A Test to Evaluate the Physical Impact on Technical Performance in Soccer

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Abstract

The aim of the study was to develop and examine a test for evaluation of the physical and technical capacity of soccer players. Fourteen youth elite (YE) and seven sub-elite (SE) players performed a physical and technical test (PT-test) consisting of 10 long kicks interspersed with intense intermittent exercise. In addition, a control test (CON-test) without intense exercise was performed. In both cases, the test result was evaluated by the precision of the 10 kicks. The players also performed the Yo-Yo intermittent recovery test level 2 (Yo-Yo IR2). For the SE-players, blood samples were obtained and heart rate was measured before, during, and after the PT-test. A muscle biopsy was collected before and after the PT-test. Coefficient of variation for the PT- and CON-test was 11.7% and 16.0%, respectively. The YE-players performed better ($P <$ 0.05) than the SE-players in both the PT-test (16.3 $\pm$ 0.8 ($\pm$*SE*) vs. 13.2 $\pm$ 1.3 points) and CON-test (24.4 $\pm$ 0.7 vs. 20.5 $\pm$ 1.6 points) with no difference in the relative PT-test result (PT-test/CON-test: 0.63 $\pm$ 0.03 vs. 0.64 $\pm$ 0.03). Summed performance of the first 5 repetitions was higher ($P <$ 0.05) than for the last 5 repetitions (8.4 $\pm$ 0.6 vs. 6.9 $\pm$ 0.5; n = 20). The YE-players performed better ($P < 0.05$) than the SE-players during Yo-Yo IR2 (1023 $\pm$ *SE* vs. 893 $\pm$ *SE* m). The mean heart rate during the PT-test was 173 $\pm$ 4 b.p.m. (90 $\pm$ 2% of HRmax). Blood lactate, glucose, and ammonia reached 5.6 $\pm$ 0.7, 6.2 $\pm$ 0.6 mmol L^{-1}, and 76 $\pm$ 11umol L^{-1} at the end of the test, respectively. After the test muscle CP, glycogen and lactate was 52.9 $\pm$ 6.6, 354 $\pm$ 39, and 25.3 $\pm$ 5.9 mmol kg^{-1} d.w., respectively. In summary, the PT-test can be used to evaluate a soccer player's technical skills under conditions similar to intense periods of a soccer game.

Key Words heart rate, lactate, creatine phosphate, glucose, ammonia, playing level

Introduction

It is well-established that soccer players during a game perform intermittent exercise with changes in activity every 3–5 seconds, and that soccer is physically demanding due to multiple brief intense actions involving jumps, turns, tackles, high speed runs, and sprints (2,4,19). Heart rate recordings and collection of muscle and blood samples have furthermore shown that the aerobic loading is high throughout a soccer match and that the anaerobic energy turnover is large during periods of the game (4,9,12,13,20,22,24). It has also been observed that the players experience fatigue both towards the end of a game and temporarily during a match (13,21). Soccer at high level is characterized by a significant amount of high-intensity exercise performed during a game. Thus, players a international elite level have been shown to perform 25% more high intensity running and 35% more sprinting during competitive games than professional players at a moderate elite level (20). However, it is unclear to what extent intense exercise affects a player's technical skills.

A number of physical tests have been used to evaluate fitness levels of soccer players at different ages, playing positions and levels (3,5,6,8,13,14,16,17,23,24). However, no test has been developed to evaluate the effect of intense soccer activities on the technical performance in soccer. In order to be valid for soccer, the exercise pattern during the test has to resemble the activities during a game and the physical demands should be similar to those occurring during intense periods of a soccer match.

Thus, the aim of the present study was to develop and examine a test to evaluate the effect of intense soccer activities on the technical performance of soccer players.

Methods

Experimental Approach to the Problem

To evaluate the influence of intense soccer activities on technical performance, a physical and technical test (PT-test) was developed. To do this, a number of procedures were carried out. Twenty-two international soccer matches (Euro2004) were analyzed by means of a hand notation sheet. A similar method has been applied to soccer to detect the incidence and location of curvilinear running during matches (7). In the present study it was the aim to determine running

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patterns and technical actions performed during high level soccer games, and thereafter incorporate the findings in the PT-test in order to simulate the activities and activity patterns observed in soccer. Thus, the running patterns and technical performances of 22 players (7 defenders, 8 midfielders, and 7 attackers) from 5 different FIFA TOP 20-countries (Denmark, England, Netherlands, Portugal, and Czech Republic) were studied. To be able to distinguish changes in activities and technical actions during the subsequent analysis, a preset color code was used (Figure 1). To be selected for analysis, a match situation had to last longer than 5 seconds and had to be technically demanding, such as dribbling or long pass; as well as physically demanding, such as sprinting or pressing before getting the ball. All matches were analyzed by the same 2 experienced observers, and in total, 195 match situations meet the inclusion criterions. By subsequent comparison of the selected match situations, a range of discrete intense game patterns were identified and generalized. These patterns were finally combined and included in the PT-test in order to simulate an intense period during a soccer match.

Also, a group of subjects carried out a preliminary edition of the PT-test. The purpose of this procedure was to determine an absolute work intensity, at which the physical and technical elements contained in the test model could be executed and reproduced in a reliable way. During this pretest, the subjects (n = 13) were told to execute 10 repetitions of the test course and run at the highest possible speed in the sprinting parts of the test. The time for the sprints was recorded by infrared light sensors with a precision of 0.01 second (Time It, Eleiko Sport, Halmstad, Sweden). The results are presented in Figure 2, which shows that running times became gradually slower and slower indicating that the subjects became progressively fatigued. For the PT-test, the running speed for the "sprints" was set to 95% of the average running time obtained during the pretests which was controlled by audio bleeps from a compact disc.

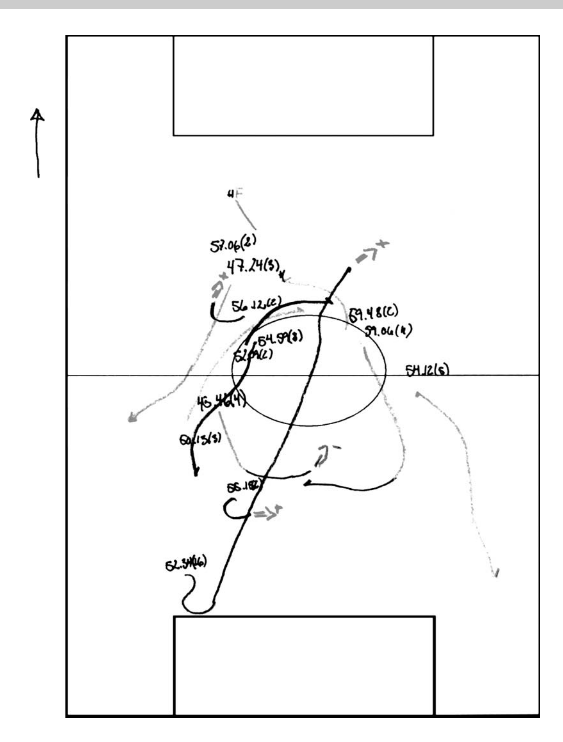

Figure 1. Fifteen minute hand notation analysis of a player prior to and in contact with the ball during a soccer match. Lines and arrows indicate location and direction of the performed action. Different colors (not shown) indicate different categories of activity, to be distinguished during subsequent analysis. Numbers indicate the time of the occurrence according to the match clock, and numbers in parenthesis indicate the duration (seconds) of the activity.

Subjects

Twenty-one healthy male soccer players participated as subjects in the study. One group (n = 14) consisted of youth elite (YE) players with an age of 18.4 (range: 16.1–20.0) years, height of 180.0 (165–190) cm, and body mass of 75.0 (63–90) kg. They had 5.5 (4–6) training sessions and played 1–2 matches a week in the period studied. The other group (n = 7) was sub-elite (SE) players, who took part in an invasive experiment to determine the physiological response of the test. They had a mean age, height and weight of 26.4 (range: 22.2–33.2) years, 180.9 (174–189) cm, and 77.1 (68.2–92.4) kg, respectively. They had 2.8 (1–4) training sessions and played 1–2 matches a week in the period studied. All subjects were informed of any risks and discomforts associated with the experiment before giving their written consent to participate. In the cases where the subjects were below 18 yrs a written informed consent was obtained from his parents.

The study confirms the code of Ethics of World Medical Association (Declaration of Helsinki) and was approved by

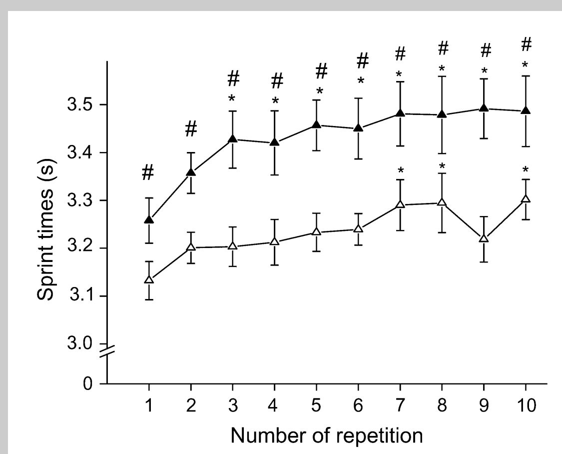

Figure 2. Sprint times during the preliminary test. Open symbols show the time of sprint from the "start line" to the "passing zone" ("forward"), and filled symbols show the time of sprint from the "passing zone" to the "finish line" ("back"). For further details see methods section.
#Significant difference between "forward" and "back."
*Significant different from the first sprint.

the Ethics Committee of Copenhagen and Frederiksberg communities. During the study some players experienced injuries and were not able to perform all tests.

Soccer Specific Technical Testing

The PT-test consists of high-intensity running and dribbling actions alternated by active recovery with low-to-moderate intensity movements observed during soccer matches (19). In addition, the subjects perform 10 long passes in the air. The quality of the pass is evaluated by means of a "goal zone" consisting of 3 rectangular squares 18 m^2 (6 m × 3 m), 32 m^2 (8 m × 4 m), and 50 m^2 (10 m × 5 m) with a test leader (TL) positioned in the middle (Figure 3A). The upper right corner of the "goal zone" is placed 30 m away from the starting line. TL may move in the attempt to catch the ball within the "goal zone", but is not allowed to jump to catch the ball. If the ball is passed in the air to TL, points are given according to the precision of the pass (3, 2, or 1 point, respectively). If the ball bounces on the ground within one of the squares, one point less is rewarded. If the ball bounces outside the "goal zone," no points are given.

The PT-test course for a right-footed player is presented in Figure 3A. The player starts at the "start/finish line" and at first has to complete the intense part of the PT-test. This consists of: i) 20 m of high-intensity running (completed in 3.42 s ~ speed of 21 km/h). ii) Dribbling and long-passing done in the following way. Entering the 36 m^2 large "passing zone," the player decelerates and performs a turn in the middle of the pitch and runs towards the start of a dribble sequence (2 × 5 m marked by cones). In control of the ball the player has to dribble the ball to the end of the dribble sequence and back (total of 10 m) with a maximum of 5 touches (2 touches used for dribbling in each direction and 1 touch used for a turn of direction at the end of the dribbling sequence). Thereafter, the player has only 1 touch to place the ball before performing the long pass towards the "goal zone". The player then turns back towards the middle of the pitch. This part has to be executed in 15.2 seconds, with the ball being passed towards the "goal zone" not later than 9 seconds after entering the "passing zone." iii) Finally, the intense part of the test is finished with 20 m of high-intensity running back towards the "starting line" (3.56 s ~ 20.2 km/h). The player decelerates (6 m) and gets ready to execute a sequence of active recovery no later than 5 seconds after passing the start/finish line. The active recovery consists of walking for 10 m (6 seconds ~ 6 km/h), followed by a short dribbling track (2 × 6 m) at low speed (5.4 seconds ~ 8 km/h). The dribbling track is executed with a maximum of 5 touches, including turning with the ball, and is finished when the player places the ball at the start of the dribbling track. This is followed by 7.5 m (2.7 s ~ 10 km/h) of backwards running, running at moderate intensity for 10 m (15 km/h ~ 3.6 s), 2 × 2.5 m side-ways running (6 km/h ~ 3 s), and finally jogging 6, 7 m (8 km/h ~ 3 s). At the end of the recovery track the player turns 180 degrees and proceeds towards the starting line repeating all the described movements of recovery on the way back. Finally, the player rests for 10 seconds before initiating a new repetition. The PT-test consists of 10 repetitions. The subjects are allowed at least 5 pre-attempts for adjustment to the procedure of the PT-test. The different movements of the PT-test is summarized and compared to analysis of high level soccer games in Table 1.

The result of the PT-test is defined as the sum of technical points obtained during the test (a maximum of 30 points). As each PT-test is performed at the same absolute work intensity, alterations in test performances, such as after a period of fitness training, will provide information about changes in the

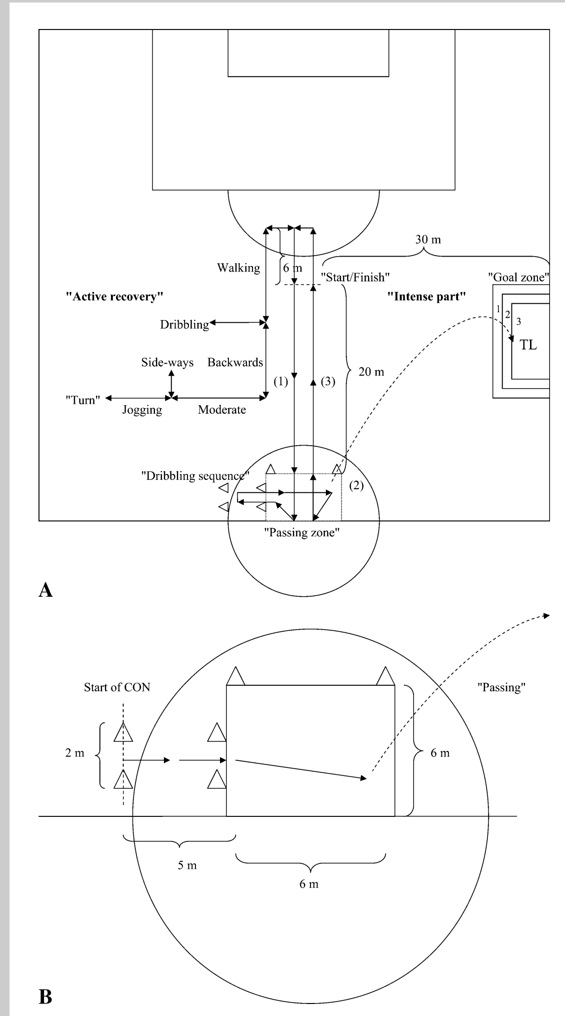

Figure 3. The PT-test course (A). Arrows show the direction of movement through the course. The dotted line shows the direction of the pass (right-footed player) to be evaluated for precision (given by values 1–3). Numbers in parenthesis correspond to the details explained for the PT-test course (see Methods). B. The course of the CON-test (B). Arrows (full) show the direction of movement trough the course of the CON-test. Arrow (dotted) shows the direction of the pass (right-footed player) to be evaluated for precision (given by values scale 1–3). Each arrow represents a single touch of the ball.

TABLE 1. Comparison of different activities during the PT-test and a soccer game.

Activity	PT-test	Soccer match
Total duration (min)	15 (90*)	90
Total distance covered (km)	~1.77 (10.6)	10.86†
Total changes in activity (no.)	~250 (1500)	1346†
High-intense running (>18 km/h)		
No.	80 (480)	217†
Distance (m)	~1200 (7200)	2374†
Time (s)	~400 (2400)	463†
Relative time (% of total time)	44	8.7†
Low-intense running (6–12 km/h)(no.)		
No.	40 (260)	587†
Distance (m)	~250 (1500)	4370†
Time (s)	~115 (684)	1660†
Relative time (% of total time)	13	29.9†
Walking (= 6 km/h)(no.)		
No.	40 (400)	379†
Distance (m)	~320 (1920)	4042†
Time (s)	~190 (1140)	2425†
Relative time (% of total time)	21	41.8†
Standing (0−5 km/h)(no.)		
No.	20	163†
Time (s)	~200 (1200)	1141†
Relative time (% of total time)	22	19.5†
Possession of the ball (% of total time)	22	1.5‡

*Numbers in parentheses correspond to 90 min of the PT-test.
†Data from Mohr et al., 2003.
‡Data from Bangsbo, 1994.

ability to execute technical actions while going through an intense activity pattern simulating the work profile of soccer. For the PT-test to specifically express the effect of the physical work on the technical performance, the test result may be compared to the result in a control (CON) test consisting of 10 long passes towards the "goal zone" performed at a low physical loading regime. In particular the player dribbles (maximum 11 m and 3 touches) into the "passing zone" before aiming a pass at the "goal-zone" (Figure 3B). The players have to start a new attempt each 30 seconds. The players are allowed at least 5 pre-attempts. Points are given as in the PT-test (a maximal number of 30 points is possible). Then, the test result can be expressed as the ratio between the total score in the PT-test and the CON-test (relative PT-test result).

Procedures

Reproducibility of the PT- and CON-test. Within 1 week of the first test day, the YE-players repeated the PT- and CON-test to evaluate the reproducibility of both tests.

Evaluation of the Physiological Response to the PT-test. The SE-players took part in the evaluation of the physiological response to the PT-test. After 15 min of rest in the supine position, the subjects had a Polar Vantage NV heart rate monitor (Polar Electro Oy, Kempele, Finland) placed around the chest for continuous heart rate recordings throughout the test. A catheter (18G, 32 mm) was placed in an antecubital vein. In preparation for obtainment of needle biopsies in m. vastus lateralis, an incision was made through the skin and muscle fascia under local anesthesia (20 mg L^{-1} lidocain without adrenalin). The incisions were covered by sterile band aid strips and a thigh bandage. A resting blood sample was obtained approximately 5 minutes prior to the warm-up period. The warm-up consisted of jogging and gymnastics at low intensities for 10 minutes followed by 3 repetitions of the PT-test course as familiarization to the running patterns of the test. Subsequently, the players rested for 5 minutes and a muscle biopsy was collected before they performed the PT-test. Blood samples were taken immediately prior to the test and in the 10-second recovery periods 3, 6, 9, 12, and 13.5 minutes into the test. A blood sample was also collected 2 and 4 minutes after the test. Another muscle biopsy was obtained at the end of the test.

To determine sweat loss during the test, the subjects were weighed wearing dry shorts before the test, and immediately after the test using a digital weight (OHAUS 1-10, Pine Brook, NJ, USA). The subjects were allowed to drink water ad libitum during the test and the water intake was recorded.

Other Performance Test Procedures. Within 1 week of the PT-test, the subjects (n = 19; 13 YE and 6 SE players) performed the Yo-Yo IR2. Briefly, the Yo-Yo IR2 consists of repeated 2 × 20 meter runs at a progressively increased speed controlled by audio bleeps from a tape recorder (16). Between each running bout, the participants have a 10 second rest period. When they twice failed to reach the finishing line in time, the distance covered is recorded and represents the test result. The test was performed in running lanes, marked by cones measuring 2 m wide and 20 m long. The players had a heart rate belt placed around the chest and a Polar Vantage NV monitor (Polar Electro Oy, Kempele, Finland) around the wrist for continuous heart rate recordings throughout the test.

Within the same week, the SE players performed an incremental treadmill running test to exhaustion for determination of maximal oxygen uptake (VO_2max) and maximal heart rate (HR_{max}). After 15 min of rest in the supine position the players had a heart rate belt placed around the chest and a Polar Vantage NV monitor (Polar Electro Oy, Kempele, Finland) around the hand wrist for continuous heart rate recordings throughout the test. The subjects started at a running speed of 14 km/h for 2 minutes, followed by 30 seconds at 16 km/h, and continued with step-wise 1 km/h increases in running speed each 30 seconds until exhaustion. During the last minutes of the test, the expired air was collected in Douglas bags. The volume of expired air was later determined using a Tissot spirometer. The Douglas bags were analysed for the content of oxygen using a paramagnetic oxygen analyzer (VacuMed, Model 17518A, Ventura, Calif.) and for carbon dioxide using a infrared carbon dioxide analyzer (VacuMed, Model 17515A, Ventura, Calif.). The analyzers were calibrated against 2 gasses with known contents of oxygen and carbon dioxide and the oxygen uptake was calculated.

All tests were performed at least 48 hours apart, and the subjects reported to the laboratory in the early afternoon. In preparation for the tests, intake of caffeine on the day of the experiment as well as alcohol consumption and heavy physical activity on the day prior to the test was avoided.

Blood Analyses

Within 10 seconds of sampling 100 μL of blood was hemolysed in an ice-cold 100 μL Triton X-100 buffer solution, and was later analyzed for lactate and glucose using an YSI 2300 lactate analyzer (Yellow Spring Instruments, Yellow Springs, Ohio; 10). The rest of the sample was rapidly (<30 seconds) centrifuged and plasma was collected and stored at −20°C until subsequent analysis. Plasma ammonia was measured spectrophotometrically.

Muscle Analysis

The muscle tissue was immediately frozen in liquid N_2 and stored at −80 °C. The frozen sample was weighed before and after freeze-drying to determine water content. After freeze-drying, the muscle samples were dissected free of blood, fat, and connective tissue and about ~1 mg dry wt tissue was extracted in a solution of 0.6 M perchloric acid (PCA) and 1 mM EDTA, neutralized to pH 7.0 with 2.2 M $KHCO_3$ and stored at −80 °C until analyzed for CP and lactate by a flurometric assay (19). Another 1–2 mg dry wt muscle tissue was extracted in 1M HCl and hydrolysed at 100°C for 3 hours and the glycogen content was determined by the hexokinase method (19).

Statistical Analyses

Any differences between running speeds during pretests were evaluated by the 2-way analysis of variance (ANOVA) with repeated measures. The summed performance (repetition 1 through 5 and 6 through 10) in the CON-test and the PT-test, the changes in muscle metabolites, blood metabolites and heart rate during the PT-test were evaluated by the 1-way analysis of variance (ANOVA) with repeated measures. When a significant interaction was detected, data were subsequently analyzed by application of a Newman-Keuls post-hoc test. Changes in performance during the CON- and PT-test and differences in performances between the CON- and PT-test were compared using a binomial test. The YE and SE players were compared using an independent t-test.

Correlation coefficients were determined and tested for significance using Pearson's product-moment test. The coefficient of variation (CV) was used as a measure of test-retest reproducibility and it was calculated as *SD* of the difference between the test and retest scores divided by the mean test score and multiplied by 100 (1). Significant level was set to $P \leq 0.05$. Values are presented as means ± *SEM.*

Results

Test-Retest Performance. No difference ($P > 0.05$, n = 13) was found in performance either between the 2 PT-tests (CV: 11.7%; Figure 4A) or between the 2 CON-tests (16.0%; Figure 4B). Thus, the relative PT-test result (PT-test score/CON test score) was also the same (0.67 ± 0.03 vs. 0.70 ± 0.01) with an intra-individual difference averaging 4 ± 2% and the CV value being 10.6% (Figure 4C).

PT-test Performance. The YE players performed better ($P < 0.05$) than the SE players in both the PT-test (16.3 ± 0.8 vs. 13.2 ± 1.3 points) and the CON-test (24.4 ± 0.7 vs. 20.5 ± 1.6 points). No difference between groups was observed for the relative PT-test result (0.63 ± 0.03 vs. 0.64 ± 0.03).

Technical performance during the PT-test tended ($P < 0.1$) to decrease from on average 1.9 ± 0.3 points at the first repetition to 1.6 ± 0.3 points at the last repetition, and the summed performance of the first 5 repetitions was higher ($P < 0.05$) than for the last 5 repetitions (8.4 ± 0.6 vs. 6.9 ± 0.5). Technical performance during the PT-test tended ($P < 0.1$) to be lower compared to CON-test in each repetition, but the difference in performance was only significant ($P < 0.05$) at the 7th and 8th repetition. The summed technical performance of the first 5 and the last 5 repetitions during the PT-test was lower ($P < 0.05$) than in CON (Figure 5). Difference in technical performance between the PT- and CON-test was greater ($P < 0.05$) during the last 5 repetitions compared to the first 5 repetitions (20.5% ± 0.56% vs. 42.9% ± 0.61%).

Yo-Yo Intermittent Recovery Test. The SE players (n = 6) covered a distance in the Yo-Yo IR2 test of 893 (520–1240) m, which was shorter ($P < 0.05$) than the performance of the YE players (1023 (760–1440) m; n = 13). No correlation (n = 18) between Yo-Yo IR2 test performance and PT-test performance or relative PT-test performance was found.

Maximal Oxygen Uptake. VO_2max of the SE players was 61.4 (52.8–65.9) mL min^{-1} kg^{-1}. VO_2max was not correlated either to the PT-test performance nor to relative PT-test performance.

Physiological Response to the PT-test

Heart Rate. Immediately before the PT-test heart rate was 150 ± 7.8 b.p.m and it increased ($P < 0.05$) to 170 ± 5 b.p.m after the

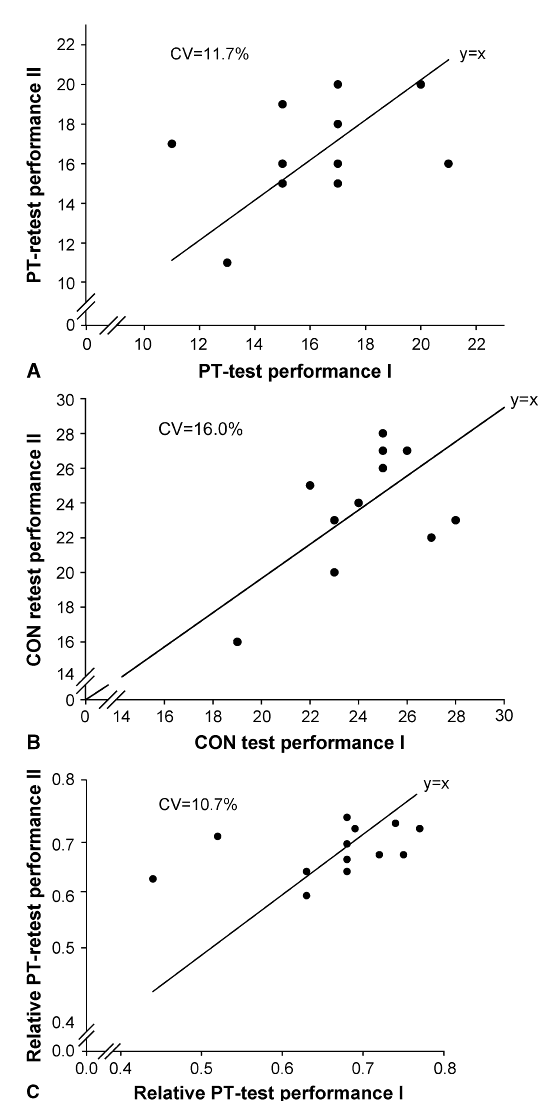

Figure 4. Test-retest of the PT-test ($r = 0.46$, $n = 13$, $P < 0.05$) (A), the CON-test ($r = 0.58$ $n = 13$, $P < 0.05$) (B), and the relative PT-test ($r = 0.44$, $n = 13$, $P < 0.05$) (C). The variance of coefficient (CV) is given. Full lines represent the line of identity ($y = x$).

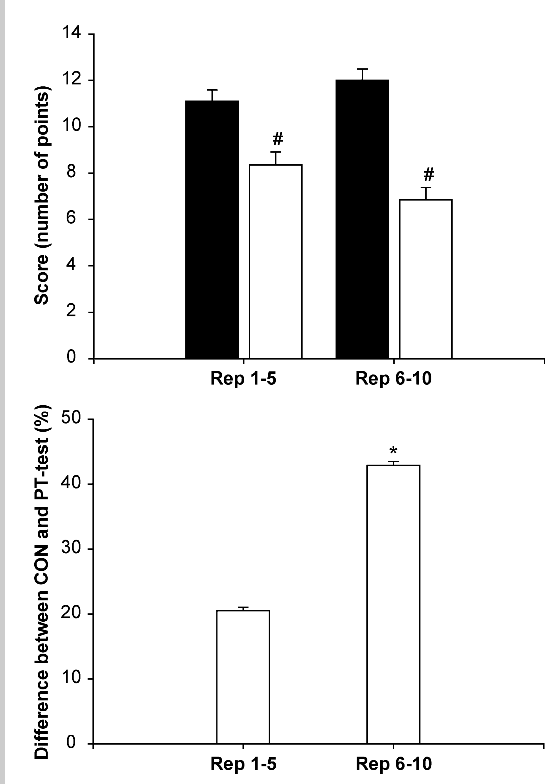

Figure 5. Number of points obtained during the first (1–5) and last 5 (6–10) repetitions in the CON- (black bars) and PT-test (upper panel), and the difference (%) in technical performance during the first (1–5) and last five (6–10) repetitions in the CON- and PT-test (lower panel). # Significant difference between the CON- and PT-test. * Significant difference between the first (1–5) and last five (6–10) repetitions.

first repetition, remaining at this level throughout the test (Figure 6). The mean heart rate during the PT-test was 173 ± 4 b.p.m., corresponding to 90 ± 2% of HRmax [194 (189–205) b.p.m], which was higher ($P < 0.05$) than during CON (137 ± 5 b.p.m.; 71 ± 3%). Relative heart rate (%HR_{max}) during the PT-test was not correlated either to the performance in CON-test, nor to the PT-test performance and relative PT-test performance.

Muscle Metabolites. Muscle CP decreased ($P < 0.05$) from 79.2 ± 2.7 to 52.9 ± 6.6 mmol kg^{-1} d.w. during the test (Figure 7A). Muscle lactate was 8.2 ± 1.2 mmol kg^{-1} d.w. before the test and higher ($P < 0.05$) at the end of the test (25.3 ± 5.9 mmol kg^{-1} d.w.) (Figure 7B). Muscle glycogen decreased ($P < 0.05$) from 427 ± 29 to 354 ± 39 mmol kg^{-1} d.w. during the test (Figure 7C).

Blood Variables. Blood lactate was 1.0 ± 0.2 mmol L^{-1} at rest and 3.6 ± 0.6 mmol L^{-1} immediately prior to the test. It increased ($P < 0.05$) progressively during the PT-test reaching 5.6 ± 0.7 mmol L^{-1} at the end (Figure 8A). Plasma ammonia was higher immediately before the test than at rest (40.6 ± 4.5 vs. 26.4 ± 2.7 umol L^{-1}) and it increased ($P < 0.05$) progressively during the test to 76.4 ± 11.1 umol L^{-1} (Figure 8B). Blood glucose was 4.0 ± 0.1 mmol L^{-1} at rest and higher ($P < 0.05$) immediately prior to the test (Figure 8C). It increased ($P < 0.05$) during the PT-test being 6.2 ± 0.6 mmol L^{-1} at the end of the test, and further to 6.6 ± 1.1 mmol L^{-1} after 4 minutes of recovery. None of the blood variables were correlated with relative PT-test performance.

Net Weight Loss. The net weight loss of the SE players was 0.8 kg ± 0.2 kg (range: 0.2−1.7 kg). Net weight loss was not correlated to any performance measures.

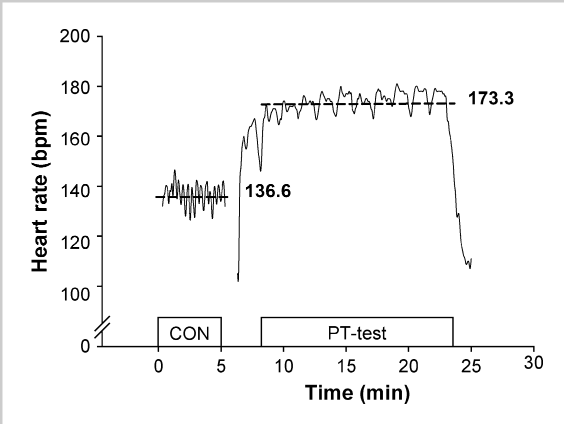

Figure 6. Example of heart rate monitoring from one player during the CON- and the PT-test. Dotted lines indicate the average heart rate.

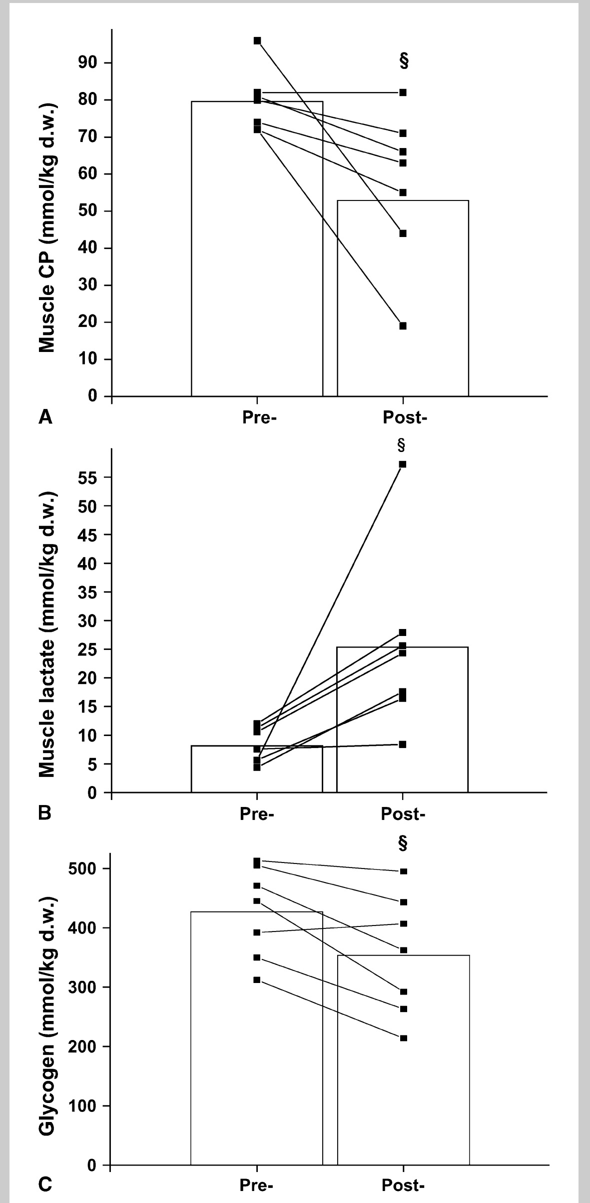

Figure 7. Muscle CP (A), lactate (B), and glycogen (C) before (Pre-) and after (Post-) the PT-test. § Significant ($P < 0.05$) difference between pre- and postvalue.

Discussion

The present study demonstrates that technical performance was reduced as the PT-test progressed, and that the performance of last 5 kicks in the PT-test was lower compared to the first 5 kicks. Furthermore, performance in the PT-test was lower than for the CON-test. These findings suggest that the physical work influenced the players' ability to kick. It was also observed that the test had a good reproducibility and that the youth elite players, as expected, had a better performance in the PT-test than sub-elite players. Furthermore, the activity pattern and the physiological responses during the test were similar to what have been observed during the intense periods of a soccer game. Thus, it appears that the PT-test can be used to evaluate a soccer player's technical skills when affected by previous intense soccer-related exercise.

The aim of this study was to develop the PT-test and examine whether it could be used to evaluate a soccer player's technical capacity under physical conditions similar to those encountered during a soccer game. Firstly, it should be considered whether the requirements of the PT-test resembled the demands during a soccer game. As shown in Table 1, the distance covered and the number of changes in activities is similar to that observed for top-class players. The amount of low and high intensity work is lower and higher, respectively, than the average during a game, but was chosen to represent the most intense periods in a game where fatigue may occur (21). That the demands during the test are similar to the requirements during parts of a game is confirmed by the physiological measurement. The mean heart rate during the test was 173 ± 4 b.p.m. or 90% of HRmax, which is similar to what has been observed in a number of matches (4,9,11,15). Likewise, the muscle and blood lactate levels were of a magnitude observed during match play, suggesting that the glycolytic system was stimulated as observed during periods of a game (4,15). The blood glucose levels were around 6.5 mmol-l at the end of the test. These levels are similar to observations during the first half of a soccer game (4), and thus, it appears that the conditions of the test were rather similar to those encountered during the more intense parts of a game.

The CV for the test was 12%. It appears to be reasonable for a test including soccer technical elements, which can not be so simple that the players can perform them even when fatigued. A significant difference in performance in the PT-test between the youth elite players and the sub-elite players was observed.

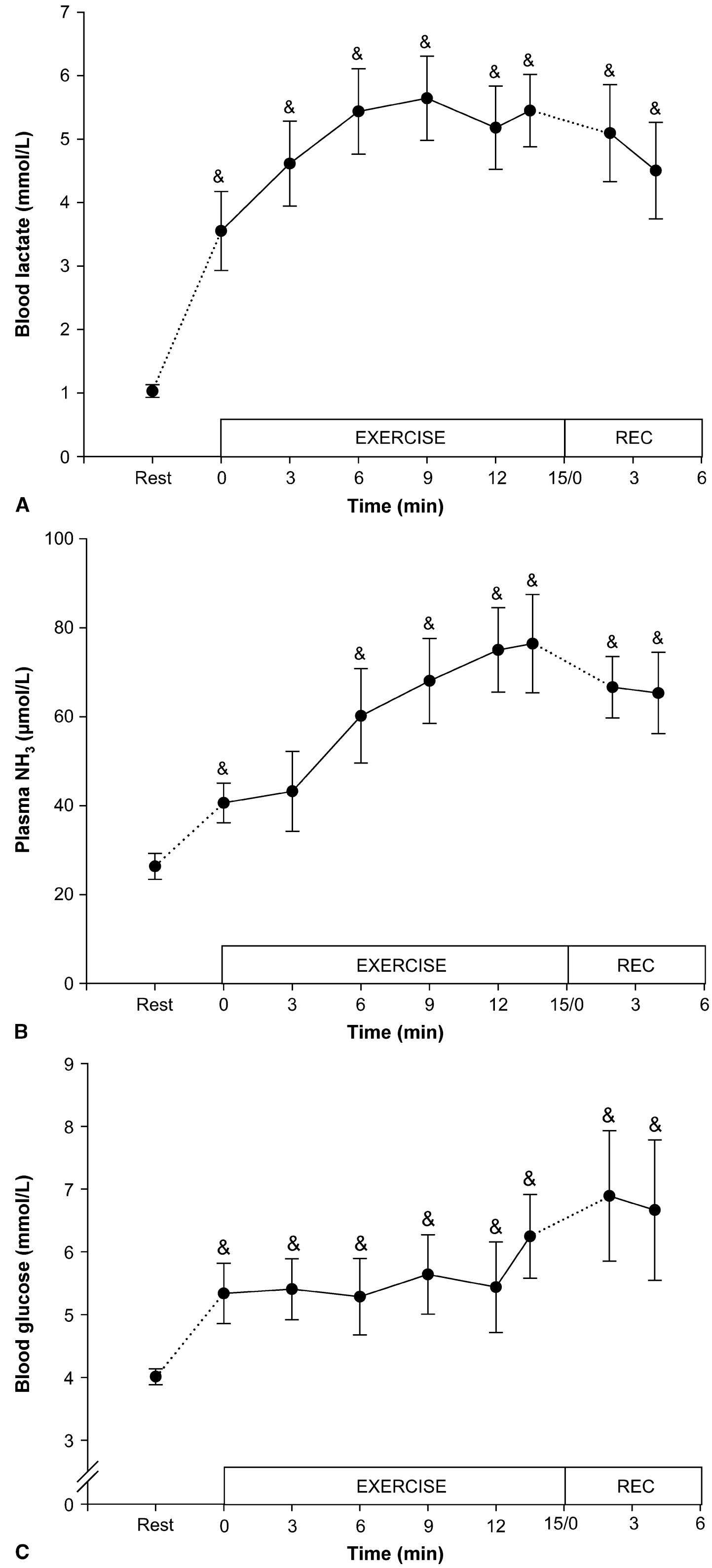

Figure 8. Blood lactate (A), plasma NH_3 (B), and blood glucose (C) before, during, and after the PT-test. & Significant ($P < 0.05$) difference from resting value.

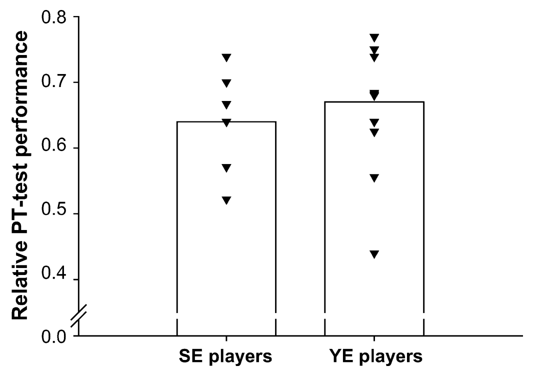

Figure 9. The relative PT-test result (PT-test result/CON-test result) for the YE- and SE-players.

This suggests that the test is sensitive enough to detect an expected difference in the technical performance of the two groups. A difference in the Yo-Yo test performance was also observed between the two groups. However, the performance of the Yo-Yo intermittent recovery test performance, which has been shown to be closely related to high-intensity exercise performance during a soccer match (13), was not correlated with the PT-test performance, suggesting that the result of the PT-test is not solely dependent on the physical performance of the player. The performance of the PT-test was different from the performance in CON-test, where the players were not affected by prior intense work. These findings, together with the physiological analysis of the test showing that the demands of the test resemble the demands of soccer, suggest that the physical stress during a game influences the technical performance of the players.

When expressing the PT-test result in relation to the CON-test (relative PT-test result), it is possible to evaluate separately the effect of the physical work on the technical performance. A significant variation was observed in both groups, and no difference was found between the two groups (Figure 9), showing that the players were differently affected by the physical work. Thus, the test shows that the players technically respond differently to the same physical loading even though none of the players showed signs of fatigue (the speeds were maintained throughout the test). Apparently, the tests can reveal the effect of the physical stress on a player's technical skill.

In summary, the PT-test examines the ability to repeatedly perform a technical element interspersed by periods of high-intensity exercise activities similar to those observed in soccer. The test has a reasonable reproducibility and good sensitivity. Thus, the test can evaluate individual difference in physical and technical performance of soccer players. Furthermore, the test can be used to evaluate the effect of a fitness or a technical training program on a player's technical skills under physical stressful situations.

Practical Implications

Before performing the test, it is advisable that the players are making a significant number (>20) of the kicks used in the test. The PT-test in the present study was performed on artificial grass, which has the advantage that it is easy to control the surface. However, it may also be performed on grass, but for comparisons of tests results the condition of the test should be the same.

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