**Title:** The reliability of a protocol examining the performance and physiological responses to 120 minutes of simulated soccer match-play

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**Abstract**

*Objectives:* The reliability of the Soccer Match Simulation (SMS) and the physiological and performance responses to 120 minutes (90 plus an additional 30 min period; extra-time) of soccer-specific exercise were investigated.

*Design:* Test-retest

*Methods:* Ten university-standard soccer players completed the SMS on two occasions under identical conditions. Capillary and venous blood samples were taken pre-exercise, half-time, at 90 min and at 120 min and further capillary samples were taken every 15 min during exercise. Core temperature (Tc) as well as physical (20 m sprint speeds, countermovement jump height, 15 m sprint velocities) and technical (soccer dribbling) performance was assessed throughout each trial.

*Results:* There was no systematic bias between trials in all variables except blood lactate. CVs and Pearson’s *r* during the last 15 min of extra-time were: Tc: 1.2%, 0.9; 20 m sprint speed: 3.5%, 0.7; jump height: 4.9%, 0.9; 15 m sprint velocities: 4.6%, 0.3; dribble velocity: 2.8%; 0.9; dribble precision: 11.5%, 0.3; blood glucose and lactate: 7.1%, 0.9 and 18.6%, 0.7; plasma insulin: 10.3%, 0.9, creatine kinase: 28.1%, 0.4, interleukin-6: 24%, 0.9; non-esterified fatty acids (NEFA): 13.2%, 0.7; glycerol: 12.5%, 0.9. Blood glucose and lactate and sprint and jump performances were reduced and Tc, NEFA, glycerol and creatine kinase concentrations were elevated in the last 15 min of ET (p < 0.05).

*Conclusions:* The SMS is a reliable protocol for measuring responses to 120 min of soccer-specific exercise. Extra-time compromises both performance and physiological responses.

*Keywords:* football, test-retest, reproducibility, fatigue, metabolic, skill

**Introduction**

Soccer is a high-intensity intermittent team sport, requiring players to perform a number of physical and technical actions for the duration of a match. For the past five decades soccer research has grown exponentially and a plethora of publications exist investigating the performance and physiological demands of soccer match-play (Ekblom, 1984; Bangsbo et al., 1994; Stolen et al., 2005). Furthermore, investigations into the efficacy of nutritional and training interventions on soccer performance are popular (Russell et al., 2012; Kingsley et al., 2014; Rollo et al., 2015). However, due to the inherent match-to-match variability associated with soccer it is difficult to make meaningful inferences about the effectiveness of such interventions during actual matches (Drust et al., 2007; Gregson et al., 2010). As such, a number of laboratory based protocols that replicate the demands of soccer match-play have been developed utilising motorised and non-motorised treadmills (Drust et al., 2000; Abt et al., 2003; Aldous et al., 2014). However, despite being both valid and reliable, such protocols lack some ecological validity due to the unidirectional nature of treadmills, and the inability to incorporate skill actions (i.e., ball dribbling).

The Soccer Match Simulation (SMS), developed by Russell and colleagues, is a valid and reliable protocol that includes backward and lateral movements, skill performance, and multiple changes of direction (Russell et al., 2011). It has been utilised to assess performance and physiological responses (Russell et al., 2012) and the efficacy of nutritional interventions during 90 min of soccer-specific exercise (Russell et al., 2012; Kingsley et al., 2014). Although soccer matches have a typical duration of 90 min, certain matches in cup and tournament scenarios require an additional 30 min period termed extra-time (ET). Previous work on ET has identified deleterious effects on physical and technical performance, with reductions in high-intensity distance covered, and the number of sprints, dribbles and passes during ET (Harper et al., 2014; Russell et al., 2015).

Preliminary qualitative work by our research group has identified that 92% of practitioners (n = 13) responsible for the preparation and recovery of soccer players believe more research should be conducted on ET, ranging from environmental effects, injury risk, recovery modalities, and the efficacy of nutritional interventions. Therefore, a reliable soccer-specific protocol is required to investigate these areas in relation to ET. As the SMS has been shown to be an effective tool in previous investigations during normal durations of soccer-specific exercise (i.e., 90 min) the aim of this study was to confirm the reliability of the SMS for extended periods of simulated soccer match-play (i.e., 120 min). We hypothesised that the SMS would demonstrate good reliability for 120 min and that an ET period would influence performance and physiological responses.

**Methods**

The study received ethical approval from the Health and Life Sciences Ethics Committee at Northumbria University. Ten male university standard soccer players (age: 22 ± 3 years, mass: 77.2 ± 7.8 kg, height: 1.80 ± 0.06 m, estimated *V̇*O2 max: 55.7 ± 1.5 ml∙kg-1∙min-1) provided written informed consent. Two identical main trials separated by 7 ± 1 days were completed, with both trials starting at the same time at each visit.

Preliminary visits preceded main trials to estimate *V̇*O2max (Ramsbottom et al., 1988)and fully familiarise participants with the protocol. Participants consumed the same evening meal and refrained from caffeine consumption in the 24 h preceding each main trial. Following an overnight fast and upon waking, participants swallowed a telemetric pill (HT150002, CorTemp, HQ Inc., USA) to allow for continuous assessment of core temperature (Tc), before arriving at the testing centre and providing a mid-flow urine sample. A resting capillary blood sample was taken before participants consumed a standardised breakfast that provided 10% of daily energy requirements (cereal and semi-skimmed milk) with 500 ml of a fluid-electrolyte beverage (Highland Spring, UK). Body mass and stature (Seca GmbH & Co., Germany) were then measured.

Both a capillary and venous blood sample was taken after participants rested for ~90 min following breakfast. A standardised warm-up (including channel drills, dynamic stretching and skill performance), during which participants consumed 200 ml of the fluid-electrolyte beverage, was then performed. After five min passive rest, performance testing (PT) preceded exercise, with countermovement jump (CMJ) height and 20-m sprint speed assessed. Participants performed three CMJ’s separated with 10 s passive recovery and three 20-m sprints interspersed with 25 s of active recovery. These measures were repeated on a further four occasions (i.e., post-first half; P2, pre-second half; P3, post-second half; P4, post-exercise; P5).

Using a modified version of the Soccer Match Simulation (SMS) (Russell et al., 2011), participants completed 120 min of intermittent exercise and skills testing; consisting of two 45 min halves and two additional 15 min periods (ET). Directed by audio signals, the SMS required the participants to cover ~14.4 km (reflecting an actual match requiring ET; Russell et al., 2015) while intermittently performing 15-m sprints and 18-m ball dribbles (assessed for precision, percentage success, and average speed). Participants were asked to dribble a ball between cones as fast and as accurately as possible, with an unsuccessful dribble performed if the ball struck the cone, or if the cone was not completed in the correct direction. Dribbles were recorded and subsequently digitised (Kinovea version 0.8.15; Kinovea Org., France) to assess dribble speed (time taken to successfully complete the distance) and precision (distance from ball to each cone). Dribbling performance was expressed as an average per 15 min of exercise (epochs; E*N*): 0-15 min (E1), 16-30 min (E2), 31-45 min (E3), 46-60 min (E4), 61-75 min (E5), 76-90 min (E6), 91-105 min (E7) and 106-120 min (E8).

A 15 min half-time (HT) period separated the two 45 min halves where participants remained seated and consumed 500 ml of a fluid-electrolyte beverage. Five min of rest followed the end of normal time and a two min passive period separated each half of ET. Body mass assessment, consumption of 300 ml of the fluid electrolyte beverage and two 66g energy-free gels preceded the start of ET.

Capillary blood samples were collected in 20 µl heparinised tubes (at rest, P1, HT and during each epoch; E1-E8) and analysed for blood glucose and lactate (Biosen C-Line; EKF-diagnostic GmBH, Germany CV: 1.5%). Venous blood samples were collected *via* venepuncture from a vein in the antecubital fossa in 6 ml lithium heparin and EDTA vacutainers at P1, P2, P4, and P5. Following centrifugation at 3000 rpm the plasma was frozen at 80°C and subsequently analysed for concentrations of insulin (Insulin ELISA; IBL International GmbH, Germany; CV: 1.8%), interleukin-6 (IL-6; Interleukin-6 ELISA, IBL International GmBH, Germany; CV: 3.4%), creatine kinase (CK; Cobas 8000; Roche Diagnostics; USA; CV%: 0.7%), non-esterified fatty acids (NEFA), and glycerol (both Randox Daytona+; Randox Laboratories Ltd., UK; CV’s: 4.7 and 0.8%, respectively).

Urine osmolality (Advanced Model 3300 Micro-Osmometer; Advanced Instruments Inc., USA; CV: 1.5%), urine-corrected mass changes, ratings of perceived exertion (RPE) and Tc were recorded during each trial. Environmental conditions were measured during exercise (Technoline WS-9032; Technotrade GmbH, Germany) and heart rate (HR) was continuously recorded (Polar RS400; Polar Electro, Finland). A mid-flow urine sample was collected and body mass measured, post-exercise.

Statistical analyses were carried out using SPSS Statistics software (IBM Inc., USA) with significance set at p≤ 0.05. Data are reported as mean ± standard deviation (SD). Following assessments of normality and variance, two-way repeated measures analyses of variance were performed for data expressed over multiple time-points to assess variability over time and between trials to allow for detection of any systematic bias between trials. LSD corrected *post-hoc* tests were employed where appropriate. As recommended by Hopkins (2000), absolute reliability was determined using coefficients of variation (CV) and calculations of typical error (TE), and relative reliability was assessed using Pearson’s product-moment correlation coefficient (*r*). Correlations of *r* = 0.3-0.5, 0.5-0.7, > 0.7 were considered moderate, strong, and very strong, respectively.

**Results**

Relative (i.e., *r*) and absolute (i.e., CV%, TE) reliability statistics are presented in Tables 1, 2, and 3. The majority of performance variables demonstrated good to very good absolute reliability (CV ≤ 7.2%); with only dribble precision and success showing higher CVs (≤ 13.3%). CMJ height, and 20 m sprint and dribble speeds were the most reliable variables as they also demonstrated good relative reliability with very strong correlations (r ≥ 0.71) (Tables 1 and 3). Sprint velocities over 15 m showed moderate to strong correlations (*r* ≥ 0.34) (Table 3). Dribble precision demonstrated moderate to very strong relationships during seven out of eight epochs (r ≥ 0.30) (Table 3).

Blood glucose, RPE, HRmean, HRpeak, and Tc demonstrated good and very good absolute reliability (CVs ≤ 8.1%), and moderate to very strong relative reliability (*r* ≥ 0.48) during exercise (Table 3). Plasma CK, insulin, NEFA, glycerol, and IL-6 had strong to very strong relationships between trials (r ≥ 0.53 – 0.99) (Table 1). Absolute reliability was disparate depending on the particular time-point in these variables, with 75% of CVs ≤ 15.8% (Table 1), with P2 being the most variable time-point. Although blood lactate had strong to very strong correlations (*r* ≥ 0.69), average CVs were 20% during exercise. Therefore, most physiological variables were reliable, depending on the specific time-point.

Environmental conditions were similar between trials (temperature: 19.7 ± 0.4°C and humidity 36 ± 8%; both p > 0.05). Likewise, there were no between-trial differences (p > 0.05) for all performance variables (i.e., 20-m sprint times, CMJ height, 15-m sprint velocity, and dribbling indices) and all but one of the physiological variables examined (i.e., RPE, HRmean, HRpeak, Tc, body mass, urine osmolality, and concentrations of CK, insulin, NEFA, glycerol, IL-6, and blood glucose) at any time-point (Tables 1, 2 and 3). For blood lactate concentrations, significant differences were observed between trials (p = 0.005, η2 = 0.315) at E1 (22 ± 23%, p = 0.014), E2 (22 ± 18%, p = 0.004), E5 (22 ± 28%, p = 0.014), and E6 (26 ± 24%, p = 0.007) (Table 3).

Sprint times over 20-m were dampened at P5 compared to P1 (p = 0.013), and P2 (p = 0.042), and CMJ height was lower at P5 versus P1 (p = 0.027) (Table 1). CMJ heights were lower at P3 compared to P1 (-12.5 ± 3.7%), P2 (-8.3 ± 4.3%) and P4 (-6.7 ± 5.0%), and 20 m sprints were slower at P3 compared to P1 (-2.1 ± 1.2%) and P2 (-5.4 ± 2.1%) (Table 1). During E8, 15-m sprint velocities were reduced (-3-9%), and RPE was elevated (+8-50%), when compared to all other time-points (p < 0.05) (Table 2). Tc during E8 was greater than P1, E1, HT, E4, and E7 (all p ≤ 0.016) (Table 3). Tc was lower at HT compared to all other time-points except P1 (all p ≤ 0.019) (Table 3).

Plasma CK concentrations were elevated at P5 compared to P1, P2 and P4 (all p ≤ 0.002) (Table 2). Plasma NEFA and glycerol concentrations were higher at P5 compared to all other time points (Table 2). Blood glucose concentrations were lower during E8 compared to baseline, P1, E3, E5, and E6 (all p ≤ 0.042) (Table 3). Blood lactate concentrations were lower during E8 compared to all other 15 min periods of exercise except E7 (all p ≤ 0.05) (Table 3). Body mass was lower at P5 (75.0 ± 6.8 kg) compared to baseline (77.0 ± 6.8 kg, -2.6 ± 1.4%, p = 0.001), and P4 (75.8 ± 6.8 kg, -1.0 ± 0.5%, p ≤ 0.0005).

**Discussion**

This is the first study to examine the reliability of a soccer-specific protocol (namely, the SMS) over 120 min of simulated match-play. In agreement with our hypotheses, the majority of variables measured yielded good reliability for 120 min. Furthermore, we observed decrements in performance and physiological perturbations during ET. Therefore, the SMS can be used in future research investigations into ET and coaches and practitioners should be aware that ET negatively impacts performance.

The SMS provides a reliable tool for measuring physical and technical performance during 120 min of soccer-specific exercise, with no systematic bias between trials demonstrating no influence of a learning effect or fatigue between trials. All physical performance variables yielded acceptable CVs (all < 10%; Atkinson et al., 1999). CVs for 15-m sprint velocities and 20-m sprint speed were 4.6% and 3.5% at 120 min, respectively, with TEs of 0.32 m·s-1 and 0.25 sec. These are comparable to previous investigations utilising match simulation protocols (Sirotic & Coutts, 2007; Russell et al., 2011; Sykes et al., 2013). CMJ height, HRpeak, HRmean and RPE all had CVs of ≤ 4.9% in ET (Tables 1 and 2), comparable to previous research using the SMS for 90 min (Russell et al., 2011). Furthermore, 20-m sprint speed, CMJ height and RPE showed strong correlation between trials (*r* ≥ 0.71). However, 15-m sprint velocities, HRmean and HRpeak demonstrated moderate to weak correlations in ET (*r* ≤ 0.48), but strong to moderate correlations during 90 min (r ≥ 0.44) (Table 2).

Technical performance (i.e., dribbling) showed varied reliability. Dribble velocity demonstrated low CVs in ET (2.6-2.8%) with low TE (0.08 m·s-1) and strong correlation (*r* = 0.87) (Table 2). Dribble precision and success had CVs of 7.8-13.3% and weak correlations (*r* ≤ 0.30) in ET (Table 2). CVs of this magnitude are higher than a previous investigation using the SMS (Russell et al., 2010), however; exercise duration was only 47 min and in a mix of professional and university-standard players, therefore the greater variation observed in the present study is possibly due to the level of player and greater physical and mental fatigue during ET.

The measured physiological variables demonstrated more variation than the performance variables, however; other than blood lactate there was no systematic bias between trials. Tc demonstrated excellent reliability with CVs of ≤ 1.3% and near perfect correlation between trials (*r* ≥ 0.99) (Table 2). Blood glucose showed good reliability in ET with CVs of ≤ 8.1% and *r* values of ≥ 0.86. To our knowledge this is the first study to assess the reliability of measures of blood glucose concentrations during a soccer-specific protocol and therefore the SMS can be used to investigate nutritional interventions such as the effect of carbohydrate ingestion on performance (Russell & Kingsley, 2014). Due to the inherent variability of metabolites, insulin, IL-6 NEFA and glycerol had CVs of ≥ 10.3%, but with strong correlations between trials (*r* = 0.96, 0.99, 0.73, and 0.86, respectively) (Table 1). CK was the most variable metabolite, however; this was expected due to large inter-individual differences. At 120 min, the difference in CK was quite small (574 ± 227 vs. 568 ± 284) but with a CV of 28.1% and a weak correlation between trials (*r* = 0.38). There was systematic bias between trials for blood lactate, with differences at some specific time points (Table 3). Therefore, caution should be taken when interpreting blood lactate results.

The calculated typical errors in Tables 1 and 2 should be considered when using the SMS to detect changes in the measured variables during intervention-type studies. For example, a greater than 4.3 cm difference in dribbling precision would have to be detected to be confident that an actual change has occurred. Although > 20 participants are recommended for reliability studies, recruitment of this magnitude is difficult due to the challenging nature of the protocol and maintaining a homogenous population who devote the time to complete the study. However, using Batterham and Atkinson’s normogram and our calculated CVs, a sample size of 10 is sufficient to detect a 5-10% difference in 20 m sprint speed, CMJ height, and dribble and 15 m sprint velocities during ET (Batterham & Atkinson, 2005). As sprinting is the most frequent action associated with goal scoring in soccer (Faude et al., 2012), and dribbling is an important factor in match success (Stone & Oliver, 2009), these are important variables to note. Furthermore, the responses we observed are analogous with previous work by our group (Harper et al., 2015), and a currently unpublished investigation in university-standard soccer players.

We detected reductions in 20 m sprint speed and CMJ height at 120 min and dampened 15 m sprint velocities and elevated RPE scores during the last 15 min of ET. This finds agreement with a case study investigating the effect of an actual ET period that observed reductions in high-intensity distance covered in ET compared to the prior 90 min (Russell et al., 2015). We also observed elevated Tc during the last 15 min of ET and reductions during HT. Reductions in Tc at HT have been hypothesised to cause compromised physical performance following a passive 15 min HT period (Russell et al., 2014; Russell et al., 2015). Our data adds to these findings, with lower CMJ heights at P3 compared to P1, P2 and P4 and reduced 20-m sprint speeds compared to P1 and P2 (Table 1).

With elevations in Tc during ET, methods to attenuate rises in body temperature warrant investigation. This is particularly relevant when matches that require ET are played in hot conditions, as certain aspects of soccer performance are negatively impacted in the heat (Mohr et al., 2012), and there seems to be a climate-dependent modulation of performance by soccer players (Nassis et al., 2015). Mohr and colleagues conducted a study in Doha, Qatar, with a 90 min match played at 43°C and found significantly higher Tc decrements in high-intensity running compared to a match between the same players at 21°C (Mohr et al., 2012). As 32% of knockout matches since 1986 in senior World Cup competitions have required ET, the efficacy of cooling strategies such as the application of cold towels and ice slurry ingestion prior to ET warrant further investigation, particularly with the 2022 FIFA World Cup being held in Qatar. Furthermore, the potential health risks associated with an additional 30 min ET period in hot climates should be investigated.

We observed further reductions in body mass during ET, with a 0.7 ± 0.4 kg drop at 120 min compared to at 90 min, which may be indicative of further dehydration in ET. Previous work from our group has observed concomitant increases in plasma osmolality and blood sodium concentrations with reductions in body mass during an ET period in professional academy soccer players (Harper et al., 2015). Therefore, methods of maintaining hydration status during ET should be sought, with ice slurry ingestion possibly providing both a cooling and a hydration strategy. Furthermore, we observed significant reductions in blood glucose in ET, with 50% of participants exhibiting concentrations considered hypoglycaemic (< 3.2 mmol·l-1) (Table 3). Ingestion of carbohydrate-electrolyte gels prior to an ET period has been shown to increase blood glucose concentrations and improve dribbling precision (Harper et al., 2015), and offers a potential nutritional strategy in matches that require ET.

We observed reduced blood glucose concentrations and elevated plasma NEFA and glycerol concentrations during ET. This may be reflective of a greater use of fat as a fuel for exercise during ET and a decreased rate of substrate level phosphorylation, as mirrored by the reduced blood lactate concentrations in ET. Although concentrations of insulin were not influenced by exercise, concentrations fell by 55 ± 80 pmol·l-1 from P4 to P5. This is well outside the TE observed at P5 (10.6 pmol·l-1) and may explain the increase in lipolysis during ET as insulin has inhibitory effects on lipolysis (Horowitz et al., 1997). Recent, unpublished findings from our research group have observed significant increases in plasma epinephrine during ET, which may also explain elevated lipolysis in ET. As maintenance of intermittent exercise capacity is dependent upon glycogenolysis (Reilly, 1997), greater fat oxidation during ET may explain reductions in sprint performance observed in the present investigation, however; this remains speculative. Further research is required to examine temporal changes in muscle glycogen concentrations during ET as epinephrine accelerates glycogen breakdown (Ball, 2015) and so may have implications for both performance and recovery (Nedelec et al., 2013).

We also observed elevated CK levels at P5 compared to all other time-points. Concentrations at P5 were higher than those observed after 90 min of actual and simulated soccer match-play (Ispirlidis et al., 2008; Magalhaes et al., 2010; Gunnarsson et al., 2013), whereas concentrations at P4 were analogous with previous studies (Ispirlidis et al., 2008; Magalhaes et al., 2010).. In corroboration with our findings, Russell et al. found greater increases in CK concentrations following a competitive match that required ET compared to following a 90 min match in the same group of players (+586.6 U·L−1 vs. 334.8 U·L−1, respectively) (Russell et al., 2015). Consequently, an ET period may have repercussions with regards to muscle damage and compromised recovery, especially as matches that require ET tend to be in close proximity (72 h) to other matches, such as in tournament scenarios or midweek cup matches.

**Conclusions**

In conclusion, we found the SMS to be a reliable protocol for measuring responses to 120 min of soccer-specific exercise. An ET period compromises performance and causes physiological perturbations that have acute and possibly chronic implications (i.e., in- and post-match). As our ongoing preliminary research has found that 92% of practitioners believe more research should be conducted into ET, researchers can use the SMS to evaluate the efficacy of intervention strategies and the profiling of fatigue responses. Furthermore, coaches and practitioners responsible for the preparation and recovery of soccer players should be cognisant of the deleterious effects of ET.

**Practical Implications**

* The Soccer Match Simulation is a reliable protocol for simulated matches of 120 min duration, however; caution should be taken when interpreting some variables at certain time-points, particularly blood lactate.
* Extra-time has negative consequences for both performance and physiological responses.
* Strategies seeking to attenuate perturbations in physical performance, hydration status and aspects of metabolism during extra-time provide future research opportunities as this period of play may occur in important tournament and cup scenarios.

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**References**