# An Exercise Protocol that Replicates Soccer Match-Play

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## Abstract

This study compared the demands of a soccer match simulation (SMS) incorporating 90 min of soccer-specific movement with passing, dribbling and shooting skills with those of competitive match-play (match). 10 elite youth soccer players participated in SMS and match-play while ingesting fluid-electrolyte beverages. No differences existed between trials for mean HR (SMS, match: $158 \pm 4$ beats·min$^{-1}$, $160 \pm 3$ beats·min$^{-1}$; $P = 0.587$), peak HR (SMS, match: $197 \pm 3$ beats·min$^{-1}$, $197 \pm 4$ beats·min$^{-1}$; $P = 0.935$) and blood glucose concentrations (SMS, match: $4.5 \pm 0.1$ mmol·L$^{-1}$, $4.6 \pm 0.2$ mmol·L$^{-1}$; $P = 0.170$). Inter-trial coefficient of variation (with Bland and Altman limits of agreement) were 2.6% (−19.4–15.4 beats·min$^{-1}$), 1.6% (−14.3–14.7 beats·min$^{-1}$) and 5.0% (−0.9–0.7 mmol·L$^{-1}$) for mean HR, peak HR and blood glucose concentrations. Although the pattern of blood lactate response was similar between trials, blood lactate concentrations were higher at 15 min in SMS when compared to match. Notably, blood glucose concentrations were depressed by $17 \pm 4$% and $19 \pm 5$% at 15 min after half-time during match-play and SMS, respectively. Time spent completing low-intensity, moderate-intensity and high-intensity activities were similar between trials ($P > 0.05$). In conclusion, the SMS replicates the physiological demands of match-play while including technical actions.

## Introduction

Soccer is a high-intensity intermittent sport which is normally played over 90 min, split into two 45 min halves that are separated by a 15 min half-time period. As one of the world's most popular sports, the impact of findings from soccer research are relatively wide-reaching; consequently, several protocols have been developed to replicate the demands of competition e.g., [20, 28, 34, 35, 51]. The primary purpose of these simulations is to control movement patterns and standardise physiological demands. In doing so, the variation in responses that exists during match-play is limited and the effects of exercise become repeatable. The most obvious benefit of simulations is that they allow for more prominent effects to be identified in sometimes subtle physiological changes resulting from supplementation protocols, strength and conditioning regimes, and/or other performance altering interventions.

Soccer is primarily aerobic in nature [4]; however, performance is heavily influenced by anaerobic actions such as those involved in the execution of skills. Notational analysis has evaluated the frequency of soccer skills undertaken throughout match-play with the most frequent actions being passing and dribbling [41, 46]. As the aim of soccer is to score more goals than the opposition, shooting is a crucial skill [50]. Nevertheless, the inclusion of ball skills throughout exercise protocols that aim to replicate the demands of a soccer match-play is rare; this is somewhat surprising because proficiency in ball skills is likely to contribute to success because longer passing sequences, where more passes are completed successfully, have been shown to produce more goals in successful teams [27] and technical aspects of game-play appear more important than the performance of high-intensity physical activity in determining success [18].

Several motorised treadmill protocols have been used to simulate soccer e.g., [20, 51]; however, the unidirectional nature of treadmills and the inability to induce maximal running speeds limit these protocols. A commonly used free-running intermittent exercise simulation protocol is the Loughborough Intermittent Shuttle Test (LIST).

The LIST has been extensively used to examine the effects of various ergogenic aids upon exercise performance e.g., [23, 33, 37]. The original version of the LIST included 75 min of intermittent activity and a run to exhaustion. However, the omission of game-specific skills, some of which have been previously found to have an energy consuming consequence [45] and have the potential to cause additional physiological demand (e.g., muscle damage from high-speed eccentric activity during kicking), reduces the ecological validity of the LIST.

Relatively few protocols exist that have included soccer skills throughout exercise [15, 24, 42] as opposed to those that have included skilled actions before and after exercise [2, 30, 31, 39]. Furthermore, the authors are not aware of any study examining the validity of such protocols by comparing the demands of simulated and actual soccer match-play using a within-subject study design. This is surprising considering that valid comparisons require the same population to be examined under both conditions [15]. Therefore, the aim of this study was to compare the physiological, movement and skill demands of a soccer match simulation with the demands of actual match-play.

## Methods

### Participants

10 soccer players (age: 15 ± 1 years, height: 1.74 ± 0.01 m, mass: 64.3 ± 1.2 kg, estimated $\dot{V}O_{2max}$: 55.8 ± 0.9 $ml \cdot kg^{-1} \cdot min^{-1}$) from the youth department of a club that competes in the English Championship volunteered to participate in the study. After approval by a university ethics committee, all players participated in both soccer match simulation (SMS) and actual match-play (match) trials. The potential risks of the study were explained and written informed consent was obtained from both players and parents/guardians before participation. The study meets the ethical standards of the journal [26]. Players were recruited on the basis that they had no injuries, were non-diabetic, did not smoke, and had regularly participated in training with a soccer team of academy standard for at least 12 months.

### Experimental design

All players attended 3 preliminary visits. The first 2 sessions incorporated practice of the main trial procedures and the remaining visit served to estimate aerobic capacity via the multistage fitness test and associated equation [43]. With the endeavour to ensure that participants started the trials in a similar physiological status, the match and the SMS trials were completed within 4 ± 1 days and players were asked to refrain from strenuous physical activity and caffeine consumption in the 2 days preceding testing sessions. Additionally, players recorded all food consumed in the 2 days before each main trial. Food records were subsequently analysed using commercially available software (CompEat version 5.8.0; Nutrition Systems, UK). All players gave verbal confirmation that they had complied with these instructions upon completion of the study.

### Main trial procedures

Upon arrival at the laboratory the players emptied their bowels and provided a mid-flow urine sample. Urine osmolality was subsequently measured by freezing point depression as a marker of baseline hydration status (Gonotec Cryoscopic Osmometer Osmomat 030; YSI Limited, UK: Intraassay co-efficient of variance = 0.2 %). A standardised 1 470 kJ meal (Energy content: 62 % carbohydrates, 25 % fats, 13 % proteins) and 500 ml of a fluid-electrolyte beverage were provided before body mass (model 770; Seca Ltd, Birmingham, UK) and stature (Portable Stadiometer; Holtain Ltd, Wales, UK) were measured. Players then remained in a rested state for approximately 120 min before commencing a standardised warm-up (consisting of running, dynamic stretching and ball skills) that preceded exercise. Main trial procedures are illustrated in ▶ **Fig. 1**.

### Soccer Match Simulation (SMS)

The SMS was performed on a synthetic running track in an indoor training facility with air temperature of 16.8 ± 0.4 °C, ambient pressure 764 ± 1 mmHg and humidity 66 ± 3 %. Participants were required to perform soccer shooting, passing and dribbling skills throughout two 45 min halves of soccer-specific activity separated by a 15-min passive recovery period (half-time). The exercise protocol was a modification of the LIST [35] adapted to include additional components that further replicate the movement demands of soccer match-play [28]. Movements were dictated by audio signals from CDs and participants alternated between sprinting and dribbling during each cycle.

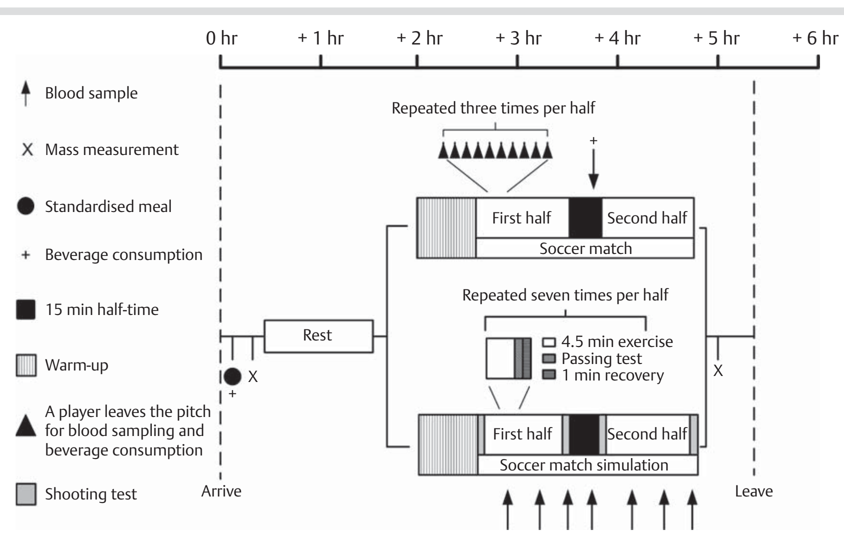


**Fig. 1** Schematic of the study design. After a standardised meal and warm-up the participants completed 2 main trials (SMS and match).

More specifically, exercise was made up of 4.5-min blocks consisting of 3 repeated cycles of three 20-m walks, one walk to the side, an alternating timed 15-m sprint (Brower timing gates; Utah, USA) or a 20-m dribble, a 4-s passive recovery period, five 20-m jogs at a speed corresponding to 40% $\dot{V}O_{2max}$, one 20-m backwards jog at 40% $\dot{V}O_{2max}$ and two 20-m strides at 85% $\dot{V}O_{2max}$. A 2 min period of soccer passing (1 min) and recovery (1 min) followed all blocks of exercise (▸ **Fig. 1**). 7 blocks of intermittent activity and skills were completed during each half of exercise. The participants covered a total distance of 10.1 km and completed 93 on-the-ball actions during the protocol (56 passes, 16 shots, and 21 dribbles), where the frequency of on-the-ball activities were similar to those performed during games in the English Football Association Premier League [12].

▸ **Fig. 2** shows the layout of the shooting and passing skill tests. Balls (Total 90 Aerow: size 5; Nike Inc., USA) were released from a ramp at a constant speed of $2.3\,m \cdot s^{-1}$ towards a 1.5 × 1.5-m square (action zone), where participants were instructed to kick the ball. The participants kicked towards one of 4 randomly determined targets (identified by a custom lighting system); consequently, the players carried out visual searching and decision making during all attempts (similar to a soccer match when looking for space or other players). Motion sensors on the ramp ensured standardization and repeatability. A delay of 0.64 s separated target identification and the ball reaching the centre of the action zone.

Participants started the shooting and passing skill tests from a standing position before jogging into the action zone when the ball was released. The 2.0 × 1.0-m passing targets were placed at distances of 4.2 m (short pass) and 7.9 m (long pass) away from the centre of the action zone. The shooting target was a standard 11-aside adult soccer goal measuring 7.33 × 2.44 m with transparent netting stretched across it. 4 target lights were placed in the corners of the goal (positioned 1.0 m horizontally inside each post and 0.5 m vertically inside the upper and lower edges of the goal) as this has been identified as optimal ball placement to beat a goalkeeper when shooting [1].

The participants were instructed to aim passes at the centre of the target that was illuminated. When shooting, participants were instructed to kick the ball as accurately as possible at the illuminated target within the goal. The bouts of passing and shooting consisted of 4 attempts, where the ball was alternately delivered from the right and left side of the action zone. To enhance ecological validity, no prior touches were allowed to control the ball [38] and participants kicked with the foot that was most suitable to successfully complete the task.

The layout of the dribbling task was similar to that employed by McGregor et al. [31] with start and finish lines placed 20-m apart. Cones 2 through 7 were placed 3-m apart, and cones 1 and 7 were 1-m away from each end of the course. Participants were instructed to dribble the ball as fast and as accurately as possible between all cones.

The outcomes for the skill tests were not determined for this study; however, the construct validity and reliability for the speed, precision and success of passing, shooting and dribbling have been previously determined [49], where test-retest reliability was determined for 20 habituated male soccer players (10 professional and 10 recreational).

## Soccer match

The same players who completed the SMS (termed the test team) played a match against a local rival team of similar playing standard (the 3 previous results between the teams differed by only one goal). The match, which was an additional fixture added to both teams competitive calendar for the purpose of this study, took place at a location that was familiar to all players (i.e., the venue was shared by both teams on home match-days) and approximately 100 spectators attended. An official referee was used and the match was 90 min in duration; consisting of two 45 min halves separated by a 15 min half-time (▸ **Fig. 1**). The match was played with official balls (Total 90 Aerow: size 5; Nike Inc., USA) and took place on a floodlit grass pitch measuring 95 × 68 m that conformed to FA regulations. Environmental conditions during match-play were 12 °C (air temperature), 749 mmHg (barometric pressure) and 80% (relative humidity).

The outfield players of the test team ($n$ = 10) were subject to periodic blood sampling and left the pitch on 6 occasions during match-play (i.e., once every 15 min). To ensure minimal disruption to the match, players were removed individually and in an order that remained consistent between time-points. The match was divided into six 15 min periods (first half: 0–15, 15–30, 30–45 min; second half: 45–60, 60–75, 75–90 min). 2 min into each of these periods, the first player left the pitch for blood sampling (i.e., after 2, 17, 32, 47, 62 and 77 min of match-play). When the first player returned to the match, the next player left the pitch; this sequence continued until the 10 players had been sampled within each 15 min period. Consecutive blood samples were separated by 1.5 ± 0.1 min.

In order to maintain the standard number of players on the pitch at all times, one utility player (deemed by coaching staff as able to fulfil all positional demands) was used as a substitute. The substitute changed positions as players left the pitch for blood

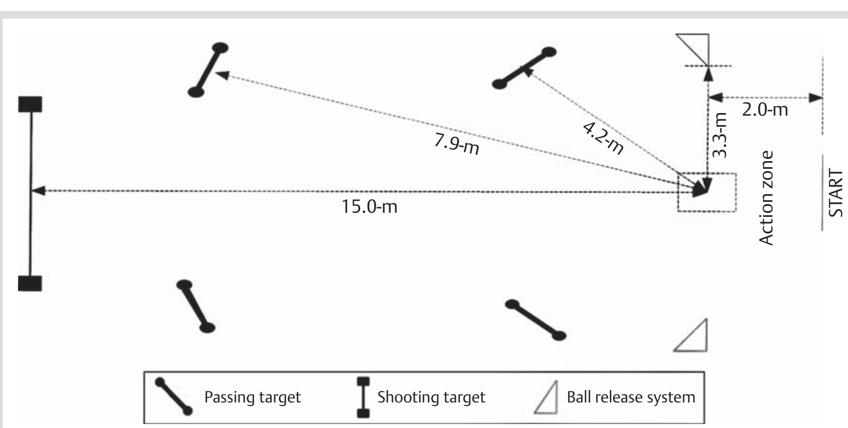


**Fig. 2** Schematic of the passing and shooting tests identifying the position of the ball release ramps, action zone, passing targets and shooting targets.

sampling. He was not subject to analyses and did not play for the first 2 min of each 15 min period.

Notational analysis data from the test team was collected using 3 cameras (DCR-HC96E; Sony Ltd, UK); 2 cameras were positioned such that the whole pitch was in view at all times and the third camera that tracked on-the-ball activity was positioned in an elevated viewpoint overlooking the half-way line. Match footage was analysed using software designed to track player movement (SportsCode; Sportstecinternational.com). Player movements were classified according to predefined operational definitions [16], with movements being categorised as one of 5 movement types (i.e., walking, jogging, striding, sprinting/dribbling or backwards jogging), which were exclusive to all others. Movement demands are expressed as the percentage of total exercise time that each modality represents whereas skilled demands reflect the total number of on-the-ball actions performed throughout match-play. In addition, on-the-ball activities were determined, as previously described, during 4 competitive league matches played by the test team at the home venue (control games). These analyses were performed in order to compare the technical requirements of the experimental match with normal league matches. All analyses were performed by a coder who had extensive experience using the software with a team competing in the English Championship. Intra-observer reliability was examined by analysing the physical and skill demands of one player throughout the full duration of the match on 2 separate occasions (separated by no longer than 7 days). The variation between these data was within the 10% limit recommended by Reed and Hughes [44]; specifically, differences between outcomes on these 2 occasions were 0% (frequency of on-the-ball skills), 1.3% (walking), 0.2% (jogging), 9.8% (stride), 3.0% (sprint/dribble) and 5.2% (backwards jogging).

### Blood sampling and metabolic measurements

Blood samples were taken throughout exercise (SMS: 15, 30, 45, 60, 75, 90 min; match: 0–15, 15–30, 30–45, 45–60, 60–75, 75–90 min) and at half-time. Whole blood samples were analysed using portable lactate (Lactate-Pro; Arkray, Japan) and glucose (Medisense Optium Xceed Glucose monitor; Abbott Laboratories, USA) analysers which were calibrated in accordance with the manufacturers' guidelines before all trials. Blood lactate concentrations provided a gross indication of the anaerobic contribution to exercise and blood glucose concentrations were measured in order to compare systemic carbohydrate availability during the SMS and match. The inter-assay coefficients of variance for blood glucose and lactate concentrations were 2.6 and 4.8%, respectively.

### Physiological measurements

Heart rate (HR) was continuously recorded throughout each trial using short-range telemetry (Polar S610; Polar, Finland) as a marker of exercise intensity. Mass losses were calculated as urine corrected differences in mass between pre and post exercise measurements. Environmental conditions were measured at the start of exercise (ETHG-912; Oregon Scientific, USA).

### Fluid intake

An initial bolus of fluid (500 ml) was consumed with the standardised meal, and additional fluid was consumed during the trials at a rate of $14\,ml \cdot kg^{-1} \cdot h^{-1}$ BM. Equal volumes were consumed 10 min before commencing each half of exercise and once every 15 min throughout exercise. During both trials, players consumed a carbohydrate-free electrolyte beverage which was flavoured with a commercially available fruit cordial (Carbohydrate content $<0.1\,g \cdot L^{-1}$). In the month before the practice sessions began players ingested water at a rate of $14\,ml \cdot kg^{-1} \cdot h^{-1}$ BM during training sessions in order to promote gastric tolerance to this rate of fluid ingestion.

### Statistical analyses

Statistical analysis was carried out using SPSS software (Version 16.0; SPSS Inc., USA). All data were reported as the mean ± standard error of the mean (SEM) and statistical significance was set at $P \leq 0.05$. For variables with single time points, ranges of limits of agreement (LOA) were calculated using previously described methods [11] to describe the magnitude of bias, inter-trial differences were evaluated using paired samples t-tests and inter-trial coefficient of variance (CV) were determined to assess random error. 2-way repeated measures analyses of variance (ANOVA; within-subjects factors: time of sample × trial) were used where data contained multiple time points during main trials. Mauchly's test was consulted and Greenhouse-Geisser correction was applied if the assumption of sphericity was violated. If a significant *P*-value was identified for the interaction effect (trial × time), trial was deemed to have influenced the exercise response and simple main effect analyses were performed. Significant main effects of time (time of sample) were further investigated using multiple pairwise comparisons with Bonferroni confidence interval adjustment.

## Results

Anthropometric characteristics were similar between trials ($P > 0.05$) and players arrived in a similarly hydrated state on both occasions ($568 \pm 7\,mOsmol \cdot kg\ H_2O^{-1}$). Macronutrient intakes were similar between trials; daily energy intake was $9.0 \pm 1.0\,MJ \cdot d^{-1}$, with 54 ± 2%, 28 ± 2%, and 17 ± 1% being obtained from carbohydrates, fats, and protein, respectively.

### Demands of exercise

▶ **Table 1, 2** present the movement and technical demands of the SMS compared to the match. The proportion of time that participants completed low-intensity activities (standing and walking), moderate-intensity activities (jogging and striding) and high-intensity activities (sprinting and dribbling) were similar during the SMS and match trials, being 38% and 37 ± 1% ($P = 0.07$), 57 and 58 ± 1% ($P = 0.29$), and 5% and 5 ± 0% ($P = 0.92$) for SMS and match, respectively. The frequency of technical actions performed during the match were similar to those recorded in the control games ($F_{(4, 36)} = 1.461$, $P = 0.261$; ▶ **Table 2**), where the between-match CV for the number of on-the-ball activities performed during the control matches was 8.3%. The frequency of on-the-ball activities during the SMS (93) was higher than match-play (59 ± 6) ($P = 0.005$; ▶ **Table 2**).

**Table 1** The percentage of time spent in each movement modality throughout 90 min of simulated (SMS) and actual match-play (match).

| Activity | SMS | Match | LOA Range |
|---|---|---|---|
| walk (% time) | 38 | 37 ± 1 | −2.1–4.2 |
| sprint (% time) | 5 | 5 ± 1 | −2.4–2.4 |
| jog (% time) | 49 | 47 ± 1 | −4.5–7.9 |
| stride (% time) | 8 | 11 ± 1 | −5.0– −0.7 |

Sprint velocities reduced throughout the SMS trial with sprints in the last 15 min being slower than the first 15 min (75–90 min, 0–15 min: 5.74±0.07 m·s$^{-1}$, 5.94±0.09 m·s$^{-1}$; time effect: $F_{(5, 45)}$ = 3.733, $P$ = 0.007).

## Metabolic and physiological responses

Mean HR in the SMS and match were 158±4 beats·min$^{-1}$ and 160±3 beats·min$^{-1}$ ($P$ = 0.587), which represented 77±2% and 78±2% of maximal values, respectively. Peak HR data were also similar between trials (SMS, match: 197±3 beats·min$^{-1}$, 197±4 beats·min$^{-1}$, $P$ = 0.935), representing 96±1% and 96±2% of maximal values for the SMS and match, respectively. The average 5 s HR response throughout both trials is illustrated in ◉ **Fig. 3** and the lower and upper LOA ranges (with CV data) for mean and peak HR between trials were −19.4–15.4 beats·min$^{-1}$ (2.6%), and −14.3–14.7 beats·min$^{-1}$ (1.6%), respectively.

Blood lactate concentrations peaked at 15 min of exercise and decreased from this sample onwards (time effect: $F_{(6, 54)}$ = 4.923, $P$ < 0.001). The pattern of response was similar between trials (time × trial interaction effect: $F_{(6, 54)}$ = 0.526, $P$ = 0.786). However, differences existed between trials for mean blood lactate concentrations (trial effect: $F_{(1, 9)}$ = 5.839, $P$ = 0.039, ◉ **Fig. 4**), with values at 15 min being 60±23% higher during the SMS when compared to match ($P$ = 0.042).

Blood glucose concentrations followed a similar pattern of response during both trials (time × trial interaction effect: $F_{(6, 54)}$ = 1.847, $P$ = 0.170, ◉ **Fig. 4**), with reductions from initial values occurring at 60 min (time effect: $F_{(6, 54)}$ = 8.961, $P$ < 0.001). LOA ranges (with CV) for mean lactate and glucose concentrations between trials were −3.7–8.5 mmol·L$^{-1}$ (34.4%) and −0.9–0.7 mmol·L$^{-1}$ (5.0%), respectively. Fluid intake was similar between trials (SMS, match: 1.85±0.08 L, 1.85±0.09 L, $P$ = 0.493); however, mass losses during SMS exceeded match (SMS, match: 1.7±0.2 kg, 0.6±0.2 kg, $P$ = 0.005).

## Discussion

▼

The primary aim of this study was to determine whether a soccer match simulation that incorporates technical actions (i.e., skills) was representative of the demands of actual match-play in terms of the physiological, movement and technical responses in elite junior soccer players. Total time spent undertaking low-intensity activities (standing and walking), moderate-intensity activities (jogging and striding) and high-intensity activities (sprinting and dribbling) were similar during the SMS and match. Heart rates and blood glucose concentrations during the SMS were representative of match-play. Although blood lactate concentrations followed a similar pattern during the SMS and match,

**Table 2** Distribution of technical actions during the match organized for the purpose of this study (match), control matches, simulation (SMS), and published data for Italian Serie A players [40] and for English Premier league players [12].

| Technical action | Frequency | | | | |
|---|---|---|---|---|---|
| | Match | Control matches | SMS | Rampinini et al. [40] | Bloomfield et al. [12] |
| ball involvements | 59±19 | 52±15 | 93 | 35–45 | 111±77 |
| passes | 34±13 | 24±10 | 56 | 23–32 | n/a |
| clearances | 2±3 | 3±2 | n/a | n/a | n/a |
| interceptions | 6±4 | 5±3 | n/a | n/a | n/a |
| blocks | 1±1 | 1±0 | n/a | n/a | n/a |
| crosses | 1±1 | 1±1 | n/a | n/a | n/a |
| shots | 1±1 | 1±1 | 16 | 1–2 | <5 |
| dribbling | 7±3 | 6±2 | 21 | n/a | 18±18 |

Data from Match, Control matches and reference [12] are mean ± SD. Data from reference [40] are range. No significant differences exist between Match and Control match. n/a signifies that values are not available

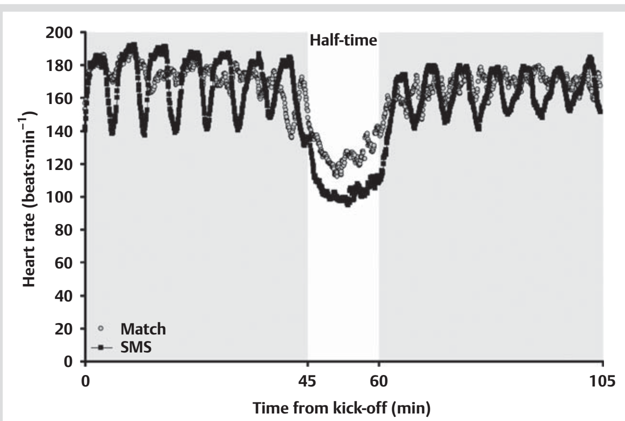


**Fig. 3** Average 5 s HR data for simulated (SMS) and actual match-play (match).

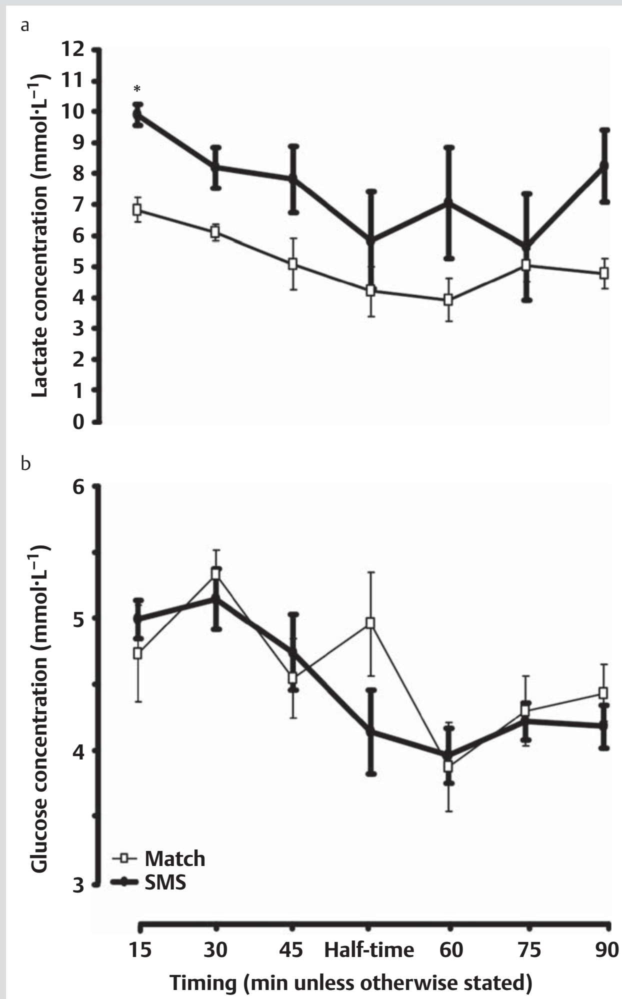


**Fig. 4** Blood lactate concentrations (**a**) and blood glucose concentrations (**b**) throughout simulated (SMS) and actual match-play (match).

blood lactate concentrations at 15 min of exercise were higher in SMS when compared to match. Notably, the reduction in blood glucose concentrations that occurred during the initial stages of the second half of exercise during the match was also present at the corresponding time-point in the SMS.

Throughout both trials, mean and peak HR values were representative of the intensities previously observed in match-play [4,5,29]. Based on CV and LOA data for mean and peak HR, the SMS replicated the demands of the match played for the purpose of this study; furthermore, no differences existed between trials in either peak (SMS, match: $197 \pm 3$ beats·min$^{-1}$, $197 \pm 3$ beats·min$^{-1}$, $P=0.935$) or mean HR (SMS, match: $158 \pm 4$ beats·min$^{-1}$, $160 \pm 3$ beats·min$^{-1}$, $P=0.587$). Consequently, physiological responses that are reflective of exercise intensity were similar for the SMS and match trials, and were also representative of the values previously observed during soccer match-play [29].

The variation in demands placed on individual players, and their response to them, makes the study of actual matches too variable to realistically expect noticeable changes following interventions. The alternative is to use an analogue of soccer which reflects the movement patterns and physiological demands of the sport while ensuring the repeatability of the exercise protocol. The audible signals used in the SMS were effective in standardising movement modalities and intensities (except for sprinting and technical actions in which maximal performance is encouraged); consequently, limited opportunities exist for participants to use self-pacing strategies. Although the frequency of physical and skilled movements remains consistent between repeated SMS trials, the blood lactate concentrations during the initial stages of exercise (i.e., 0–15 min) were higher during the SMS when compared with the actual match-play. This finding probably reflects an inability to alter the duration of recovery between successive exercise bouts of high-intensity exercise during the SMS, whereas self-pacing strategies allow blood lactate concentrations to be moderated during the initial stages of match-play. In addition, it is important to acknowledge that the design of the SMS meant that blood samples were taken within 2 min of high-intensity activity and that blood lactate concentrations collected during soccer-specific exercise are largely dependent on prior activity in the immediate pre-sampling period [5]. Nevertheless, values elicited by the SMS reflected those that have been previously observed in soccer players [29].

Mean blood glucose concentrations during the SMS were representative of the values achieved during the match and published literature [29]. Compared to initial values we observed a reduction in blood glucose concentrations in the order of $17 \pm 4$% and $19 \pm 5$% at the onset of the second half of exercise (termed exercise-induced rebound glycaemic response) in both the match and the SMS trials, respectively. Reductions in blood glucose concentrations have been reported to occur after half-time during soccer match-play [6]; however, this is the first study to identify an exercise-induced rebound glycaemic response during simulated and actual match-play while players are routinely receiving a carbohydrate-free fluid-electrolyte beverage. Considering that previous researchers have incorporated less frequent blood sampling than employed during this study e.g., [10,13,39], it is possible that the exercise-induced rebound glycaemic response has not been identified previously due to a lack of sampling resolution. Impaired blood glucose concentrations have been associated with reduced cognitive [8,9] and physical [2,36,52] performances. As soccer requires the execution of sports-specific skills during high-intensity intermittent exercise, and the brain is primarily dependent upon blood glucose for maintenance of cerebral function [21], exercise-induced reductions in blood glucose concentrations have the potential to influence skilled performances in soccer. In respect to this hypothesis, Bandelow et al. [3] recently demonstrated that higher blood glucose concentrations were associated with faster visual discrimination, faster fine-motor speed and faster psycho-motor speed after soccer match-play in the heat. Nevertheless, the relationship between blood glucose concentrations and skill performance during soccer remains to be determined.

A general consensus exists that top outfield players cover distances in the region of 10–12 km per game with the majority of distance covered by walking and low-intensity running [17,22,32,47,48,53]; however, in comparison to their senior counterparts, the movement demands of elite junior soccer players during match-play has received relatively little attention. Notational analysis data collected during this match identified that elite junior players also spent the majority of total exercise time engaging in low- and moderate-intensity locomotion ($37 \pm 1$% and $58 \pm 1$%, respectively). This finding supports previous data from Brazilian youth soccer players during match-play [40]. Throughout 90 min of the SMS, participants covered a total distance of 10.1 km; of which walking (38%), jogging (49%) and striding (8%) accounted for the greatest proportions of total exercise time. Consequently, the SMS replicates the physical demands of soccer match-play and replicates movement in a manner that corresponds to previously published values [17,47,48,53].

The exercise protocol used in this study was a modified version of the LIST which has been adapted to include additional movement components to further replicate the demands of soccer match-play [28]. Additionally, the SMS incorporates soccer-specific skills and a 15-min half-time period, which further enhances the ecological validity of this protocol. Relatively few studies have incorporated ball skills throughout soccer-specific exercise protocols [15,24,42]. This is somewhat surprising considering the energy consuming consequence of such actions [45], and the potential that technical aspects of the game have in determining the result of a fixture. Although the total number of on-the-ball activities performed during the SMS (93) was greater than comparable actions performed during the match ($59 \pm 6$; ▶ **Table 2**), periodically removing players from the field of play to obtain blood samples reduced the opportunity for the participants to perform technical skills during match-play. In addition, the SMS can provide outcome measures for passing, shooting, and dribbling with demonstrated test-retest reliability and construct validity [49].

The pattern of activity in the SMS enabled the consumption of fluid throughout exercise in such a way that adheres to published guidelines e.g., [14] and reflects the hydration regimes used by professional sports teams. In addition, the protocol allows researchers to administer interventions without compromising movement demands or gastric tolerance. Despite fluid intake being similar in both trials, more body mass was lost during the SMS when compared to match-play. It is likely that this finding reflects differences in the environmental conditions that were associated with the test locations, where the SMS was undertaken in an indoor training facility and the match was played outdoors. Nevertheless, mass losses observed in the SMS and the match were similar to those observed by previous authors [7].

This study demonstrates that the SMS is a tool that simulates soccer-specific activity while monitoring physiological responses. In addition, its design also enables the measurement of skilled performances throughout soccer-specific activity. When such data are required, the layout of the SMS can incorporate video cameras that enable the assessment of technical performances throughout 90 min of intermittent exercise.

2 important considerations in validation studies are the extent to which the protocol agrees with an established technique [11] and the degree to which the protocol emulates the real-world situation (i.e., ecological validity). The present study uses a within-participant design to compare the physiological, movement and skill demands of the SMS with actual match-play. Although within-participant comparisons are suitable for validity studies because the influence of inter-subject variation is controlled, game-to-game variations in the demands of game-play might limit the generalisation of these findings. While acknowledging that factors such as the nature of the game (i.e., friendly or competitive), venue (i.e., home or away) [19] and physical conditioning [25] can influence responses to match-play, the match played in this study was a highly competitive encounter between 2 local rivals at a venue which allowed both teams to receive home support. In support, the notational analysis data obtained during the match closely replicated the demands faced by the same team while competing in their domestic league (**Table 2**). These data were determined for 1 experimental match and 4 control games; therefore, caution should be exercised when generalising these findings to describe the demands of normal soccer match-play.

In conclusion, the SMS elicited similar physiological and movement demands to soccer match-play in youth soccer players. Therefore, the SMS is a tool that replicates the demands of soccer match-play while maintaining experimental control. The SMS has potential application to researchers who wish to examine the effects of various ergogenic aids such as nutritional supplements and strength and conditioning regimes that aim to improve performance in soccer players.

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