Carbohydrate Ingestion Improves Performance of a New Reliable Test of Soccer Performance

Kevin Currell, Steve Conway, and Asker E. Jeukendrup

The aim of the study was to investigate the reliability of a new test of soccer performance and evaluate the effect of carbohydrate (CHO) on soccer performance. Eleven university footballers were recruited and underwent 3 trials in a randomized order. Two of the trials involved ingesting a placebo beverage, and the other, a 7.5% maltodextrin solution. The protocol comprised a series of ten 6-min exercise blocks on an outdoor Astroturf pitch, separated by the performance of 2 of the 4 soccer-specific tests, making the protocol 90 min in duration. The intensity of the exercise was designed to be similar to the typical activity pattern during soccer match play. Participants performed skill tests of dribbling, agility, heading, and shooting throughout the protocol. The coefficients of variation for dribbling, agility, heading, and shooting were 2.2%, 1.2%, 7.0%, and 2.8%, respectively. The mean combined placebo scores were 42.4 ± 2.7 s, 43.1 ± 3.7 s, 210 ± 34 cm, and 212 ± 17 points for agility, dribbling, heading, and kicking, respectively. CHO ingestion led to a combined agility time of 41.5 ± 0.8 s, for dribbling 41.7 ± 3.5 s, 213 ± 11 cm for heading, and 220 ± 5 points for kicking accuracy. There was a significant improvement in performance for dribbling, agility, and shooting ($p < .05$) when CHO was ingested compared with placebo. In conclusion, the protocol is a reliable test of soccer performance, and ingesting CHO leads to an improvement in soccer performance.

Keywords: reliability, football, nutrition

Soccer is one of the world’s most popular sports (Reilly & Gilbourne, 2003), and with the increasing competition and commercial interests many clubs have chosen a more scientific approach to the sport. Researchers, coaches, and support staff have been involved in investigating the effects of different nutritional and training interventions on soccer performance. Performance in soccer is determined by many factors, however, so measuring soccer performance of an individual player is problematic.
A test of soccer performance should be reliable; that is, the test should give the same result each time when no intervention is undertaken (Atkinson & Nevill, 1998) and should be a valid representation of soccer match play. The protocol should also be sensitive enough to detect small changes in performance that are important to athletes.

Previous research has tended to focus on either the physiological (Bangsbo & Lindquist, 1992; Drust, Reilly, & Cable, 2000; Nicholas, Nuttall, & Williams, 2000; Wragg, Maxwell, & Doust, 2000) or the skill components (Ali, Foskett, & Gant, 2008; Ali, Williams, Hulse, et al., 2007; Finnoff, Newcomer, & Laskowski, 2002; Reilly & Holmes, 1983). Physiological simulations of soccer have been conducted on both a treadmill (Drust et al.) and using shuttle-running (Bangsbo & Lindquist; Nicholas et al.; Wragg et al.) protocols. Treadmill and shuttle-running-based protocols have been shown to produce heart-rate and oxygen-consumption responses similar to those of match play (Drust et al.; Nicholas et al.), which suggests that they provide valid physiological representations of soccer match play. Little work has been conducted on the reliability of such protocols; Nicholas et al. concluded that the Loughborough Intermittent Shuttle Test was a reliable measure of soccer performance. The performance measure of a run to exhaustion after intermittent shuttle running, however, is not a valid simulation of soccer performance.

Soccer performance includes many skill components. Reliable skill protocols have been developed for passing (Ali et al., 2007a; Ali et al., 2008), dribbling (Reilly & Holmes, 1983), and shooting (Ali, Williams, Hulse, et al., 2007; Finnoff et al., 2002). Skill-performance protocols have been shown to distinguish between ability level in both male (Ali, Williams, Hulse, et al., 2007) and female players (Ali et al., 2008). Other researchers have suggested that skill protocols might not distinguish between players of different skill levels (Rosch et al., 2000).

There have been few studies that have attempted to combine tests of soccer-skill performance in a physiological simulation of soccer match play. Investigations that have combined soccer-skill performance in a physiological simulation either have not been representative of the duration of soccer match play (Cox, Mujika, Tumilty, & Burke, 2002; Welsh, Davis, Burke, & Williams, 2002) or have only included skill-performance tests after completion of a simulation of soccer match play (Ali, Williams, Nicholas, & Foskett, 2007; McGregor, Nicholas, Lakomy, & Williams, 1999; Ostojic & Mazic, 2002).

There have been relatively few controlled studies investigating the effect of carbohydrate (CHO) ingestion on soccer performance. Those that have been undertaken suggest that CHO ingestion improves sprint time, motor skill (Northcott, Kenward, Purnell, & McMorris, 1999; Welsh et al., 2002), and soccer-specific skills (Ali, Williams, Nicholas, & Foskett, 2007; Ostojic & Mazic, 2002; Zeederberg et al., 1996) compared with water alone. Indeed, water alone has been shown to improve performance compared with no fluid ingestion (McGregor et al., 1999).

Therefore, the first aim of the study was to investigate the reliability of a new test of soccer performance. A second aim was to investigate the effect of the ingestion of a CHO beverage on soccer performance.
Methods

Participants

Eleven male participants took part in the study (age 21.4 ± 1 years, height 1.81 ± 0.05 m, body mass [BM] 80.0 ± 8.7 kg). All participants were at least recreational-level soccer players. All participants gave their written consent, and the study was approved by the local ethics committee.

Experimental Design

Participants were first required to complete a practice trial to become accustomed to the specific nature of the protocol. During this trial participants made four attempts at each of the soccer-specific tests and completed two exercise periods. They then performed the protocol at the same time of day (7.45 a.m.) for three consecutive weeks. All trials took place on an outdoor water-based Astroturf pitch, in the middle of the soccer season. No differences were seen in environmental conditions between trials.

On the evening preceding the first trial participants were asked to record their dietary intake. They were then required to eat the same diet on the evening before each of the remaining two trials. On the morning of each trial participants were given a standardized breakfast 30 min before the onset of exercise. This breakfast consisted of one breakfast bar (Nutrigrain, Kellogg’s, UK; 535 kJ, 27 g CHO, 3 g fat, 2 g protein).

Participants undertook three experimental trials in random order. These consisted of either ingesting an artificially sweetened placebo twice (Trials A and B) to determine the reliability of the protocol or a CHO trial in which a 7.5% maltodextrin solution was ingested so as to investigate the effect of CHO on performance. The placebo beverage was matched in both taste and color to the CHO solution, and no participant was able to distinguish between the two beverages. Thirty minutes before the start of each experimental trial participants ingested 6 ml/kg BM of the experimental beverage, with 4 ml/kg ingested at halftime. Every 12 min during the exercise protocol participants ingested 1 ml/kg BM (approximately 1.1 L per session, which is similar to sweat rates and actual ingestion seen during match play; Shirreffs, Sawka, & Stone, 2006).

Experimental Protocol

The participants reported to the Astroturf pitch for breakfast 30 min before the test was to start. They were then seated for 15 min before completing a standardized warm-up consisting of jogging and stretching: two laps of the circuit (outlined in Figure 1) followed by 5 min during which the participants could undertake their own stretching protocol. Each participant then performed all four soccer-specific skill tests before commencing exercising.

The protocol comprised a series of ten 6-min exercise blocks. Each exercise block was separated by the performance of two of the four soccer-specific tests, immediately after which the next block was undertaken (Figure 2). In total the duration of the protocol was 90 min, spilt into two 45-min halves. During the exercise periods participants were required to perform a field test (Ekblom, 1989) that mimicked the movements used during soccer match play (Figure 1).
Figure 1 — Schematic of the course run by the participants based on the protocol of Ekblom (1989).
Participants followed the course as set out in Figure 1 with varying intensity. The intensity of the exercise was designed to be similar to the activity pattern typically recorded during soccer match play (Reilly & Thomas, 1976). Consequently, each 6-min block incorporated in total 100 s walking, 140 s jogging, 80 s cruising, and 40 s sprinting. The 6-min block was divided into four 90-s blocks in which participants performed 10 s walk, 10 s jog, 10 s cruise, 10 s jog, 10 s cruise, 15 s walk, 5 s sprint, 15 s jog, and 5 s sprint. This 90-s block was repeated four times in each 6-min block of exercise (Figure 1). The speed of the jog was defined to the participants as 50% maximum speed, and the cruise was described as 95% maximum speed. Participants were verbally encouraged to match the required intensities during each exercise period. A compact disc was developed to ensure consistent delivery of instructions and timing via a sound system throughout the protocol.

**Soccer-Specific Tests**

**Agility.** The agility test involved running through a series of markers as quickly as possible (Figure 3). Each participant had two attempts at the agility circuit, with their best time being recorded. Times were measured to the nearest 0.1 s using electronic timing equipment (Eleiko, Sport, Sweden). Participants were instructed to complete the course as quickly as possible.

**Dribbling.** Each participant had to negotiate a course of five cones set out directly behind one another as quickly as possible (Figure 4). The first cone was
**Figure 3** — Schematic of the agility protocol.

**Figure 4** — Schematic of the ball-dribbling protocol. Each arrow represents the distance between the cones.
placed 2.74 m from the start, the second cone was 1.83 m from the first, Cones 2 and 3 were separated by 0.91 m, and Cones 3 and 4 were separated by 1.83 m, as were Cones 4 and 5. At the final cone the participant circled it and repeated the course in a similar fashion. Electronic timing equipment was employed, and each participant had two attempts.

**Kicking Accuracy.** A goal mouth was split into nine equal targets by a series of ropes (Figure 5). Each target was allocated a different score. Because this was a test of kicking accuracy, not shooting ability, the center was worth 5 points, and the corners only 1 point. Participants had 10 attempts from 16.46 m away, using their preferred foot and with the ball being stationary. On the completion of one kick the next immediately followed.

**Heading.** A ball was suspended in the air, and its height could be adjusted at intervals of 4 cm. Jump height was calculated by subtracting a player’s standing stature from the highest height of the ball above the ground where contact was made. Participants were allowed a 1-m run-up and had three attempts at each height. The highest jump when they hit the ball with their forehead was recorded.

### Analysis and Statistics

For all soccer-specific skills an aggregate score of the six completed repetitions was used to get a total score for each skill in each trial. The placebo trials (A and B) were analyzed for reliability using a coefficient of variation (CV), which expresses the typical error (TE) as a percentage (Hopkins, 2000):

$$CV = 100 \times e^{TE/100} - 100$$

where TE is

$$\frac{SD}{\sqrt{2}}$$

and $e$ is the natural logarithm.

---

**Figure 5** — Scoring grid for the kicking-accuracy protocol.
Confidence intervals for the CV were calculated using the method of Hopkins (2000). The presence of any systematic error between placebo trials was analyzed using a paired-samples \( t \) test. The relationship between measurement error and aggregate score for each skill test was analyzed using Pearson’s \( r \). This was completed for each soccer-specific skill. A paired-samples \( t \) test was used to analyze any differences between mean placebo score and the CHO trial for the overall score. A repeated-measures ANOVA was used to analyze the effects of trial and sprint on each skill test, with post hoc analysis being undertaken using Tukey’s post hoc test.

Data evaluation was performed using SPSS version 12.0.1 (Chicago, IL). Significance was set at the \( p < .05 \) level. Data are reported as mean and standard error \((M \pm SEM)\) unless otherwise stated.

**Results**

The reliability analysis for each skill test can be seen in Table 1. This shows the CV for each skill at each time point, alongside the CV for the overall aggregated score for each skill test. The CV remains consistent throughout the skill tests, suggesting that there is no learning or fatigue effect on the reliability of the tests.

### Agility

The combined times for all six agility runs were 42.5 ± 0.9 s, 42.4 ± 0.8 s, and 41.6 ± 0.8 s for trials A, B, and CHO, respectively. There was no significant difference between the two placebo trials, \( t(10) = 0.286, p = .781 \), and no heteroscedasticity was present \((r = –.348, p = .294)\). There was a significant 2.0% (95% CI 0.6–3.5%) improvement in performance when CHO was compared with placebo, \( t(10) = –3.162, p = .01 \). Analysis of each individual skill test showed a significant decrease in performance throughout the test, \( F(5, 50) = 4.413, p = .002 \), with a significant attenuation of this performance decrease with CHO ingestion at all time points, \( F(5, 50) = 5.434, p < .001 \) (see Figure 6[a]).

### Dribbling

The combined times for all six dribbling runs were 43.2 ± 1.1 s, 43.0 ± 1.1 s, and 41.75 ± 3.5 s for trials A, B, and CHO, respectively. There was no significant difference between the two placebo trials, \( t(10) = 0.590, p = .568 \), and no heteroscedasticity was present \((r = –.198, p = .559)\). There was a significant 3.2% (95% CI

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Coefficients of Variation (%) for the Skill Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skill test</td>
<td>1</td>
</tr>
<tr>
<td>Agility</td>
<td>2.0</td>
</tr>
<tr>
<td>Dribbling</td>
<td>1.1</td>
</tr>
<tr>
<td>Heading</td>
<td>6.8</td>
</tr>
<tr>
<td>Kicking accuracy</td>
<td>3.8</td>
</tr>
</tbody>
</table>
Figure 6 — Change in performance over time for (a) agility, (b) dribbling, and (c) kicking. *Significantly different from carbohydrate trial.
2.1–4.3%) improvement in performance when CHO was compared with placebo, $t(10) = -6.308, p < .001$. Although there was a clear trend for a decrease in performance throughout the trial and for CHO to attenuate this decrease in dribbling ability (Figure 6[b]), no significant difference was found.

**Heading**

The combined heights for all six heading efforts were 208 ± 11 cm, 213 ± 11 cm, and 213 ± 11 cm for trials A, B, and CHO, respectively. There was no significant difference between the two placebo trials, $t(10) = 0.667, p = .520$, and no heteroscedasticity was present ($r = -.010, p = .977$). There was a nonsignificant 1.2% (95% CI 4.1–6.6%) change in performance when CHO was compared with placebo, $t(10) = 0.355, p = .730$. No significant fatigue was seen over the trial, with CHO also having no effect on the fatigue profile.

**Kicking Accuracy**

The total scores were 211 ± 6 points, 214 ± 5 points, and 220 ± 5 points for trials A, B, and CHO, respectively. There was no significant difference between the two placebo trials, $t(10) = -1.230, p = .247$, and no heteroscedasticity was present ($r = -.364, p = .271$). There was a significant 3.5% (95% CI 1.0–6.0%) improvement in performance when CHO was ingested compared with placebo, $t(10) = 2.954, p = .014$. There was a significant decrease in kicking accuracy throughout the trial, $F(5, 50) = 1.292, p < .001$. Despite a trend toward CHO’s attenuating the decline in kicking accuracy, however, this did not reach significance (Figure 6[c]).

**Discussion**

The main aim of this study was to develop a new protocol to measure soccer performance. As far as we are aware this is the first protocol developed based on a physiological simulation of soccer match play over 90 min that also included measures of skill performance. The protocol was shown to be reliable, and CHO ingestion improved soccer performance.

The current study tried to maximize the ecological validity by not only simulating the physiological demands of soccer but also including more movements in the protocol and including skill elements. The movements were based on the field test of Ekblom (1989) and included forward, backward, sideward, and jumping movements so as to better simulate soccer play. The speeds at which the participants ran were based on Reilly and Thomas’s (1976) match analysis. Although Nicholas et al.’s (2000) study was also based on Reilly and Thomas’s match analysis, they did not include movements in directions other than forward or any jumping movements, which reduces the validity of the protocol compared with that seen in this study.

The skills of agility, dribbling, and kicking accuracy showed relatively little day-to-day variation, with CVs of 1.2%, 2.2%, and 2.8%, respectively. These low CVs indicate good reliability, which agrees with other studies of soccer skill (Ali, Williams, Hulse, et al., 2007; Ali et al., 2008; Finnoff et al., 2002; Reilly & Holmes, 1983). The dribbling protocol in this study was based on that of Reilly.
and Holmes, which showed a correlation coefficient of .95 for test–retest, suggesting good reliability (Atkinson & Nevill, 1998). The Loughborough Soccer Passing Test involves performing 16 passes into four marked zones as quickly as possible, and the Loughborough Soccer Dribbling Test involves dribbling a ball through six cones each placed 3 m apart as quickly as possible, 10 times with 1 min rest between trials. It was shown that both tests were reliable and valid measures of soccer skill (Ali, Williams, Hulse, et al., 2007; McGregor et al., 1999). In contrast, heading showed a greater variation, with a CV of 7.0%, which might have been a result of the ball’s only being increased in height in 4-cm increments. As can be seen from Table 1 there does not seem to be a change in reliability as fatigue occurs. This is the first study, however, that has investigated the reliability of skill protocols through soccer-simulating exercise, and the first to use the skill protocols as the measure of soccer performance, again adding to the validity of this protocol.

The results of the current study clearly show that skill performance decreases throughout match-play simulation (Figure 6). Although only agility reached significance there are clear fatigue trends in dribbling and kicking ability that would affect elite soccer performance. This is in agreement with previous studies that have shown skill performance to decrease throughout simulation (McMorris & Rayment, 2007; Rostgaard, Iaia, Simonsen, & Bangsbo, 2008) and actual match play (Rampinini et al., 2008; Rampinini, Impellizzeri, Castagna, Coutts, & Wisloff, 2007). Rampinini et al. (2007) showed that during elite-level soccer performance in Italy technical performance clearly decreased throughout a match. They also found that maintaining technical performance was linked to better performance.

CHO ingestion has been shown to improve performance of many different types of sporting activities, especially those lasting for longer than 45 min (Jeukendrup, 2004). The current study showed a significant effect of CHO on agility, dribbling, and kicking accuracy but not on heading ability. Similar findings have been found after a soccer match in which dribbling ability and passing accuracy were shown to be improved with CHO ingestion compared with placebo (Ostojic & Mazic, 2002). Welsh et al. (2002) showed that when a 6% CHO solution was given throughout four 15-min blocks of intermittent shuttle running there was an improvement in 20-m sprint time, a motor-skill test, and self-reported perceptions of fatigue during the latter stages of exercise compared with placebo. CHO ingestion during soccer has also been shown to reduce glycogen utilization (Leatt & Jacobs, 1989) and improve skill performance after a physiological simulation of soccer match play (Ali, Williams, Nicholas, & Foskett, 2007). Zeederberg et al. (1996) found no benefit, however, from ingesting a 6.9% CHO solution during actual match play when video analysis was used to analyze skill proficiency. Their study was conducted throughout actual match play, however, so there might have been too many factors that were not controlled, and therefore the detection of an effect of CHO might have been more difficult.

Ingesting CHO during the simulation prevented the drop in skill performance seen throughout the exercise protocol. This could have benefits to elite match play; Rampinini et al. (2007) showed that teams who finished higher up the league table in Italy had the smallest decrease in skill performance compared with less successful teams.

Fatigue during prolonged exercise has been shown to be associated with a decrease in muscle glycogen concentration and blood glucose concentrations.
(Coyle et al., 1983). CHO ingestion has been shown to attenuate the fall in blood glucose concentrations during prolonged exercise (Coyle et al.) and to spare muscle glycogen concentrations during a soccer match (Leatt & Jacobs, 1989), therefore reducing the onset of fatigue. CHO ingestion has also been shown to maintain central nervous system function during prolonged exercise (Nybo, 2003), which might play an important role in skill performance in soccer.

One vitally important factor is perception. Research has shown that skilled players can more successfully identify patterns of play, are able to anticipate events, and are able to focus their vision on the most important information available to them (Williams, 2000). As yet, however, no research has been conducted that includes measures of perception in a soccer-specific performance protocol.

There are a number of limitations to the current study that need to be addressed in future investigations. The changes in speed seen during the exercise protocol were down to the athletes’ perception of speed. Therefore, this introduces an element of variation that should be accounted for. There was also no measure of total distance covered throughout the test. Measuring total distance covered and having a greater control of speed throughout the test would provide for a more controlled protocol.

In conclusion, the protocol developed was shown to be a reliable measure of soccer performance. It was also shown that CHO ingestion can improve soccer performance compared with water alone.

References


