©Journal of Sports Science and Medicine (2002) 1, 47-53
http://www.jssm.org

Research article

EFFECTS OF A CARBOHYDRATE-ELECTROLYTE DRINK ON SPECIFIC SOCCER TESTS AND PERFORMANCE

Sergej M. Ostojic[1] ✉ and Sanja Mazic[2]

[1] Exercise and Sport Nutrition Laboratory, O.C.A. Sports Medicine Institute, Pancevo, Yugoslavia.
[2] Institute of Physiology, School of Medicine, University of Belgrade, Belgrade, Yugoslavia.

Received: 02 May 2002 / Accepted: 07 June 2002 / Published (online): 20 June 2002

ABSTRACT

The aim of this study was to examine the effects of a carbohydrate-electrolyte drink on specific soccer tests and performance. Twenty-two professional male soccer players volunteered to participate in the study. The players were allocated to two assigned trials ingesting carbohydrate-electrolyte drink (7% carbohydrates, sodium 24 mmol.l^{-1}, chloride 12 mmol.l^{-1}, potassium 3 mmol.l^{-1}) or placebo during a 90 min on-field soccer match. The trials were matched for subjects' age, weight, height and maximal oxygen uptake. Immediately after the match, players completed four soccer-specific skill tests. Blood glucose concentration (mean±SD) was higher at the end of the match-play in the carbohydrate-electrolyte trial than in the placebo trial (4.4±0.3 vs. 4.0±0.3 mmol.l^{-1}, $P < 0.05$). Subjects in the carbohydrate-electrolyte trial finished the specific dribble test faster in comparison with subjects in the placebo trial (12.9±0.4 vs. 13.6±0.5 s, $P < 0.05$). Ratings of the precision test were higher in the carbohydrate-electrolyte trial as compared to the placebo trial (17.2±4.8 vs. 15.1±5.2, $P < 0.05$) but there were no differences in coordination test and power test results between trials. The main finding of the present study indicates that supplementation with carbohydrate-electrolyte solution improved soccer-specific skill performance and recovery after an on-field soccer match compared with ingestion of placebo. This suggests that soccer players should consume carbohydrate-electrolyte fluid throughout a game to help prevent deterioration in specific skill performance.

KEY WORDS: Fluid ingestion, soccer match, blood glucose.

KARBONHİDRAT-ELEKTROLİT BİR İÇECEĞİN FUTBOLA ÖZGÜ TESTLER VE BAŞARI ÜZERİNE ETKİLERİ

ÖZET

Bu çalışmanın amacı karbonhidrat-elektrolit bir içeceğin futbola özgü testler ve başarı üzerine olan etilerini incelemekti. 22 profosyonel erkek futbolcu çalışmaya katılmak için gönüllü oldu. Oyuncular 90 dak'lık futbol maçı sırasında karbonhidrat-elektrolit (%7 karbonhidrat, 24 mmol.l^{-1} sodyum, 12 mmol.l^{-1} klor, 3 mmol.l^{-1} potasyum) veya plasebo içen olmak üzere iki gruba ayrıldı. Gruplar yaş, vücut ağırlığı, boy ve maksimal oksijen alımı olarak benzerdi. Maçı takiben oyuncular futbola özgü 4 yetenek testini tamamladı. Maçın sonunda kan glikoz konsantrasyonu (a.o.±SS) karbonhidrat-elektrolit grubunda plasebo grubundan daha yüksekti (4.4±0.3 karşı 4.0±0.3 mmol.l^{-1}, $P < 0.05$). Karbonhidrat-elektrolit grubundaki denekler plasebo grubundaki denekler ile karşılaştırıldığında özel top sürme testini daha hızlı tamamladılar (12.9±0.4 karşı 13.6±0.5 san, $P < 0.05$). Doğruluk testinin oranları plasebo grubu ile karşılaştırıldığında karbonhidrat-elektrolit grubunda daha yüksekti (17.2±4.8 karşı 15.1±5.2, $P < 0.05$). Fakat koordinasyon testi ve güç testi sonuçları için gruplar arasında farklılıklar yoktu. Sunulan çalışmanın bulguları karbonhidrat-elektrolit solusyonu eklemenin plasebo alımı ile karşılaştırıldığında futbola özgü yetenek ve maç sonrası toparlanmaya iyileştirdiğini göstermektedir. Bu, karbonhidrat-elektrolit sıvı tüketinin maç boyunca futbola özgü yeteneklerin kötülüşmesi konusunda koruyucu katkısı olduğuna işaret etmektedir.

ANAHTAR KELİMELER: Sıvı alımı, futbol maçı, kan glikozu.

INTRODUCTION

The onset of fatigue during prolonged submaximal high-intensity exercise is associated with (a) reduction, if not depletion, of muscle glycogen (Bergstrom et al., 1967), (b) reduction in blood glucose concentration (Coyle et al., 1986), and (c) dehydration (Sawka and Pandolf, 1990). The ingestion of carbohydrate-electrolyte fluid during prolonged exercise may prevent dehydration and attenuate the effects of fluid loss on cardiovascular function and exercise performance (Montain and Coyle, 1992) and delay the onset of fatigue (Coyle et al., 1983; Coggan and Coyle, 1989). The improvement in endurance capacity may be a consequence of glycogen sparing (Tzintzas et al., 1996).

Team sports are characterized not only by intermittent high-intensity exercise but also by the contribution of a wide range of skills (McGregor et al., 1999). It has been observed that, during a soccer match, there is an increase in the number of goals scored as the game reaches its end (Reilly, 1996). This phenomenon may occur because of a reduction in the work rate of the players or because of mental fatigue, leading to lapses in concentration, technical errors and deterioration in skills (Reilly, 1996). Muscle glycogen has been observed to decline over the course of a soccer match (Saltin, 1973) therefore an association between low work rate and low muscle glycogen stores and blood glucose concentration is evident.

Several studies have evaluated the effects of carbohydrate-electrolyte supplementation during intermittent soccer-like physical activity (McGregor et al., 1999; Quanz, 1999). Carbohydrate supplementation delays the onset of fatigue during soccer and this may be responsible for the improved performance late in game (McGregor et al., 1999). However, there is no information available investigating the influences of carbohydrate-electrolyte drink on intermittent activities during on-field soccer match, specific soccer skills and recovery. The effects have only been investigated in a competitive soccer match situation under less controlled situation (Leatt and Jacobs, 1989; Zeederberg et al., 1996). The aim of this study was to examine the effects of a carbohydrate-electrolyte drink on specific soccer tests and performance.

METHODS

Subjects

Twenty two professional male soccer players (1st Yugoslav National league) gave their informed consent and volunteered to participate in the study which had the approval of the University's Ethical Advisory Commission. All participants were fully informed verbally and in writing about the nature and demands of the study as well as the known health risks. They completed a health history questionnaire, and were informed that they could withdraw from the study at any time, even after giving their written consent.

Experimental design

The overall design of the study consisted of three phases. In the first phase, all subjects (two soccer squads) underwent an on-field soccer match. The match consisted of 90 minutes of action: two 45-min periods with a short break (15 min) in-between, with technical and tactical demands same as on the real competitive soccer match (running, kicking a ball, jumping, heading, throwing, goal-keeping). We presumed this game-play simulated physical demands faced by soccer players during a real competition (no match analysis). The second phase began immediately after the on-field soccer match and consisted of four soccer-specific skill tests. All subjects were allocated to four groups (n_1=6, n_2=6, n_3=5 and n_4=5) and each group alternately completed all four tests. The dribble test was similar to that described by McGregor et al. (1999) while the precision test, coordination test and power test were similar to that described by Radosav (1992). The subjects were familiar with mentioned skill tests as part of their regular training process. After all participants completed the specific soccer-skills tests (15 min after the end of match), the third phase (relaxation-recovery) began through 1 hour. During that period, all subjects undertook similar activities like after the end of a real soccer match (rest, massage, change of clothes, etc).

Seven days before the experiment all subjects consumed the same standard diet (55% of the calories were derived from carbohydrate, 25% from fat and 20% from protein) to ensure that their glycogen stores were equally loaded. In the 72 hours before the experiment, the subjects were asked to refrain from any prolonged exercise. Subjects reported to the examination field at 11 A.M. after a repose of between 10 and 12 hours. On the test day subjects consumed a standard breakfast (providing an average of 800 (42) kcal) 4 hours before the test. After that period, all subjects drank only plain water ad libitum. During the trial, some atmospheric factors were measured (ambient temperature 24.5 (0.5)^{0}C, mean relative humidity 57 (2)%). Subjects emptied their bladders before the preliminary measurement of nude body mass, which was recorded by balance beam scale (Avery Ltd. Model 3306 ABV) before the start of the match, after the first and second half and after the relaxation period (1 hour after the end of match). Heart rate was recorded before the match (at rest), after the first and second half (45 min and 90 min respectively), 1 min after the end of match (acute recovery mark)(Ostojic and Zivanic, 2001) and 1 hour after the end of relaxation period using short-range radio telemetry (Polar Sport Tester^{TM}, Polar Electro Oy, Kempele, Finland). Subjective ratings of perceived exertion (6- to 20- point scale) (Borg, 1973) were obtained at rest (before the match), 45 min (after the first half), 90 min (after the second half) and 1 hour after the end of relaxation period.

The players were allocated to two assigned trials: ingesting carbohydrate-electrolyte (CHOE) drink (carbohydrates 7%, sodium 24 mmol.l^{-1}, chloride 12 mmol.l^{-1} and potassium 3 mmol.l^{-1}) or placebo (plain water). The groups were matched for subjects' age, weight, height and maximal oxygen uptake (Table 1). To balance the difference in playing positions and technics all control (water placebo) players were on one team and all carbohydrate-electrolyte–treatment players in the other soccer team. The solutions were of similar color, taste and texture. Subjects consumed the fluids immediately before exercise (5 ml.kg^{-1} body mass) and every 15-min thereafter (2 ml.kg^{-1} body mass). This pattern of drinking corresponds to a scenario in a real soccer match when players are allowed to consume fluids without leaving the field (injury treatment, penalty brakes, substitutions). The fluids ingested were kept in the refrigerator at 10^{0}C and removed 10 minutes before consumption.

Table 1 Descriptive characteristics of the subjects in carbohydrate-electrolyte (CHOE) and placebo group. Values are mean (SD). No significant differences were found between groups, *P* > 0.05.

Variables	**CHOE group** (*n* = 11)	**Placebo group** (*n* = 11)
Age (years)	22.9 (2.2)	23.5 (1.9)
Height (cm)	185.4 (7.0)	183.2 (5.4)
Weight (kg)	77.5 (6.8)	77.3 (4.2)
VO_2 max (ml.kg^{-1}.min^{-1})	55.2 (8.9)	55.9 (6.0)
HR_{max} (beats.min^{-1})	197 (2)	195 (3)

Blood analysis

A 10 ml blood sample was withdrawn from an antecubital vein in the forearm at rest, after the first half (45 min), after the second half (90 min) and after 1 hour of relaxation. Five ml of blood was dispensed into a tube, left to clot (1 h) and then centrifuged (4^{0}C) at 6000-rev·min^{-1} for 15 min to obtain serum. Plasma free fatty acids were determined using commercially available kit (Wako Chemicals GmbH kit, UK) and plasma glycerol by the method described by Laurell and Tibbling (1966). Serum sodium and potassium concentrations were determined by flame photometry (Ciba Corning 480), and serum chloride by culometric titration (Jenway Chloride Meter; Jenway Ltd., Dunmow, Essex, UK). From the remaining 5 ml of whole blood, 20 µl was deproteinized with 200 µl of 2.5% perchloric acid, centrifuged and frozen at – 20^{0}C for subsequent analysis for lactate and glucose (Maughan, 1982).

Statistical analysis

The data are expressed as means (SD). Statistical significance was assessed using Student's *t* test for correlated samples. Two-ways analysis of variance with repeated measures was used to establish if any significant differences existed between players' responses over time. Where significant differences were found, the Tukey test was employed to identify the differences.. *P* values of less than 0.05 were considered to be statistically significant. The data were analyzed using the statistical package SPSS, PC program, version 7.5 (SPSS Inc., USA).

RESULTS

The physical characteristics of the subjects that participated in the study are listed in Table 1. No significant differences were found between the two groups for any of the the variables in Table 1. Results on body mass loss, heart rate, rate of perceived exertion, concentration of blood glucose, blood lactate, plasma free fatty acids, plasma glycerol and serum sodium, potassium and chloride during the study are shown in Table 2. Body mass losses were higher after the first half, second half and total play in placebo trial (*P* < 0.05). Deficit after 1 hour of relaxation was significantly higher in the placebo group (*P* < 0.05). There was a trend for the heart rates to be higher in the placebo trial during the match, although there were no statistically significance between trials. In the relaxation period, heart rate was higher in the placebo trial after 1 min of relaxation (*P* < 0.05). The ratings of perceived exertion described by players at 0 min and 45 min were similar in both trials but at 90 min, the ratings were higher in the placebo trial (*P* < 0.05). After one hour of relaxation, the ratings of perceived exertion were higher in the placebo trial than in the carbohydrate-electrolyte trial (*P* < 0.05). Resting blood glucose concentration was similar in the two trials. Blood glucose concentration was higher at the end of the first half (*P* < 0.05) and at the end of the second half (*P* < 0.05) in the carbohydrate-electrolyte trial in comparison with placebo trial. Blood lactate concentrations measured at rest and during the experiment were similar between trials.

Plasma glycerol concentration was higher at the end of the first half of match (45 min) in the placebo trial ($P < 0.05$). There were no statistically significant differences between trials for plasma free fatty acids concentration and serum sodium, potassium and chloride concentrations.

Table 2. Body mass loss, heart rate, rate of perceived exertion (Borg scale), concentration of blood glucose, blood lactate, plasma free fatty acids (FFA), plasma glycerol and serum sodium, potassium and chloride during the study in carbohydrate-electrolyte (CHOE) and water trial. Values are mean (SD). *Statistically significant at $P < 0.05$ for CHOE vs. water trial.

	Trial	Time				
		Rest (0 min)	**End of I half** (45 min)	**End of II half** (90 min)	**1st min of recovery** (91 min)	**End of recovery** (150 min)
Body mass loss	CHOE	-	0.3 (0.3)*	0.9 (0.3)*	-	0.2 (0.1)*
(kg)	Water	-	0.5 (0.3)	1.4 (0.5)	-	0.4 (0.2)
Heart rate	CHOE	62.8 (5.0)	154.6 (18.5)	164.7 (12.8)	105.2 (8.0)*	65.7 (4.5)
(beats·min^{-1})	Water	63.3 (5.6)	162.9 (11.8)	170.2 (14.4)	113.1 (10.0)	64.9 (5.3)
Rate of perceived	CHOE	6.5 (0.7)	12.9 (1.2)	14.4 (1.1)*	-	7.1 (0.7)*
exertion	Water	6.2 (0.4)	13.6 (1.6)	17.1 (1.4)	-	7.5 (0.6)
Blood glucose	CHOE	4.2 (0.4)	4.8 (0.2)*	4.4 (0.3)*	-	4.3 (0.3)
(mmol·l^{-1})	Water	4.3 (0.4)	4.6 (0.4)	4.0 (0.3)	-	4.2 (0.2)
Blood lactate	CHOE	1.0 (0.3)	3.1 (0.2)	2.3 (0.4)	-	1.3 (0.4)
(mmol·l^{-1})	Water	1.0 (0.3)	2.8 (0.2)	2.5 (0.2)	-	1.3 (0.5)
Plasma FFA	CHOE	0.5 (0.1)	0.4 (0.1)	0.9 (0.2)	-	-
(mmol·l^{-1})	Water	0.5 (0.1)	0.5 (0.1)	0.9 (0.1)	-	-
Plasma glycerol	CHOE	64.7 (6.4)	267.3 (19.1)*	406.0 (44.5)	-	-
(µmol·l^{-1})	Water	64.0 (9.1)	301.3 (24.4)	422.7 (27.9)	-	-
Serum sodium	CHOE	135.8 (1.6)	-	140.4 (2.4)	-	-
(mmol·l^{-1})	Water	136.3 (1.5)	-	141.4 (2.5)	-	-
Serum potassium	CHOE	4.5 (0.3)	-	4.9 (0.3)	-	-
(mmol·l^{-1})	Water	4.5 (0.1)	-	5.0 (0.2)	-	-
Serum chloride	CHOE	98.2 (1.0)	-	101.9 (2.1)	-	-
(mmol·l^{-1})	Water	97.7 (1.4)	-	100.9 (1.6)	-	-

Specific soccer tests

Subjects in the carbohydrate-electrolyte trial finished the specific dribble test faster than subjects in the placebo trial (P < 0.05). Ratings of the precision test were higher in the carbohydrate-electrolyte trial than in the placebo trial (P < 0.05) but there were no differences in coordination test and power test results between trials (Table 3).

Table 3 Results of specific soccer tests in carbohydrate-electrolyte (CHOE) and placebo trial. Values are mean (SD). *Statistically significant at $P < 0.05$ for CHOE vs. placebo trial.

	Specific test			
	Precision (rate)	Power (s)	Coordination (rate)	Dribble (s)
CHOE trial	17.2 (4.8)*	2.4 (0.1)	3.9 (1.3)	12.9 (0.4)*
Placebo trial	15.1 (5.2)	2.4 (0.1)	2.9 (1.3)	13.6 (0.5)

DISCUSSION

The main finding of the present study was that supplementation with carbohydrate-electrolyte solution improved soccer-specific skill perfor-mance and recovery after on-field soccer match play, compared with ingestion of placebo.

Many studies reported decremental effects of dehydration and hyperthermia on intermittent prolonged exercise but there is a lack of information relating on-field sports activity. Even 2% of body mass loss impaired endurance performance (Saltin and Costill, 1988) and mental functioning (Gopinathan et al., 1988). During the placebo trial body mass decreased more than in the CHOE trial probably due to larger sweat and urine losses (Maughan, 2001). This loss of body mass possibly led to an increased thermal strain with negative impact on specific skill performance and higher ratings of perceived exertion during a placebo trail, which requires further on-field investigation with sweat rate, urine losses and body temperature measurement. Accumulation of blood in veins and reduction in stroke volume results in decreased central blood volume and reduction in cardiac output (Hamilton et al., 1991). Compensation for this decreased cardiac output normally occurs through a small increase in heart rate (Montain and Coyle, 1992). This is supported by evidence of an increase in heart rate during the placebo trial. Hamilton et al. (1991), Montain and Coyle (1992) and Hargreaves et al. (1996) reported that, during the moderate-intensity exercise, the magnitude of the increase in heart rate was directly related to the degree of dehydration. Perhaps ingestion of carbohydrate-electrolyte fluid maintained skin blood flow and thermoregulation, and reduced dehydration and hyperthermia induced fatigue (Wong et al., 1998).

Several studies reported that ingestion of carbohydrate-electrolyte solutions during prolonged intermittent exercise could delay fatigue. However, few studies are concerned with CHOE ingestion during rest period and recovery. In laboratory studies, Tabata et al. (1984) and Coggan and Coyle (1989) were able to postpone exhaustion after a specific protocol by supplying orally glucose solution. In field studies, Kirkendall et al. (1988) and Leatt and Jacobs (1989) reported the beneficial effects of CHOE ingestion on exercise performance by sparing muscle glycogen. Bangsbo (1994) considered that by the end of a soccer game, most players become depleted of muscle glycogen and ingestion of CHOE solution during half-time would be able to spare muscle glycogen. Although our study adopted different exercise protocol, drinking pattern and the nature of the work bout, we consider this study supports mentioned field and laboratory studies. Deterioration in specific skills (precision, dribbling) might be linked to depletion of muscle glycogen stores in the placebo trial because blood glucose is the main energy substrate for metabolism in the central nervous system. Lowered glucose concentrations might be the cause of the decrement in specific soccer skills in the placebo trial – performance observed in sports such as soccer, which require both tactical thought and cooperative technical interaction between players (Shepard and Leatt, 1987). To improve soccer specific skills late in play it is important to maintain blood glucose levels during the match.

Concentrations of blood lactate were higher than the resting values in all subjects in both trials but most of the measured concentrations during the study were below 3 $mmol.l^{-1}$ and therefore within aerobic conditions. This data suggest that lactic acid accumulation and resultant metabolic acidosis had no disturbing effect on performance (Quanz, 1999). Atypically low blood lactate values (~2-3 $mmol.l^{-1}$) obtained during the study are probably result of measurements from the forearm and venous blood. If the measurements were made from arterial blood and suitable lower body part (to make it as close as possible to the actually working muscles during a soccer game) the lactate levels could have been considerably higher. The higher plasma glycerol concentrations in the placebo trial suggest an increased contribution of fat to energy metabolism. The utilization of carbohydrates was limited because of presumably depleted glycogen stores and decreased level of blood glucose in the placebo trial.

In the present study, serum electrolyte evaluation showed no effects attributable to the type of solution provided during the study. Consistent with other investigations, lack of a significant difference might be explained by a number of factors including the short duration of match-play, fluid deficit less than 2% of body mass and/or non-competitive conditions (Wells et al., 1985; Shepard and Leatt, 1987; Quanz, 1999).

Rehydration after the match is an important part of recovery in intent to promote restoration of fuel stores and to enhance the retention of ingested fluid. In the carbohydrate-electrolyte trial, we found significantly smaller body mass deficit (after 1 hour), lower heart rate (after 1 min) and lower ratings of perceived exertion (after 1 hour) throughout the relaxation period. In accordance to others, although speculative, it has been suggested that carbohydrate-electrolyte ingestion may improve parameters of recovery due to maintaining fluid homeostasis, promoting recovery of fuel stores and enhancing the retention of ingested fluid. (Saltin, 1973; Kirkendall et al., 1988; Wong et al., 1998; Ostojic, 2000).

CONCLUSION

In conclusion, this study provides further supportive evidence that soccer players should drink carbohydrate-electrolyte fluid throughout a game to help prevent deterioration in specific skill performance and improve recovery. These findings have relevance in the design of optimal rehydration plan to improve performance and reduce fatigue and cardiovascular stress during match play.

REFERENCES

Bangsbo, J. (1994) Physiological demands. In: *Football (Soccer)*. Ed: Ekblom, B. London: Blackwell Scientific Publishers. 43-58.

Bergstrom, J., Hermansen, L., Hultman, E. and Saltin, B. (1967) Diet, muscle glycogen and physical performance. *Acta Physiologica Scandinavica* **71**, 140-150.

Borg, G.A.V. (1973) Perceived exertion: a note on 'history' and methods. *Medicine and Science in Sports & Exercise* **5**, 90-93.

Coggan, A. and Coyle, E. (1989) Metabolism and performance following carbohydrate ingestion late in exercise. *Medicine and Science in Sports & Exercise* **21,** 59-65.

Coyle, E.F., Coggan, A.R., Hemmert, M.K. and Ivy, J.L. (1986) Muscle glycogen utilization during prolonged strenuous exercise when fed carbohydrate. *Journal of Applied Physiology* **61,** 165-172.

Coyle, E.F., Hagberg, J.M., Hurley, B.F., Martin, W.H., Ehsani, A.A. and Holloszy, J.O. (1983) Carbohydrate feeding during prolonged strenuous exercise can delay fatigue. *Journal of Applied Physiology* **55,** 230-235.

Gopinathan, P.M., Pichan, G. and Sharma, V.M. (1988) Role of dehydration in heat stress-induced variations in mental performance. *Archives of Environmental Health* **43,** 15-17.

Hamilton, M.T., Gonzales-Alonzo, J., Montain, J. and Coyle, E.F. (1991) Fluid replacement and glucose infusion during exercise prevent cardiovascular drift. *Journal of Applied Physiology* **71,** 871-877.

Hargreeves, M., Dillo, P., Angus, D. and Febbraio, M. (1996) Effect of fluid ingestion on muscle metabolism during prolonged exercise. *Journal of Applied Physiology* **80,** 363-366.

Kirkendall, D.T., Foster, C., Dean, J.A., Grogan, J. and Thompson, N.N. (1998) Effects of glucose polymer supplementation on performance of soccer players. In: *Science and Football*. Eds: Reilly, T., Less, A., Davies, K., Murphy, W.J. London: E & FN Spon. 33-41.

Laurell, S. and Tibbling, G. (1966) An enzymatic fluorometric micromethod for the determination of glycerol. *Clinica Chimica Acta* **13,** 317-322.

Leatt, P.B. and Jacobs, I. (1989) Effect of glucose polymer ingestion on glycogen depletion during a soccer match. *Canadian Journal of Sport Sciences* **14,** 112-116.

Maughan, R.J. (1982) A simple, rapid method for the determination of glucose, lactate, pyruvate, alanine, 3-hydroxybutyrate and acetoacetate on a single 20-μL blood sample. *Clinica Chimica Acta* **122,** 231-240.

Maughan, R.J. (2001) Physiological responses to fluid intake during exercise. In: *Sports Drinks: Basic Science and Practical Aspects*. Eds: Maughan, R.J. and Murray, R. Boca Raton: CRC Press. 129-151.

McGregor, S.J., Nicholas, C.W., Lakomy, H.K.A. and Williams, C. (1999) The influence of intermittent high-intensity shuttle running and fluid ingestion on the performance of a soccer skill. *Journal of Sports Sciences* **17,** 895-903.

Montain, S. and Coyle, E. (1992) Influence of graded dehydration on hyperthermia and cardiovascular drift during exercise. *Journal of Applied Physiology* **73,** 1340-1350.

Ostojic, S.M. (2000) *The effects of carbohydrate-electrolyte ingestion on the performance and recovery of soccer players*. MSc thesis, Faculty of Medicine, University of Belgrade, Belgrade.

Ostojic, S.M. and Zivanic, S. (2001) Effects of training on athropometric and physiological characteristics of elite Serbian soccer players. *Acta Biologiae et Medicinae Experimentalis* **27,** 76.

Quanz, G. (1999) Effect of an intermittent carbohydrate intake on performance during a soccer match-play – a simulation study using treadmill exercise. *Insider* **7,** 7-12.

Radosav, R. (1992) Soccer specific tests and practice. In: *Football: technique-metodology-practice*. Ed: Radosav, R. Novi Sad: Sport's World. 129-156.

Reilly, T. (1996) Motion analysis and physiological demands. In: *Science and Soccer*. Ed: Reilly, T. London: E & FN Spon. 65-81.

Saltin, B. (1973) Metabolic fundamentals in exercise. *Medicine and Science in Sports* **5**, 137-146.

Saltin, B. and Costill, D.L. (1988) Fluid and electrolyte balance during prolonged exercise. In: *Exercise, Nutrition and Energy Metabolism*. Eds: Horton, E.S. and Terjung, R.L. New York: Macmillan. 150-158.

Sawka, M.N. and Pandolf, K.B. (1990) Effects of water loss on physiological function and exercise performance. In: *Perspectives in Exercise Science and Sports Medicine, Vol. 3: Fluid Homeostasis During Exercise*. Eds: Gisolfi, C.V. and Lamb, D.R. Carmel, IN: Benchmark Press. 1-38.

Shepard, R.J. and Leatt, P. (1987) Carbohydrate and fluid needs of the soccer player. *Sports Medicine* **4,** 164-176.

Tabata, I., Atomi, Y. and Miyashita, M. (1984) Blood glucose concentration dependent ACTH and cortisol responses to prolonged exercise. *Clinical Physiology* **4,** 299-307.

Tzintzas, O-K., Williams, C., Wilson, W. and Burrin, J. (1996) Influence of carbohydrate supplementation early in exercise on endurance running capacity. *Medicine and Science in Sports & Exercise* **28,** 1373-1379.

Wells, C.L., Schrader, T.A., Stern, J.R. and Krahenbuhl, G.S. (1985) Physiological responses to a 20-mile run under three fluid replacement treatments. *Medicine and Science in Sports & Exercise* **17,** 364-369.

Wong, S.H., Williams, C., Simpson, M. and Ogaki, T. (1998) Influence of fluid intake pattern on short-term recovery from prolonged, submaximal running and subsequent exercise capacity. *Journal of Sports Sciences* **16,** 143-152.

Zeederberg, C., Leach, L., Lambert, E.V., Noakes, T.D., Dennis, S.C. and Hawley, J.A. (1996) The effect of carbohydrate ingestion on the motor skill proficiency of soccer players**.** *International Journal of Sport Nutrition* **6**, 348-355.

AUTHORS BIOGRAPHY:

Sergej M. OSTOJIC
Employement:
Exercise and Sport Nutrition Lab., O.C.A. Sports Med. Inst., Pancevo,YU
Degrees:
MD (1996), MSc (2000), Specialization (2001), Medical Faculty of University of Belgrade, YU.
Research interest:
Soccer science and medicine. Physiological testing of the high-performance athlete. Sports nutrition and supplementation.
E-mail: sergej@panet.bits.net

Sanja MAZIC
Employement:
Institute of Physiology, School of Medicine, University of Belgrade, Belgrade, YU.
Degrees:
MD (1993), MSc (1997) Medical Faculty of University of Belgrade, YU.
Research interest:
Physiological testing of the high-performance athlete. Assessment in sport psychology. Heart rate variability during exercise.
E-mail: saga@arkayu.net

✉ **Dr. Sergej M. Ostojic**
Exercise and Sport Nutrition Laboratory, O.C.A. Sports Medicine Institute, Kikindska 13/11, Pancevo 26000, Yugoslavia**.**