Validated soccer simulation protocol for youth: evidence from U13–U15 players

Protocolo de simulación de fútbol validado para jóvenes: evidencia en jugadores U13–U15

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Abstract

Introduction: A football simulation protocol is a standardized exercise protocol designed to replicate the physical and physiological demands of a real football match under controlled conditions.
Objective: The aim of this study was to assess the reliability and validity of a soccer simulation protocol designed for U13, U14, and U15 soccer players.
Methodology: Twenty (n=20) outfield players (U13: n = 7, 1.57 ± 0.06 m, 47.8 ± 6.8 kg; U14: n = 7, 1.70 ± 0.06 m, 60.4 ± 8.4 kg; U15: n = 6, 1.75 ± 0.07 m, 58.1 ± 2.6 kg) from Auckland Football Federation volunteered to participate in the study. Participants completed the protocols on two occasions to determine test–retest reliability. Each protocol required players to cover a total running distance equivalent to match play at varying intensities in a cyclical pattern, divided into four exercise blocks separated by five-minute recovery periods.
Results: No significant differences were observed between trials in heart rate, countermovement jump, sprint speed and perceptual scales (P>0.05). Test–retest analysis demonstrated moderate to high reliability, with intraclass correlation (r= 0.50 to 0.80) and low standard error of measurement. Concurrent validity assessment showed significant positive correlations (r= 0.77 to 0.82) between match-play and the protocols for all age groups.
Discussion: The study validated a soccer-specific simulation protocol for under 13 to under 15 players, facilitating more comprehensive investigation and bridging the performance gap between youth and adult players.
Conclusion: The protocols is a valid and practical tool for assessing youth players.

Keywords

Exercise testing; football; match performance; youth.

Resumen

Introducción: Un protocolo de simulación de fútbol es un protocolo de ejercicio estandarizado diseñado para replicar las demandas físicas y fisiológicas de un partido real de fútbol en condiciones controladas.
Objetivo: El objetivo de este estudio fue evaluar la fiabilidad y validez de un protocolo de simulación de fútbol diseñado para jugadores U13, U14 y U15.
Metodología: Veinte (n=20) jugadores de campo (U13: n = 7, 1.57 ± 0.06 m, 47.8 ± 6.8 kg; U14: n = 7, 1.70 ± 0.06 m, 60.4 ± 8.4 kg; U15: n = 6, 1.75 ± 0.07 m, 58.1 ± 2.6 kg) de la Federación de Fútbol de Auckland se ofrecieron voluntariamente a participar en el estudio. Los participantes completaron los protocolos en dos ocasiones para determinar la fiabilidad test–retest. Cada protocolo requería que los jugadores cubrieran una distancia total de carrera equivalente a la del juego real, a diferentes intensidades y en un patrón cíclico, dividido en cuatro bloques de ejercicio separados por períodos de recuperación de cinco minutos.
Resultados: No se observaron diferencias significativas entre pruebas en la frecuencia cardíaca, salto con contramovimiento, velocidad de sprint y escalas perceptivas (P>0.05). El análisis test–retest demostró una fiabilidad moderada a alta, con correlación intraclase (r= 0.50 a 0.80) y bajo error estándar de medición. La evaluación de validez concurrente mostró correlaciones positivas significativas (r= 0.77 a 0.82) entre el juego real y los protocolos en todos los grupos de edad.
Discusión: El estudio validó un protocolo de simulación específico de fútbol para jugadores de 13 a 15 años, facilitando una investigación más completa y reduciendo la brecha de rendimiento entre jugadores juveniles y adultos.
Conclusiones: El protocolo es una herramienta válida y práctica para la evaluación de jugadores jóvenes.

Palabras clave

Pruebas de ejercicio; fútbol; rendimiento en el partido; jóvenes.

Introduction

Soccer is the most popular team sports globally (Atan & Kassim, 2019, 2020; Baydemir & Alp, 2018; Oliveira et al., 2019). According to a wide-scale survey by Fédération Internationale de Football Association (FIFA) in 2006, approximately 270 million people or 4% of the world's population were actively involved in soccer worldwide. Surprisingly, the growth in total of youth soccer participation increase to 7 % compared to the first survey conducted in the year 2000 (Kunz, 2007). Nevertheless, little research attention has been devoted to the youth soccer compared to the adult players. Overall, the popularity of soccer has led to teams and players embracing scientific applications for training and preparation mostly for adults players. Consequently, a significant body of research has developed which is evident in the numbers of research findings published across a variety of disciplines, namely physiology (Lopez-Fernandez et al., 2018), performance analysis (Aquino et al., 2020; Ballesta, Garcia-Romero, Jose Carlos, & Alvero Cruz, 2015), nutrition and performance (Galanti et al., 2015; García-Rovés et al., 2014) and injury related to soccer (Forbes et al., 2013; Rago et al., 2019; Ahmad Shushami & Abdul Karim, 2020). As technology has advanced, monitoring players during match play has become a fundamental approach to gain understanding on soccer demands (Andrzejewski, Chmura, Pluta, & Konarski, 2015; Aughey, 2011; Julian, Page, & Harper, 2021; Paul, Bradley, & Nassis, 2015). Typically, the physical demands of soccer are measured by the total distance covered by the players. The examination of the activity pattern and physical aspects of soccer play enables coaches to identify the strengths and weaknesses of the players under their care. In turn, this information and data may help them to prioritise areas for improvement among their players. Moreover, researchers have used these data to develop specific performance tests that simulate physiological responses as close as possible to actual soccer match-play (Fernandes-da-Silva et al., 2016; Da Silva et al., 2011).

In the last decade, the Soccer Simulation Protocol (SSP) has been used as a more comprehensive approach to investigate soccer specific performances (Atan & Kassim, 2020; Nicholas et al., 2000; Sládečková et al., 2019; Stone et al., 2011). The protocols attempt to replicate the exercise patterns and physiological responses similar to that occur in match play such as; the total distance covered, duration, match activity patterns and time spent in each match activity pattern (Atan & Kassim, 2020). These running activities are repeated in cyclical patterns with the speed of each pattern being dictated by an audible signal (Da Silva & Lovell, 2020; Zagatto et al., 2016). The development of these protocols arose from a need to derive clear benefit from manipulating various variables in soccer performance in a controlled scientific environment (Currell & Jeukendrup, 2008). The inherent variability in soccer from match to match makes it difficult to draw meaningful inferences from interventions conducted. In actual match settings, player performance is influenced by uncontrolled variables such as opponent quality, tactical decisions, referee judgments, environmental conditions, and psychological factors, which make it difficult to isolate specific performance indicators for systematic investigation. These factors reduce the reliability and comparability of results across matches and participants (Julian et al., 2021; Trewin, Meylan, Varley, & Cronin, 2018). Furthermore, access to competitive matches is often limited by soccer rules and team priorities, making long-term or repeated data collection in real matches impractical (Atan & Kassim, 2020). Therefore, to understand the demands of soccer in similar to match play, there is a need to investigate players using the SSP as a more practical method that allows control for research purposes.The SSP allows for standardization of match conditions, ensuring that all participants are exposed to the same physical and technical demands. Consequently, may generate consistent, repeatable, and high-quality data while preserving ecological validity by replicating match-like demands.

To date, most of these protocols have been developed for adults and there are limited protocols reported useful for young athletes (Da Silva & Lovell, 2020; Williams et al., 2010; Cone et al., 2011). Far less attention has been paid to develop age appropriate SSP for young soccer players as the playing durations and the total distance covered are dependent on their age groups and less than that of adult games (Atan & Kassim, 2019). Moreover, young players have different physiological attributes during prolonged intermittent exercise including different substrate utilization, less well developed thermoregulatory responses, inferior aerobic and anaerobic capacity and lower glycogen stores (Atan, Jakiwa & Azli, 2024). The use of SSP is necessary in this study due to the practical, methodological, and scientific limitations associated with collecting data from real competitive matches. There have been previous attempts to develop protocols suitable for young athletes but these attempts have been hindered by various methodological limitations (Phillips, Turner, Gray, Sanderson, & Sproule, 2010; Phillips, Turner, Sanderson,

& Sproule, 2012; Zagatto et al., 2016). No study has yet effectively simulated a SSP that focuses on young players that included intermittent running with repeated sprint ability based on actual match analysis data, undertaken formal reliability and validity testing or and integrated match-play movements like backward and sideways running in young players.

Considering that today, potential young athletes with talent have start training and specialize at an early stage (Sarmento & Pereira, 2018; Richardson et al., 2012; Idowu, 2018), there is an unmet need for a suitable protocol to help in the foundational development of these young talents. The development of a soccer running protocol for young players (≤ U15) is necessary, as there are many concerns that surround the training and participation of young athletes in competitive soccer. Guidelines for youth sports have been established with very little scientific evidence and still contain vague descriptions concerning the age of participants, hours and structure of practice (Merkel, 2013). A SSP suited to younger age groups can be used in many ways, among which are investigating training/ ergogenic interventions and monitoring athletic progress as in adult studies. Results from this investigation would be able to develop suitable guidelines for youth soccer to train and compete in a safe yet effective manner.

The key factors for a good performance test are its validity and reliability. A valid test protocol replicates the soccer match as close as possible (Da Silva et al., 2011; Rustam et al., 2024). Validity in the SSP protocol refers to the simulation of similar movement patterns, total distance covered, the duration of playing and recovery intervals as well as the physiological responses found in match play (Atan, Azli, Jakiwa & Rustam, 2023; Currell & Jeukendrup, 2008). Whereas, reliability refers to the protocol's consistency or reproducibility when it is performed repeatedly (Hopkins, 2000). Given the limitations associated with assessing young players from different age groups, we have devised novel shuttle-running simulations for youth players based on match analysis data from three age groups (U13, U14 and U15). These protocols were designed to simulate the total distance covered, duration of playing, physiological demands and match activity patterns observed during match-play. Therefore, this study aims to assess the reliability and validity of these new simulation protocols adaptations for use with young soccer players aged 12-15 years old. The simulated match model is not merely a substitute for real competition but a scientific tool that enables controlled, reliable, and replicable examination of performance variables that would otherwise be difficult to observe under actual match conditions. It is hypothesized that there is no differences between trials and the SSPs is a valid representation of the youth soccer match-play.

Method

Match Analysis

Prior to the development of the SSPs, match analysis data were collected on 85 outfield players competing within the Auckland Football Federation (AFF) Metropolitan League who volunteered to participate in the study. The participants were categorized into 3 age groups, based on their age as of January 1st in the calendar year, classed as under 13 years (U13; n = 28, 1.54 ± 0.8 m, and 43.9 ± 7.1 kg), under 14 years (U14; n = 27, 1.66 ±0.4 m, and 56.5 ± 8.6 kg), and under 15 years (U15; n = 30, 1.67 ± 0.8 m, and 58.1 ± 9.5 kg). The match analysis data provide useful information for developing framework for developing age-specific soccer simulation protocols (see Table 1).

All games were played in agreement with the rules outlined by the FIFA. All age groups played 11-a-side games, on a full-sized pitch (60 x 100 m), with a "rolling substitute policy." Match configuration varied between age groups, with U13 playing 2 x 30-minute periods, U14 playing 2 x 35-minute periods, whereas the U15 played 2 x 40-minute periods New Zealand Football rules in line with FIFA recommendations. For each age group, teams were allowed to use up to 3 substitutes (from 5 named substitutes) with unlimited interchange of players at any time during the match.

Participants

For validation of the SSPs, players were recruited from the representative teams from the Auckland Football Federation (AFF), Auckland, New Zealand. Twenty (n = 20) young male outfield soccer players volunteered to participate in the study. The participants were categorised into three age-groups: under 13 y (U13; n = 7, 1.57 ± 0.06 m, 47.8 ± 6.8 kg), under 14 y (U14; n = 7, 1.70 ± 0.06 m, 60.4 ± 8.4 kg) and under 15 y (U15; n = 6, 1.75 ± 0.07 m, 58.1 ± 2.6 kg). All participants provided consent to participate and their parents gave their written informed consent, and the study was approved by the local institutional ethics committee.

Sample Size Calculation

The sample size and the statistical power was calculated using the G*Power software (Prajapati, Dunne, & Armstrong, 2010). With an alpha = .05 and power = 0.80, G*Power displays a proposed sample size of n = 20 to detect this level of effect size (ES = 0.5). This will be adequate for the main objective of this study. Similar numbers (≤) of participants have been used in previous studies investigating the reliability of protocols and youth population, i.e. using a power of 80% and α of 0.05, with effect sizes between 0.69 and 0.59, that study required a sample size of between 16 to 23 participants (Michailidis et al., 2020).

Familiarization

All participants attended one preliminary session to familiarise themselves with the protocol procedures along with height and body mass (BM) measurements. The participants were fully familiarised with the countermovement jump (CMJ) and perceptual scales; ratings of perceived exertion (RPE) (Borg, 1998), feeling scale (FS) (Hardy & Rejeski, 1989) and felt arousal scale (FAS) (Svebak & Murgatroyd, 1985).

Experimental Design

Following familiarisation, the SSPs were performed in full on two occasions (separated by 7 days). Participants were asked to refrain from strenuous physical activity 24 h before each trial, record dietary intake (24 h before the first protocol) and required to replicate the same diet prior to trial 2. Both trials took place on an outdoor artificial grass field in temperate conditions (18-22°C, 40-60% relative humidity; ETHG-912; Oregon Scientific, USA). There were no differences in temperature or humidity between trials.

On arrival, participants emptied their bladder and a small sample of urine was used to measure hydration status via a handheld refractometer (Sur-Ne, Atago Co. Ltd, Japan). Body Mass (BM) was recorded using electronic weighing scales (HV200KGL NTEP, Industrial Balance, USA). After donning the 5 Hz Global Positioning Unit (GPS) unit (with interpolated 10 Hz output) and heart rate strap (GPSports Systems, Australia), participants performed 10 min of a standardised warm-up, consisting of jogging, striding and dynamic stretching. Participants consumed 5 mL·kg-1 BM of water before commencing the main trial from individual, clearly labelled, sipper bottles.

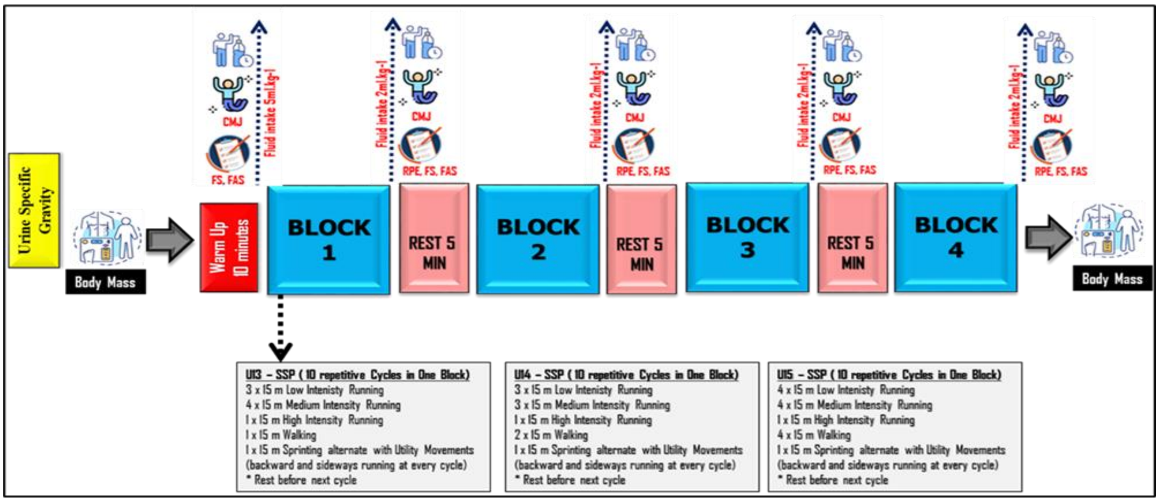
The SSP was set up accordingly for each age group; U13 performed 4 x 15-min 'blocks' of exercise (SSP-13) separated by 3 min recovery, U14 performed 4 x 17.5-min of exercise (SSP-14) separated by 5 min recovery and U15 performed 4 x 20-min of exercise (SSP-15) separated by 5 min recovery (see Figure 1). The multiple breaks also represented the 15 min rest duration during the half time interval in a soccer match. The FS and FAS scales were administered prior to exercise. Within the rest periods between exercise blocks, RPE, FS and FAS (in that order) and CMJ were administered and participants ingested the equivalent of 2 ml·kg-1 BM of water (see Figure 1). Heart rate (HR) was monitored continuously at 5-s intervals (GPSports Systems, Australia) and BM was again obtained on completion of the protocol.

SSP-13, SSP-14 and SSP-15 Protocols

These protocols were designed to replicate the activity pattern typically recorded in youth soccer. The activities during the SSP were based on match analysis data i.e. replicating total distance (m) and time spent in each match activity for each age group (Table 1). Due to a 'rolling' substitution policy, the total distances in each match were calculated in relative terms which is distance covered per playing minute (m.min-1) to accurately represent the typical distances covered in each age group.

The SSP were designed in cyclical patterns and the speed of each match activity was defined accordingly to the match speed thresholds (middle range) for each age group (Table 2).All SSPs consist of four blocks of exercise that simulates match-playing time according to age-groups. These protocols require participants to run between two lines (15 m apart) at various speeds (Figure 2). The exercises include low and high intensity activities such as walking, low intensity running, medium intensity running, and high intensity running, sprinting as well as utility movements (Table 2). At every cycle, participants were required to alternate between sprinting and utility (backward running at the first 7.5 m followed by sideways running). Speeds for each activity were dictated via an audible signal (and voice) from software specifically developed for these tests. Marker cones were placed at 7.5 m to indicate when participants should change utility movements (Figure 1). Sprint speed (km·h-1) was measured in one direction using 5 Hz GPS unit (GPSports Systems, Australia). For other performance measure, the participants performed CMJ pre, during and post-exercise (see Figure 2).

Figure 1. Schematic Representation of the SSPs for each age group



*Abbreviation: CMJ-Countermovement jump, FS-Feeling Scale, FAS-Felt Arousal Scale, RPE-Rating Perceived Exertion

Statistical Analysis

All results are reported as means ± standard deviations. Paired sample t-test was used to determine whether there were any differences in physiological and physical measures between trials for each age group. Pearson's correlation (*r*) and intra-class correlation coefficients (ICC) were used to determine the repeatability between trials set of scores. In the ICC, the "two-way random" method was used as suggested by Atkinson & Nevill, (1998). The standard error of measurement (SEM) with 95% confidence intervals (95% CI) was further used to assess the reliability. The common method to calculate is SEM = SD (√1-ICC) however this only applicable to 68% of population. To make it applicable for 95% of population this formula was used: 95% CI = 1.96 x SEM (Atkinson & Nevill, 1998). Pearson product movement correlation (r) was also used to assess the concurrent validity of the SSPs. All statistical analyses were performed with SPSS software (version 21.0, SPSS inc, Chicago, IL) with the level of significance set at p ≤ 0.05.

Table 1. The total distance covered, percentage of distance and time spent in each movement in actual match-play (match) and the soccer simulation protocol

Activity	Distance		% of distance in each match activity		% of time spent in each match activity	
	Match (m·min-1)	Protocol (m)	Match	Protocol	Match	Protocol
SSP-13 U13 (60 min protocol)						
Total distance	5700	6000				
Standing	-	-	-	-	15	16%
Walking	700	600	12	10%	25%	20%
Low Intensity Running	1800	1800	32%	30%	32%	30%
Medium Intensity Running	2000	2400	35%	40%	19%	24%
High Intensity Running	900	600	16%	10%	6%	4.4%
Sprinting	300	300	5%	5%	1.4%	1.7%
Utility movement		300		5%	* 4 %	3.3%
SSP-U14 (70 min protocol)						
Total distance	6700	6600				
Standing	-	-	-	-	14%	15%
Walking	1100	1320	16%	20%	29%	36%

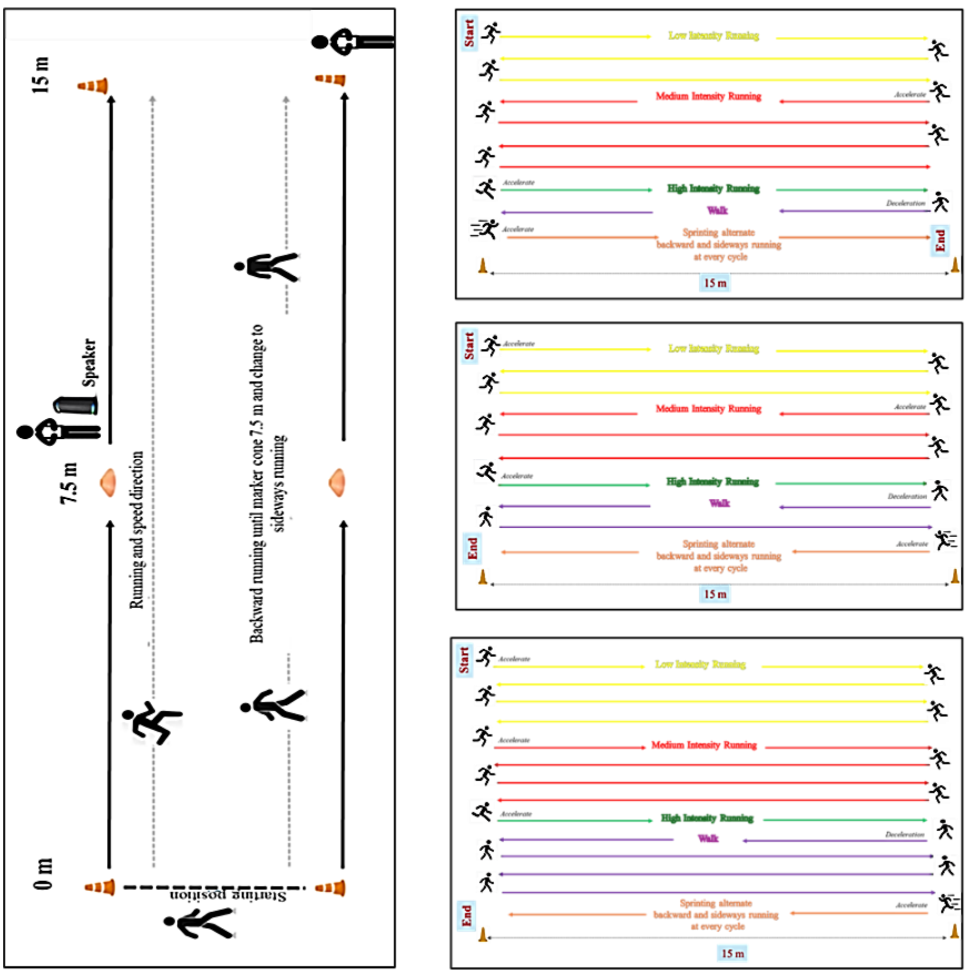
Low Intensity Running	2000	1980	30%	30%	31%	25%
Medium Intensity Running	2300	1980	34%	30%	19%	16%
High Intensity Running	900	660	14%	10%	5%	4.2%
Sprinting	400	360	6%	5.5%	2%	1.4%
Utility movement		300		4.5%	* 4%	3.4%
SSP-U15 (80 min protocol)						
Total distance	7600	7800				
Standing	-	-	-	-	14%	15%
Walking	1800	1560	24%	20%	39%	34%
Low Intensity Running	2400	2340	31%	30%	27%	28%
Medium Intensity Running	2500	2340	33%	30%	16%	15%
High Intensity Running	600	780	8%	10%	3%	3.8%
Sprinting	300	360	4%	4.6%	1%	1.5%
Utility movement		420		5.4%	* 4%	3.5%

* Utility movement was adapted from Capranica et al. (2010) which is 4% of time spent in a soccer match

Table 2. Order and running speeds for SSPs

Activity	SSP 13 (60 min protocol)		SSP 14 (70 min protocol)		SSP 15 (80 min protocol)	
	BLOCKS 4 x15 min	CYCLE 10 Cycle	BLOCKS 4 x 17.5 min	CYCLE 10 Cycle	BLOCKS 4 x 20 min	CYCLE 10 Cycle
Low Intensity Running	3 x 15 m	1.66 m.s^{-1}	3 x 15 m	1.88 m.s^{-1}	4 x 15 m	1.77 m.s^{-1}
Medium Intensity Running	4 x 15 m	2.72 m.s^{-1}	3 x 15 m	3.00 m.s^{-1}	4 x 15 m	3.33 m.s^{-1}
High Intensity Running	1 x 15 m	3.75 m.s^{-1}	1 x 15 m	3.75 m.s^{-1}	1 x 15 m	4.27 m.s^{-1}
Walking	1 x 15 m	0.83 m.s^{-1}	2 x 15 m	0.88 m.s^{-1}	4 x 15 m	0.97 m.s^{-1}
Sprinting alternate with utility movements (backward & sideways running)	1 x 15 m	Max Intensity/ 2.72m.s^{-1}	1 x 15 m	Max Intensity/ 3.00 m.s^{-1}	1 x 15 m	Max Intensity/ 3.00m.s^{-1}

Figure 2. Running direction for the SSP for U13, U14 and U15 respectively



Results

A summary of the physiological and physical measurements for both trials in the SSP-13, SSP-14 and SSP-15 is in Table 3. Summary of result for r, ICC, 95 % of CI are presented in Table 4.

Physiological Measurements

There were no differences between trials in BM loss (kg loss) (p=0.848, p=0.622, p=0.869) and similar hydrated state on both trials (p= 0.666, p=0.967, p=0.344) in these protocols (SSP-13, SSP-14 and SSP-15) respectively. The SEM was low in these variables indicating the repeatability of these protocols (Table 4)

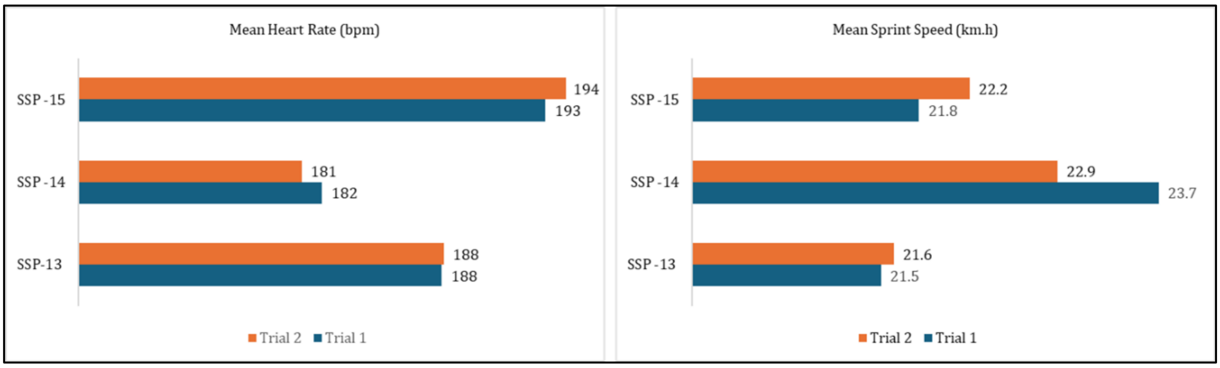
The HR data showed similar trends in all age groups. The HR increased towards the end of exercise as expected. There were no differences between trials (U13: p=0.781, U14: 0.433, U15: p=0.372) (Figure 3). High correlations were observed in U13 (r=0.86, p=0.012) and U14 (r=0.81, p=0.024), however, moderate correlation in U15 although not significant (r=0.48, p=0.341). The ICC show similar result as r (Table 4) with LOA in U13: 2.4 to 2.6 beats.min-1, U14: 7.8 to 5.6 beats.min-1 and U13: 5.0 to 7.6 beats.min-1.

Table 3. Performance and physiological measures in the soccer simulation protocol for three age groups (mean ± SD)

Measure	SSP-13 n=7		SSP-14 n=7		SSP-15 n=6	
	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
Body mass loss (kg)	-0.06 ± 0.5	-0.08 ± 0.3	0.34 ± 0.5	0.47 ± 0.7	0.33 ± 0.4	0.36 ± 0.2
USG	1.017 ± 0.01	1.015 ± 0.01	1.017 ± 0.01	1.016 ± 0.01	1.015 ± 0.01	1.019 ± 0.01
RPE	11.7 ± 1.7	10.7 ± 1.3	11.3 ± 1.2	10.9 ± 2.0	13.1 ± 0.7	12.5 ± 0.5
FS	3.2 ± 1.5	3.1 ± 1.6	3.2 ± 1.3	2.8 ± 1.9	1.0 ± 1.1	1.3 ± 1.1
FAS	3.1 ± 0.6	3.5 ± 0.8	4.3 ± 1.0	4.2 ± 1.1	2.0 ± 0.6	2.5 ± 1.3
CMJ (cm)	16.5 ± 1.9	16.4 ± 1.8	17.1 ± 1.7	17.0 ± 1.5	19.1 ± 1.4	18.9 ± 1.2
Peak sprint speed ($km \cdot h^{-1}$)	21.5 ± 2.9	21.6 ± 2.5	23.7 ± 1.2	22.9 ± 1.0	21.8 ± 0.8*	22.2 ± 0.9*
Heart rate ($beats \cdot min^{-1}$)	187.9 ± 1.8	188.1 ± 2.5	182.8 ± 2.3	181.7 ± 5.1	193.1 ± 3.6	194.4 ± 1.3

Abbreviation:
USG= Urine specific gravity
SSP-13= Soccer simulation protocol for under 13; SSP-14=Soccer simulation protocol for under 14; SSP-15=Soccer simulation protocol for under 15
RPE=Rating of perceived exertion; FAS= Felt arousal scale; FS: Feeling scale
CMJ=Counter movement jump
* Significant difference between trials $p < 0.05$

Figure 3. Mean heart rate and Sprint Speed for the SSPs



Physical Measurements

There were no differences in CMJ and peak sprint speed (Figure 4) was observed between trials in SSP-13 (p=0.829, p=0.854) and SSP-14 (p=0.656, p=0.088). A significant high correlation (Table 4) was also observed in SSP-13 for CMJ (p=0.656) and peak sprint speed (p=0.036). Meanwhile in SSP-14, a significant high correlation was noted in CMJ (p=0.001) but not in the peak sprint speed (p=0.207). Similar trend was observed in SSP-15, a significant high correlation was observed in both r and ICC for both CMJ (p=0.001, p=0.015) and peak sprint speed (p=0.001, p=0.003) respectively. The SEM in CMJ and peak sprint speed were reported lower and results in 95% CI (Table 4) providing the repeatability of these protocols.

Perceptual Scales

As expected, both trials showed the RPE increased in a linear fashion towards the end of SSPs, meanwhile the FS dropped towards the end of the protocols. Meanwhile, the trend in the FAS was undulated. Even so, all the perceptual scales (RPE, FS and FAS) followed a similar pattern of response during both trials with no significant differences between trials in all SSP's (Table 3 and 4). These provide evidence the repeatability of these protocols.

Table 4. Pearson' correlation (*r*), intra-class correlation coefficients (ICC), standard error of measurement (SEM) and 95% confidence intervals (95% CI) in SSP for three age groups

Variable	SSP-13				SSP-14				SSP-15			
	r	ICC	SEM	95% CI	*r*	ICC	SEM	95% CI	*r*	ICC	SEM	95% CI
RPE	0.76*	0.84	±0.2	±0.4	0.85*	0.86	±0.2	±0.4	0.24	0.38	±0.3	±0.6
FS	0.99**	0.99	±0.01	±0.02	0.25	0.38	±0.8	±1.6	0.82*	0.89	±0.1	±0.2
FAS	0.50	0.67	±0.2	±0.4	0.65	0.78	±0.2	±0.4	0.92**	0.82	±0.2	±0.3
CMJ	0.94**	0.97	±0.1	±0.1	0.96**	0.98	±0.02	±0.04	0.98**	0.98	±0.02	±0.04
Peak sprint speed	0.96*	0.98	±0.1	±0.1	0.95	0.96	±0.04	±0.1	0.98*	0.98	±0.01	±0.02
Heart rate	0 .87*	0.77	±0.5	±0.9	0.82*	0.76	±0.8	±1.6	0.48	0.47	±1.1	±2.3

r= Pearson's product-moment correlation; ICC= Intraclass correlation; SEM= Standard error of measurement; 95% CI= 95% confidence interval; CV= coefficient of variation
RPE=Rating of perceived exertion; FAS= Felt arousal scale; FS: Feeling scale
CMJ=Counter movement jump
* significant difference between trials p < 0.05

Validity of the Soccer Simulation Protocol

The results show that the match activities found in the U13, U14 and U15 actual match play and the SSPs were strongly correlated (r= 0.80, 0.84 and 0.85) respectively. To provide more evidence of the face validity of the SSPs, comparison between match activities was made and are shown in Table 1. It is clear that similar trends can be seen in both match play and SSPs. The largest proportion or about 60 % of the time was spent in low intensity activities ranging from walking and LIR. This was followed by MIR and about 1-3% was spent in high intensity activities. The SSPs attempts to replicate as close as possible what has been reported to occur in U13, U14 and U15 match play. A paired sample t-test was also conducted to investigate the physiological responses during match play and in the SSPs. There was a statistically significant difference (p< 0.05) in the HR scores in match play compared to the SSPs. The lower HR in the SSPs is most likely due to the lack of actual ball involvements and attacking or defending movements done in match play.

Discussion

The primary aim of this study was to assess the reliability and validity of three related soccer simulation protocols for use with young soccer players aged 12-15 years old. The main findings of this recent study approved the new SSPs is reliable and valid representation of youth soccer. Therefore, it could be used to investigate young players exercising with prolonged intermittent exercise activities that were similar to the demands found in match play. Although it is difficult to simulate every physical and physiological demand in soccer, this new SSPs tries to replicate as close as possible the actual match play and tries to minimize the limitations exhibited by previous protocols that have been set up for both adult or young players. The SSPS attempts to simulate the duration, distance covered, match running patterns and speed, number of sprints, sprint distance and physiological responses seen in actual match play. The development of this protocol included attempts to simulate the important components found in a soccer match encompassing both aerobic and anaerobic demands. During prolonged soccer match play, the key factors to performance is the ability to sustain prolonged intermittent running and perform repeated sprints or high intensity activities. As has been discussed earlier, in the literature, about 90% of demand in soccer is from aerobic activities and about 10% is from anaerobic activities (Angius, Olla, Pinna, et al., 2012).

The reliability of this new protocol was established through the conduct of two main trials separated by a period of 7 days. This allowed sufficient time for players to rest between trials and this time frame was in line with other reliability studies that examined the repeatability of similar new protocols (Da Silva et al., 2020; Nicholas et al., 2000). It was found no differences in BM loss, USG, RPE, FAS, FS CMJ, peak sprint speed and HR between these two trials This supports the hypothesis mentioned earlier that physiological and physical measurements could be similar between trials. Trend showed that HR and RPE increased, and sprint decreased towards the end of the protocols as was expected. There was a linear progressive increase in RPE and HR and decreases in sprint seen in both trials and this indicated that there was a similar internal load throughout of the exercise performed. This trend was also reported in other studies where it was found that HR and RPE both increased: 115 ± 5 to 165 ± 9 beats.min-1 and 11 to 17 (Tatcher & Batterham, 2004) and 160 to 200 beats.min-1 and 12 to 18 respectively (Coratella, Beato, & Schena, 2016) with a few other studies reporting an increment in HR throughout the protocol (Nicholas et al., 2000; Russell, Rees, Benton, & Kingsley, 2011; Sirotic & Coutts, 2008). In these protocols, the speed data was attained through maximum speed effort performed by the participants and their actual data was recorded using a 5 Hz GPS unit carried by each of them. The decrement seen in sprint performance is typically observed in soccer match play and this is also in line with other protocols such as the BEAST90 (Williams et al., 2010) and the original Lougborough Intermittent Shuttle Test (Nicholas et al., 2000). These suggest that the SSPs induce a similar physiological load to soccer match play and consistent when the SSP's perform repeatedly. Nevertheless, it was observed the mean HR and peak sprint speed was slightly low compared to the match data, which can be justified because there is no involvement of the ball or game situation such as attacking or defending (Atan & Kassim, 2020). We also had included the sideways and backward running (3-4%) time spent in this activities to add novelty in this SSP. To date, no single simulation protocol was found to be valid and reliable and has been developed directly from match analysis data in young soccer players. The replication of suitable match activities and their associated physiological load in conjunction for a youth football protocol has so far been unsuccessful as previous protocol that been used to investigate young players is a modified version of adult protocol. These constraints include; did not replicate the playing duration in the actual football matches, the protocol was not develop from match analysis data to replicate the physical and physiological demands of youth football, lack of ecological validity in the protocol, no reliability or validity information have been disclosed despite these two components being essential in performance testing (Atan & Kassim, 2020).

Overall, the SSPs showed moderate to excellent test-retest reliability for all variables apart from FS ratings for SSP-U14 and HR in SSP-U15. Further assessment of the reliability was determined by SEM and 95 % CI analyses. These two analyses were suggested by several other researchers for use in determining reliability (Atkinson & Nevill, 1998, 2001). When the scores of SEM were small or equal to 0, then the test is considered to be reliable. In this present study the SEM values were found to be from 0.01 to 0.8 (except for the HR in the U15 was 1.1), thus indicating small values and thereby supporting that the protocol was consistent and repeatable.

The development of the SSP has several important purposes as research tools. It is now possible to investigate this specific age group using a reliable and valid protocol. At present, there is limited studies investigating the effects of various ergogenic aids/training interventions upon soccer performance (preparatory or half time strategies). This protocol is suitable for the examination of young soccer players because it has reasonably similar specific movements such as repeated sprint movements, intermittent running and may include specific soccer skills (seen as room for improvement in the future). There has been limited research done compared to adults as there were limited tools developed that were suitable for this population. This protocol can therefore be used when evidence is required with regards to the testing of the efficacy of treatments or interventions such as nutritional, training or other ergogenic aid interventions that may help improve soccer performances. With this protocol, the researcher has greater experimental control over the research participants compared to real match play and the effectiveness of treatments can be performed under controlled conditions as needed. Having evidence that carbohydrate-electrolyte (CHO-E) ingestion in adults have a significant enhancement in intermittent endurance capacity as well as better maintenance of skill and sprint performance, improved thermoregulation and reduced risk of heat injury (Atan & Kassim, 2019), more and more people wondering if young athletes will experience the same advantage of CHO-E ingestion as their adult counterparts. Data from match analysis studies of youth soccer suggest that children do not perform an abbreviated version of the running demands of adults (Atan, Foskett, Ali, 2014). The currents SSP's were developed based on the match duration as determined by FIFA for the age categories. The multiple breaks represented the 15 minutes' rest duration during the half time interval in a soccer match. In the SSP's duration are represented by 4 exercise blocks separated by 3 x 5 minutes' rest breaks. These multiple breaks have been included in order to provide time for the consumption of fluids and to allow time for intervention purposes (for future research).

Furthermore, in the context of return to match play following rehabilitation, the protocol provides a controlled environment in which players can safely reintroduce match-specific movements. The SSPs expose players to levels of physical and psychological stress comparable to typical soccer match play, allowing them to practice intentional movements (e.g., changing direction), assess readiness, and gradually adapt to game-like demands without the unpredictability of full competitive matches in a non-contact and controlled setting (Bossuyt, García-Pinillos, Raja Azidin, Vanrenterghem, & Robinson, 2016). This highlights the protocol's practical value not only for performance assessment but also as a structured tool to guide safe and effective return-to-play strategies. It could also serve as a test battery for talent identification or as an evaluation tool when selecting young players, providing an objective assessment of each player's readiness. By quantifying performance capabilities, it offers valuable feedback to both players and coaches, highlighting individual strengths and areas for improvement.

The advantages of this current SSP's that it is easy to replicate and be set up by future researchers or for use by coaching staff in a soccer team. Limited tools and equipment are needed and no complicated software is required, therefore this makes the SSPs easily accessible at different levels of soccer play. Moreover, the SSPs can be 1) performed indoors (researchers can control environmental conditions) or outdoors (natural grass or artificial surface), and players can wear their regular soccer footwear); 2) peak sprint speeds can be measured either using sprint gates, stopwatches or with GPS. With sprint gates, 1 to 4 participants can be tested simultaneously while GPS would offer more accurate data collection and more participants measured at any time throughout the protocol. For these reasons, these SSP's provides a practical method that is both sufficiently accurate and reliable for assessing young soccer players. However there is no study without limitation. First, it excludes physical contact, a key aspect of match play that affects movement, fatigue, and physiological responses. Second, soccer-specific technical and tactical skills, such as dribbling, passing, and decision-making, are not included, as the focus is primarily on physical demands like total distance covered and running at different intensities. Future research could integrate these elements to enhance the ecological validity of the SSP's.

Conclusions

In conclusion, these SSPs replicate as close as possible the typical movement patterns and replicate similar physiological response in soccer match play in young players (aged 12-15 y). Simulating the same variables in soccer match-play into a standardise protocol is quite challenging as there are many other variables should be included such as ball involvements, physical contacts with opponents or other psychological stress during match play. Limitation to this current protocol that can be improved by future study is to include physical contact and soccer skills such as passing, dribbling and shooting in these SSPs, therefore may enhance the ecological validity of this protocol.

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