}O_{2max}$, 51 ± 9 $ml \cdot kg^{-1} \cdot min^{-1}$). 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

$\dot{V}O_{2max}$ Test: To determine $\dot{V}O_{2max}$ subjects completed a ramp exercise protocol performed on a motorised treadmill (Woodway, PPS51 Med-i, Cranlea). The test began at 6 $km \cdot h^{-1}$, and increased by 0.1 $km \cdot h^{-1}$ 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). $\dot{V}O_{2max}$ 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^{o} from horizontal, as this is considered optimum (19).

Experimental Design: Visit 1 (FAM_1): FAM_1 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 (FAM_2, PSA):* Four days after the completion of FAM_1 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 FAM_2, which consisted of the first 45 min of the iSPT protocol. *Visit 3 (FAM_3):* Subjects were rested for 6 – 10 days after completing FAM_2 before taking part in FAM_3, which involved the full 90 min protocol. *Visits 4 and 5 ($iSPT_1$ and $iSPT_2$):* Subjects then rested for 7 – 9 days and 6 – 10 days before taking part in $iSPT_1$ and $iSPT_2$ respectively.

179 **#Table 1 about here#**

180

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

192

193 The activity pattern (e.g. mean duration of each movement category) of the iSPT was based
194 upon previous time and motion studies of soccer (6, 37). The 15 min protocol block was
195 developed to allow comparison of both the performance and physiological capacity
196 between/within halves - an approach used by several previous protocols (1, 31). The iSPT
197 consisted of seven different movement categories that were determined and classified as a
198 percentage of PSS (Table 2). The relative speeds for most speed thresholds were modelled
199 upon the work of Abt (1), however these were adjusted to compensate for the unorthodox
200 movement and the inability to include modes of movement such as backwards and sideways
201 running on the NMT (19). Four self-selected high-speed runs (variable run - 13^{th}-14^{th} 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 ± SD. All data were analysed using a two-way-repeated-measures ANOVA. FAM_3, $iSPT_1$ and $iSPT_2$ 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 $iSPT_1$ and $iSPT_2$. 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 FAM_3, $iSPT_1$ and $iSPT_2$. Reliability statistics for all performance and physiological variables during $iSPT_1$ and $iSPT_2$, including the ICC (>0.80; >0.84) and CV values (<4.5%; <4.6%), are shown in Table 3.

246

247 **#Table 3 about here#**

248

249 **Between Halves**

250 All performance and physiological variables showed significant differences between halves
251 in one or both of the $iSPT_1$ and $iSPT_2$ (Table 4). A significant decrease in TD between halves
252 was evident in $iSPT_1$ (28 ± 25 m, p = 0.002) and $iSPT_2$ (142.3 ± 83.9 m, p = 0.01). A
253 significant decrease in HSD between halves was observed in $iSPT_1$ (10.1 ± 13.2 m, p = 0.02)
254 and $iSPT_2$ (28.5 ± 15.3 m, p = 0.001). Similarly, a significant decrease in SD between the first
255 and the second half was evident in both $iSPT_1$ (9.3 ± 12.3 m, p = 0.02) and $iSPT_2$ (16.1 ± 12.2
256 m, p = 0.01). However, there was a significant decrease in PSS within $iSPT_2$ (0.7 ± 1.4 $km \cdot h^{-1}$,
257 p = 0.02), but not in $iSPT_1$ (0.2 ± 1.3 $km \cdot h^{-1}$, p = 0.55).

258

259 A significant decrease in VRD between halves was evident ($iSPT_1$: 2.3 ± 4.6 m, p = 0.04;
260 $iSPT_2$: 6.1 ± 8.8 m, p = 0.04). Additionally, a significant decrease in FRD was observed
261 ($iSPT_1$: 2.1 ± 2.0 m, p < 0.01; iSPT2: 6.0 ± 5.0 m, p = 0.02). A significant decrease in JD
262 between halves was evident in both $iSPT_1$ (27.7 ± 42.7 m; p = 0.04) and $iSPT_2$ (34.9 ± 45.4
263 m; p = 0.02). A significant decrease in RD in the second half was evident in both trials ($iSPT_1$
264 3.6 ± 9.9 m, p < 0.01; $iSPT_2$: 19.6 ± 24.0 m, p = 0.02). There was a significant decrease in
265 WD within $iSPT_2$ (21.6 ± 31.7 m; p = 0.04), but not in $iSPT_1$ (13.3 ± 23.1 m; p = 0.07).

266

A significant decrease in BLa was also noted between halves ($iSPT_1$: 0.5 ± 1.0 mmol, p = 0.02; $iSPT_2$: 0.6 ± 1.0 mmol p = 0.02). HR showed no significant difference in $iSPT_1$ (0.6 ± 5 $b \cdot min^{-1}$; p = 0.89), however was significantly decreased in $iSPT_2$ (4 ± 6 $b \cdot min^{-1}$; 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 $iSPT_1$ (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 $km \cdot h^{-1}$ CI: 0.22-1.9 $km \cdot h^{-1}$, 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 $iSPT_2$ (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 $km \cdot h^{-1}$ 95% CI: 0.20-3.10 $km \cdot h^{-1}$, 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

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

315

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

325

326 The reliability of individual variables can have an influence upon the sample size required to
327 detect an adequate change (7). Batterham and Atkinson (7), provided a nomogram using a
328 variable's CV% to estimate the sample size required to detect any change associated with
329 interventions, as also used in recent soccer-related research (14, 31). Applying this
330 nomogram to the primary performance variables (TD: 1.4%, VRD: 1.4%, TSD: 2.2%, PSS:
331 4.5%) suggests that a minimum sample size of between 5 and 10 is adequate to detect a 10%
332 change (7), in-line with previous findings (31). To detect a 5% change for the same variables
333 a sample size between 11 and 20 would be required.

334

335 *Validity:* In the present study, all validity data were determined from an average of $iSPT_1$ and
336 $iSPT_2$. Assessing the validity of a soccer simulation is difficult without utilising the same
337 subjects within a match-play situation using expensive specialist equipment (*e.g.* GPS).
338 Furthermore, within a match the physical performance will vary due to the impact of game
339 factors (14). Therefore, iSPT was devised to approach the activity profile of soccer players
340 balancing the control of a laboratory situation and the general activity pattern of soccer
341 match-play.

342

343 Mean TD was 8968 ± 430 m in iSPT, similar to previous match-play observations (28) (8638
344 ± 1158 m). Evidently, when comparing TD within university standard soccer players (8968 ±
345 430 m) with elite European league players (10,860 ± 260 m - (22)) a difference of ~1900 m is
346 observed. Such differences are likely underpinned by maximal oxygen consumption, with a
347 difference of ~9 $ml \cdot kg^{-1} \cdot min^{-1}$ between university players (51 ± 9 $ml \cdot kg^{-1} \cdot min^{-1}$) and highly
348 trained (58 to 62 $ml \cdot kg^{-1} \cdot min^{-1}$) 'elite' players (22), as discussed elsewhere (34).

349

350 The mean HSD in iSPT (2122.37 ± 140.13 m) is again in line with match-play data detailed
351 elsewhere (2116 ± 369 m - (12)), and supports the definition of HSD running as >65% of
352 PSS, as employed in iSPT. SD covered in iSPT (980 ± 75 m) was greater than values (650-
353 771 m) reported previously (6, 22). Mean sprint duration in soccer performance has been
354 reported to be ~3.5 s shorter than in iSPT (22). However, a shorter sprint duration would have
355 probably been less reliable due to the different running mechanics when running on a NMT
356 and poor reliability of 3 s sprint efforts (18, 19).

It is recognised that the amount of SD, HSD and TD covered are less in the second half compared to the first half of a soccer match (22, 23). Such decrements are evident between the first and second halves of $iSPT_1$ and $iSPT_2$, demonstrating external validity. The significantly lower TD covered in the second half compared to the first half (25-151 m) is consistently reported within the literature, (12, 22) which is comparable with $iSPT_1$ (28 ± 25) and $iSPT_2$ (142 ± 84). Conversely, some research has suggested that TD is not significantly less in the second half, demonstrated within elite European soccer players (12), suggesting that despite there being a decline in physical performance in some cases, this may not be a systematic change.

A significant reduction (5.1%) in PSS was reported during $iSPT_2$ in the second half (20.6 ± 1.4 $km \cdot h^{-1}$) of the protocol compared with the first half (21.6 ± 1.2 $km \cdot h^{-1}$), similar with reductions reported previously (3). Other soccer simulations have failed to find such a substantial decrease in physical performance, where it was reported that PSS decreased by 2% (35). One reason why such a substantial decrease in PSS may occur is due to the duration of the sprint effort used in iSPT (6 s) (35). A 6 s sprint effort was used due to the different running mechanics that have been noted when sprinting on a NMT (1, 18, 19). It was reported in previous studies (18, 31) that a 3 s sprint produced less reliable sprints compared to using a 6 s sprint. Furthermore, the practical realities of running mechanics on a NMT make a 6 s sprint more appropriate to assess physical performance (19).

379 The iSPT contains three 15 min blocks per half enabling measurement of decrements in
380 physical performance between and within halves. The variable run element novel to iSPT
381 details the fatigue in high-speed running performance. HSD significantly decreases in the last
382 15 min of match-play (23), and it was found in $iSPT_1$ and $iSPT_2$ that there was a significant
383 decrease in VRD in the last 15 min of the second half compared to the first 15 min of match-
384 play (Figure 2). The iSPT provides evidence that VRD can quantify, to some degree, the
385 fatigue demonstrated by other "classic" variables of HSD, such as FR, in line with the
386 experimental objectives. A previous NMT based soccer-specific simulation (30) reported no
387 reduction in VRD, however, this used a 45 min protocol, which was seemingly not long
388 enough to induce a decline in VRD.

389

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

401

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 decrements in soccer physical performance (8, 24, 26), which would be ideal for policy making for governing bodies, scientists and coaches.

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Figure Captions

Figure 1: The 45 min activity profile of iSPT for a participant with a peak sprint speed of 23 $km \cdot h^{-1}$

Figure 2: HSD, SD, PSS and VRD covered in each 15 min period throughout $iSPT_1$ and $iSPT_2$. HSD, SD, PSS and VRD were significantly less ($p < 0.05$) in the last 15 min of the second half of $iSPT_1$* and $iSPT_2$** 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 ± 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 $iSPT_1$ and $iSPT_2$. 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 $iSPT_1$ and $iSPT_2$. Any discrepancies between the means and the CIM are due to rounding errors.