UDC:796.015.572:613.192
Original scientific paper

THE EFFECTS OF A COCONUT WATER BEVERAGE ON BLOOD GLUCOSE HOMEOSTASIS DURING PROLONGED AEROBIC EXERCISE

Peter J. Chomentowski 3rd[1], Joshua A. Alis[1], Rayanne K. Nguyen[2], Judith M. Lukaszuk[2], David A. Walker[3], Amanda J. Salacinski[4]

[1*]*Kinesiology and Physical Education, Northern Illinois University, DeKalb, IL, USA*
[2]*Health and Human Sciences, Northern Illinois University, DeKalb, IL, USA*
[3]*Educational, Technology, Research and Assessment, Northern Illinois University, DeKalb, IL, USA*
[4]*Department of Movement Science, Sport and Leisure Studies, Westfield State University, Westfield, MA, USA*
[*]*Corresponding author e-mail*: *pchomentowski@niu.edu*

Abstract

Consumption of a carbohydrate-electrolyte beverage during prolonged exercise has been shown to maintain plasma glucose levels in recreational and competitive athletes. In the last few years, however, alternatives such as coconut water beverages have drawn attention due to a desire for a natural beverage compared to a manufactured carbohydrate-electrolyte beverage. The purpose of this study was to examine the effects of a coconut water beverage on blood glucose during prolonged exercise. Eleven endurance trained males participated in a randomized double blind study. Each subject completed three 90-minute trials consisting of a treadmill run at 60-70% of their maximal oxygen uptake while consuming one of three beverages per trial (water, carbohydrate beverage, coconut water beverage). Every 15 minutes the subject consumed 12 ounces of the blinded beverage. Blood glucose was measured at baseline, 15 min, 30 min, 45 min, 60 min, 75 min, and 90 min of the treadmill run. There was a significant difference ($p<.05$) in blood glucose values between water and the coconut water beverage at 45 min, 60 min, 75 min, and 90 min time points. No significant difference was found for blood glucose values between the coconut water beverage and a carbohydrate-electrolyte beverage ($p>.05$). This study indicates that a natural coconut water beverage had a significant effect on blood glucose homeostasis during prolonged exercise compared to water alone.

Keywords: Sports beverage, aerobic activity, running, endurance athlete, coconut water

Introduction

Aerobic athletic ability is a foundation for sporting activities and subsequently can require the athlete to perform prolonged activity at a moderate to high intensity (65% to 85% maximal oxygen uptake). A common theme with prolonged moderate to high intensity aerobic exercise is the development of fatigue which can be accompanied by a decreased exercise performance (Davis, Welsh, & Alderson, 2000; Lepers, Hausswirth, Maffiuletti, Brisswalter, & Van Hoecke, 2000), muscle strength (Lepers, Pousson, Maffiuletti, Martin, & Van Hoecke, 2000; & Millet, Martin, Lattier, & Ballay, 2003) and power output (Sahlin, & Seger, 1995).

Exercise fatigue is considered multifactorial and the development can result either from central or peripheral factors (Welsh, Davis, Burke, & Williams, 2002). However, fatigue occurring during exercise in cool or temperate conditions is associated with depletion of carbohydrate in the liver and muscles (Coggan, & Coyle, 1991; Coyle, Hagberg, Hurley, Martin, Ehsani, & Holloszy, 1983). Consequently, fatigue often occurs when muscle glycogen and blood glucose stores become depleted during prolonged exercise (Coyle, 1995). Many researchers have identified that termination from athletic exercise that corresponds with 65% to 85% of maximal oxygen uptake has been more closely accredited to glycogen depletion (Coyle, 1995; Karlsson, & Saltin, 1971; Tsintzas, William, Boobis, & Greenhaff, 1996), reduction of carbohydrate availability (Coyle, 1983), and dehydration (Armstrong, Costill, & Fink, 1985; Burge, Carey, & Wayne, 1993). Research has shown that carbohydrate supplementation ingested before and during exercise can have positive effects in delaying the onset of fatigue during high intensity exercise (Davies & Thompson, 1986; Welsh, et al., 2002) and improving performance (Coggan, & Coyle, 1987; Coyle, et al., 1983; Coyle & Coggan, 1984). This strategy has been endorsed by the 2007 American College of Sports Medicine Exercise and Fluid Replacement Position Stand (Sawka, Burke, Eicher, Maughan, Montain, & Stachenfeld, 2007) and demonstrates that most studies show an improvement in endurance performance or capacity when subjects consume a carbohydrate fluid as compared with water alone. While endurance exercise fatigue can be influenced by multifactorial mechanisms, it is believed that the primary mechanism for this improved performance is an enhanced maintenance of plasma glucose (i.e. prevention of hypoglycemia), thereby resulting in augmented carbohydrate oxidation by the muscle (Stellingwerff, Boon, Gijsen, Stegen, Kuipers, & van Loon, 2007) and delayed use of liver glycogen.

Carbohydrate supplementation studies (Tsintzas, Liu, Williams, Campbell, & Gaitanos, 1993; Maughan, Bethell, & Leiper, 1996; Tsintzas, et al., 1996; Angus, Hargreaves, Dancey, & Febbraio, 2000) have been carried out comparing a carbohydrate-electrolyte solution and water on quantifiable variables of exercise fatigue and performance with prolonged intense exercise. Carbohydrate-electrolyte beverages are the preferred supplementation choice of aerobic athletes (Von Duvillard, Arceiero, Tietjen-Smith, & Alford, 2008) and this may be due to recommendations for consumption and/or the worldwide marketing of sports carbohydrate beverages. One of the concerns with carbohydrate sports drinks is the addition of fructose and/or maltodextrin, artificial flavors, sweeteners, and added electrolytes (Kalman, Feldman, Krieger, & Bloomer, 2012). This inclusion has led to an apprehension by athletes to use carbohydrate drinks due to finding them undesirable or unpalatable. Drink palatability is important since an individual will not drink a sufficient quantity of a drink he/she does not like (Hubbard, Szlyk, & Armstrong, 1990). This has led to an increased desire for “natural” beverages with some athletes and recreational active fitness enthusiasts seeking alternatives to the manufactured sport drinks (Kalman, et al., 2012).

Previous findings have shown that natural fruit drinks such as coconut water have been effective as hydration drinks during exercise and clinically in patients suffering from severe dehydration (Adams & Bratt, 1992). Coconut water is a natural beverage that is rich in potassium, contains sodium, chloride and carbohydrate, and it has been demonstrated to have hydration effects similar to carbohydrate-electrolyte sports drinks (Chavalittamrong, Pidatcha, & Thavisri, 1982). Most of the published research has focused on coconut water, carbohydrate electrolyte sports drinks (Ismail, Singh, & Sirisingh, 2017; Kalman, et al., 2012; Saat, Singh, Sirisinghe, & Nawawi, 2002), and measures of hydration status as primary outcomes.

Therefore, the purpose of the present study was to examine the effects of a coconut water beverage, a carbohydrate electrolyte sports drinks and water on blood sugar concentration levels in aerobically-trained men. We hypothesized that a natural coconut water beverage would lead to greater blood glucose maintenance during prolonged exercise compared to ingested water alone.

Methods

Participants

Seventeen male subjects aged 18-45 years of age were recruited from local running clubs. The criterion for participation included subjects running ≥ three times a week for one year, the ability to perform a VO_{2max} test on a treadmill, attainment of a maximal oxygen consumption test within the inclusion criterion, nondiabetic, and be considered a low cardiovascular risk according to the ACSM's Guidelines for Exercise Testing and Prescription (Pescatello, Arena, Rieba, & Thompson, 2014). Subjects had to demonstrate a plateau in maximal oxygen uptake combined with either a RER of >1.1 and/or a maximal heart rate of plus/minus five beats per minute for three consecutive 15-second time points. Two subjects were excluded due to the maximal oxygen uptake testing, three subjects dropped out due to personal injury and one subject due to time issues. Eleven physically active healthy subjects were enrolled in this study and were used for the final analysis of data (table 1). Institutional Review Board approval was obtained for the proposed study and an informed consent was signed by each participant prior to participation. Health history and a blood health questionnaire were also obtained before any laboratory testing started.

Protocol

Preliminary Screening:

Following the medical history and consent, anthropometric measurements were taken in light clothes and bare feet using an InBody520 body composition analyzer (Cerritos, CA, 2011). Participants were asked to abstain from intense exercise 24 hours prior to the exercise sessions as well as refrain from eating two hours before the trial, and to void their bowels before testing. Maximal oxygen uptake test (VO_{2max}) was determined using a modified Balke treadmill test and was used to establish their running intensity for the exercise trails (60% to 70% of maximal oxygen uptake). Following the testing, subjects were presented with a two sample meals and were asked to consume either of the meals on their own between 2-4 hours before the exercise testing sessions. The meals consisted of approximately 870 calories and 136 grams carbohydrates.

Pre-Experimental session*:*

On all testing days, subjects were asked to report in comfortable and appropriate running attire and shoes, and follow established protocol regarding abstaining from exercise 24 hours and food at least two hours prior to their exercise session. Upon arrival subjects were asked to complete a 24-hour dietary recall with a nutritional technician before testing and data was recorded as intake per kilogram body weight. (Calories, kcal/kg; carbohydrates, g/kg; protein, g/kg). Anthropometric data was collected every test visit to assess weight change between sessions using the InBody520. In each trial, subjects were randomly assigned to consume either local filtered tap water (W), a coconut beverage (CB), or a carbohydrate beverage (CHO). For the current study, the CB used was COCO5 (Coco5, Chicago, IL). The CHO used was a popular sports carbohydrate-electrolyte drink. All beverages were served in bottles in which the subject was unable to see the beverage. The order of each trial and beverage was double blind. The beverages were mixed and distributed by a third party who did not disclose information to the subjects or the researchers until the completion of the project. The CB and CHO were closely matched in CHO and calorie content: 12 oz. CB contained 60 calories and 12 g CHO and the 12 oz. CHO contained 53 calories and 14 g CHO. The taste and consistency were similar for the CB and the CHO beverage. Carbohydrates in the CB beverage were derived from pure cane sugar and in the CHO beverage they consisted of sucrose and dextrose.

Exercise Trials:

Upon arriving to the laboratory testing facilities, the subjects were required to meet with the nutritionist to discuss their meals. The nutritionist recorded when they had eaten during the last 12-hours, what type of food they consumed, how much was consumed, and how much fluid they had consumed prior to attending the exercise session.

Subjects completed three exercise trails with a seven-day rest period between each session. Before testing, the subjects had baseline variables collected: heart rate, ratings of perceived exertion (RPE), and blood glucose. RPE was collected using the OMNI scale. Blood samples were collected with a capillary catheter via a finger prick and blood plasma glucose was analyzed using the Yellow Springs Instruments (YSI) 2300 Stat-Plus Glucose and Lactate analyzer (Yellow Springs, OH). Two 25 µL of whole blood was collected and YSI samples were required to be within ±4 $mg \cdot dL^{-1}$ to be used for analysis and the average of these two measurements was used as the YSI 2300 value.

The exercise trial consisted of a 90-minute treadmill run (Woodway, Waukesha, WI) at 60-70% their established maximal oxygen uptake with a self-selected speed to allow the subject to run for the entire 90-minutes. Twice during the test, the subjects were randomly connected to the True One 2400 metabolic cart (Parvo Medics; Sandy, UT) to assess that they were still exercising in the desired range. If needed, the researchers adjusted the speed of the treadmill as necessary to maintain the 60-70% range for maximal oxygen uptake (incline remained at 0% for the duration of the trial). At 15 minute intervals (15, 30, 45, 60 and 75), subjects were asked to step off the moving treadmill belt (“straddling” the treadmill) and were given 12ounces of one of the three beverages (W, CB, CHO) and asked to drink all of it within 60 seconds and then continue running. During this 60-second rest the three baseline variables were also collected again (HR, RPE, blood glucose). Following the test (90 min mark) subjects had the variables collected again but no beverage was consumed.

Statistical Analysis

Demographic data, independent variable, and dependent variables were recorded in Excel (Microsoft Corporation, Redmond, WA) and then analyzed using SPSS Statistics v.21 (SPSS, Inc., Chicago, IL). An alpha level of $p \leq .05$ was considered statistically significant for all comparisons. One-way (ANOVA) was performed to determine changes in body weight over time. Changes in blood glucose were analyzed using a two-way analysis of variance (ANOVA). Repeated measures ANOVA were used to assess differences in calories, carbohydrates and protein intake between testing sessions for the 24-hour recall.

Results

Eleven male subjects completed the study and individual demographics (mean±standard deviation) are shown in table 1. Body mass was recorded during all visits for deviations during the seven-day rest period between exercise sessions. One-way repeated measures ANOVA was conducted to determine whether there was a statistically significant difference in body weight among conditions. There were no outliers and the data were normally distributed at each time point, as assessed by boxplot and Shapiro-Wilk test ($p>.05$). The assumption of sphericity was met, as assessed by Mauchly's test for sphericity. Changes in body weight were not statistically significant between the testing sessions, $F\ (2,16) = 1.441$, $p=.27$, (see Table 1).

Table 1. Subject Baseline Demographics

n	11
Age	24.9±6.7
BMI	24.1±2.4
Height (cm)	178.2±5.3
VO_{2Max}	56.1±5.3
Trail 1 – Wt.	77.5±7.6
Trail 2 – Wt.	77.7±8.1
Trail 3 – Wt.	77.2±8.6

Note: VO_{2Max} = ml.kg.min^{-1}, values are mean±SD

The 24-hour dietary recall for the three testing sessions was analyzed and it was indicated that nutrition status was not a confounding factor. All data were normal distributed and sphericity was able to be assumed. There was no significant difference (all, $p > .05$) for total calories (kcal/kg), carbohydrates (g/kg) or protein (g/kg) intake between the three exercise testing sessions for each subject's nutritional status for a 24-hour period before the testing.

The repeated measures ANOVA was conducted to examine differences among conditions over exercise time. The assumption of sphericity was met for the W, CB and CHO, as assessed by Mauchly's test for sphericity ($p > .05$). The W group elicited significant changes in blood glucose concentrations over time $F(6,48)=7.702$, $p<.05$, $\eta 2=.491$, (see Table 2). Pairwise comparisons revealed the only statistically significantly difference was between the baseline and the 15 min time point ($p<.05$). Similarly the CB displayed statistically significant changes in blood glucose concentrations over time $F(6,48)=10.643$, $p<.05$, $\eta 2=.571$, as well the CHO demonstrated significant changes in blood glucose concentrations over time $F(6,48)=13.569$, $p< .05$, $\eta 2=.629$. Pairwise comparisons for both groups indicated statistically significant changes in blood glucose concentrations between baseline and all time points. (see Table 2).

Table 2. Subjects blood glucose concentrations across 90 minutes of aerobic exercise.

	W	**CHO**	**CB**
Base	78.8±12.1	78.6±11.5	79.9±13.9
15 min	64.0±9.4	63.1±7.6	64.1±11.7
30 min	71.4±8.4	76.3±9.7	76.8±12.9
45 min	73.5±9.7	87.1±9.5	85.6±11.9
60 min	70.4±9.7	82.5±8.0	80.5±12.1
75 min	68.6±9.2	78.3±6.4	78.4±11.8
90 min	67.6±7.5	76.9±7.9	77.4±11.3

Note: Mean±SD; Values = mg/dL; W = water beverage, CHO = carbohydrate beverage, CB = coconut water beverage.

The results indicated significant differences among conditions at different time points for blood glucose concentrations during the exercise testing. Repeated measures ANOVA displayed differences in blood glucose measures at certain time points (45 min, 60 min, 75 min, & 90 min) between the W, the CHO, and the CB beverage exercise tests (see Table 3). Pairwise comparisons demonstrated significant differences for several time points, (see table 4). The 45 min time point both CHO and CB displayed statistically significant differences in blood glucose levels compared to the W group. At the 60 min time point only the CHO was statistically significant different and for the 75 min and 90 min time points the CB was statistically significantly different from the W group (see Table 4). No statistically significant difference was observed between the CHO and the CB at any of the time points. ($p>.05$).

Table 3. Glucose ANOVA F-statistics for three beverages across time

	F	p-value	Partial eta	Power
Base-T1	.035	.96		.055
15 min-T2	.030	.97		.054
30 min-T3	.909	.41		.192
45 min-T4	5.114	.01*	.254	.787
60 min-T5	4.706	.02*	.239	.745
75 min-T6	3.967	.03*	.209	.667
90 min-T7	4.056	.03*	.213	.667

Note: *= p< .05;

Table 4. Blood glucose comparisons between the three beverages at minutes 45 thru 90

	Drink (1)	Drink (2)	Mean difference	p value
45 min	W	CHO	-13.6	.02*
		CB	-12.0	.04*
	CHO	CB	1.5	1.0
60 min	W	CHO	-12.2	.03*
		CB	-10.4	.06
	CHO	CB	1.7	1.0
75 min	W	CHO	-9.7	.06
		CB	-9.7	.05*
	CHO	CB	-0.0	1.0
90 min	W	CHO	-9.2	.07
		CB	-9.7	.05*
	CHO	CB	-0.5	1.0

Note: *= p< .05; W = water beverage, CHO = carbohydrate beverage, CB = coconut water beverage.

Discussion/Conclusion

The purpose of this study was to examine the effects of a coconut beverage on blood glucose levels during aerobic exercise. The findings of the current study suggest that supplementation with a coconut beverage is more effective in maintaining blood glucose concentration levels during prolonged exercise compared to supplementing with water alone. This study is in agreement with previous literature that supplementation of a carbohydrate beverage during aerobic exercise can maintain blood glucose better than consuming a water beverage (Ali, Williams, Nicholas, & Foskett, 2007; Bosch, 2007; Cermak & van Loon, 2013; Coleman, 1994; Jeukendrup, 2007; Stellingwerff, et al., 2007).

Research has indicated the importance of taking in a source of carbohydrates during long endurance exercise at a submaximal intensity (Campbell, Prince, Braun, Applegate, & Casazza, 2008; Cermak, et al., 2013; Coleman, et al., 1983; Currel, & Jeukendrup, 2008; Ivy, Costill, Fink, & Lower, 1979; Jeukendrup, Brouns, Wagenmakers, & Saris, 1997; Jeukendrup, 2007), although not all studies have found the same similar results on performance with ingested carbohydrates (Flynn, Costill, Hawley, et al., 1987; Madsen, Maclean, Kiens, Christensen, 1996). Yet, Jeukendrup (2007) suggested taking a carbohydrate supplementation every 15-20 minutes during prolonged bouts of exercise can be beneficial for blood glucose homeostasis. Those results indicated that during prolonged exercise (greater than 60 min.) that blood glucose levels for the water supplementation group followed the physiological trend of decreasing over time due to muscle uptake of blood glucose for ATP synthesis. It was demonstrated, however, that carbohydrate supplementation aided in maintaining a consistent blood glucose concentration across the 90 minutes of moderate aerobic exercise.

In the current study, supplementation with a coconut water beverage (every 15 min.) provided similar results on exercising blood glucose homeostasis compared with a carbohydrate beverage. Blood glucose levels were significantly different for several times points during prolonged aerobic exercise ($\geq$ 60 minutes) compared to just the water supplementation only. These findings supported our hypothesis that coconut water could provide a means to maintaining blood glucose levels during exercise, and may be an acceptable substitute for individuals who may not be able to tolerate carbohydrate sports beverages.

Coconut water is a natural beverage that provides sources of carbohydrates and electrolytes (Chavalittamrong, et al., 1982) and several studies have demonstrated its ability to have hydration effects similar to carbohydrate electrolyte sports drinks (Ismail, et al., 2007; Kalman, et al., 2012; Kuberski, & Saltin, 1979; Satt, et al., 2002). Research examining the effects of ingested coconut water on blood glucose levels as a marker of performance during prolonged aerobic exercise in athletes is limited (Kalman, et al., 2012). Therefore, the current study suggests that the use of a coconut beverage is a viable option to replace and replenish glucose when exercising for a prolonged amount of time compared to water alone.

A limitation to this study was that the subjects were not in a fasting state ($\geq$ 4 hours) before the exercise testing sessions and this could have had an effect on blood glucose concentrations during the testing. Nutritional technicians recorded the time (2-4 hours prior) and food consumed for the subjects last meal to ensure they consumed one of the two sample meals provided to them during the screening (870 calories and 136 grams carbohydrates). The subjects were not in a fasting state due to time of the exercise testing which occurred in the late afternoon. However, normal response in nondiabetic individuals 2 hours after a meal is a blood glucose concentration of less than 140 mg/dL. All of the subjects displayed a resting blood glucose level between 70-99 mg/dL, which matched the normal range for a fasting person without diabetes (Baseline average, 78.6 mg/dl).

Acknowledgements

We would like to thank COCO5 (Chicago, IL) for product donation of the coconut water beverage for the study.

References

[1]. Adams, W., & Bratt, D.E. (1992). Young coconut water for home rehydration in children with mild gastroenteritis. *Tropical and Geographical Medicine*, 44(1-2);149-53.

[2]. Ali, A., Williams, C., Nicholas, C., & Foskett, A. (2007). The influence of carbohydrate-electrolyte ingestion on soccer skill performance. *Medicine and Science in Sports and Exercise*,39:1969-1976.

[3]. Angus, D.J., Hargreaves, M., Dancey, J., & Febbraio, M.A. (2000). Effect of carbohydrate or carbohydrate plus medium-chain triglyceride ingestion on cycling time trial performance. *Journal of Applied Physiology.* 88(1):113-119.

[4]. Armstrong, L.E., Costill, D.L., & Fink, W.J. (1985). Influence of a diuretic dehydration on competitive running performance. *Medicine and Science in Sports and Exercise*,17(4):456-461.

[5]. Bosch, A.N. (2007). Carbohydrate ingestion during exercise: An aid to endurance performance. *International Journal of Sports* Medicine, 8(1):24-30.

[6]. Burge, C.M, Carey, M.F., & Payne, W.R. (1993). Rowing performance, fluid balance, metabolic function following dehydration and rehydration. *Medicine and Science in Sports and Exercise*, 24(12):1358-1364.

[7]. Campbell, C., Prince, D., Braun, M., Applegate, E., & Casazza G.A. (2008). Carbohydrate-supplement form and exercise performance. *International Journal of Sport Nutrition and Exercise Metabolism*, 18:179-190.

[8]. Cermak. N.M., & van Loon L.JC. (2013). The use of carbohydrates during exercise as an ergogenic aid. *Sports Medicine*, 43(11):1139-1155.

[9]. Chavalittamrong, B., Pidatcha, P., & Thavisri, U. (1982). Electrolytes, sugar, calories, osmolarity and pH of beverages and coconut water. *The Southeast Asian Journal of Tropical Medicine and Public Health*, 13(3):427-431.

[10]. Coggan, A.R., & Coyle, E.F. (1987). Reversal of fatigue during prolonged exercise by carbohydrate infusion or ingestion. *Journal of Applied Physiology*, 63(6):2388-2395.

[11]. Coggan, A.R., & Coyle, E.F. (1991). Carbohydrate ingestion during prolonged exercise: effects on metabolism and performance. *Exercise and Sport Sciences review*, 19:1-40.

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

[13]. Coyle, E.F., & Coggan, A.R. (1984). Effectiveness of carbohydrate feeding in delaying fatigue during prolonged exercise. *Sports Medicine*, 1(6):446-448.

[14]. Coyle E.F. (1995). Substrate utilization during exercise in active people. *The American Journal of Clinical Nutrition*, 61:968S-979S.

[15]. Coleman E. (1994). Update on carbohydrates: Solid versus liquid. *International Journal of Sport Nutrition and Exercise Metabolism*, 4:80-88.

[16]. Currell, K., & Jeukendrup, A.E. (2008). *Medicine and Science in Sports and Exercise*, 40(2):275-28.

[17]. Davies, J.M., & Thompson, M.W. (1986). Physiological responses to prolonged exercise in ultramarathon athletes. *Journal of Applied Physiology*, 61:611– 617.

[18]. Davis, J.M., Welsh, R.S., & Alderson, N.A. (2000). Effects of carbohydrate and chromium ingestion during intermittent high-intensity exercise. *International Journal of Sport Nutrition and Exercise Metabolism*, 10:476-485.

[19]. Flynn, M.G., Costill, D.L., Hawley, J.A., Fink, W.L., Neufer, P.D., Fielding, R.A., & Sleeper M.D. (1987). Influence of selected carbohydrate drinks on cycling performance and glycogen use. *Medicine and Science in Sports and Exercise*, 19(1):37-40.

[20]. Hausswirth, C., Bigard, A.X., Berthelot, M., Thomaïdis, M, & Geuzennec, C.Y. (1996). Variability in energy cost of running at the end of a triathlon and a marathon. *International Journal of Sports Medicine*, 17:572-579.

[21]. Hubbard, R.W., Szlyk, P.C., & Armstrong, L.E. (1990). Influence of thirst and fluid palatability on fluid ingestion during exercise. *Perspectives in Exercise Science and Sports Medicine, Vol. 3. Fluid Homeostasis during Exercise*. D. R. Lamb, C. V. Gisolfi (Eds.). (pp.39-95). Carmel: Benchmark Press, Inc.

[22]. Ismail, I., Singh, R., & Sirisingh, R.G. (2007). Rehydration with sodium enriched coconut water after exercise induced dehydration. *The Southeast Asian Journal of Tropical Medicine and Public Health*, 38(4):764-785.

[23]. Ivy, J.L., Costill, D.L., Fink, W.J., & Lower, R.W. (1979). Influence of caffeine and carbohydrate feedings on endurance performance. *Medicine and Science in Sports and Exercise*, 11(1):6.

[24]. Jeukendrup, A., Brouns, F., Wagenmakers, A.J.M, & Saris, W.H.M. (1997). Carbohydrate-electrolyte feedings improve 1-hour time trial cycle performance. *International Journal of Sports Medicine*, 18(2):125-129.

[25]. Jeukendrup, A.E. (2004). Carbohydrate intake during exercise and performance. *Nutrition*, 20, 669-677.

[26]. Jeukendrup, A.E. (2007). Carbohydrate supplementation during exercise: Does it help? How much is too much? *Gatorade Sports Science Institute*, 20(3).

[27]. Kalman, D.S., Feldman, S., Krieger, D.R., & Bloomer R.J. (2012). Comparison of coconut water and a carbohydrate-electrolyte sport drink on measures of hydration and physical performance in exercise-trained men. *Journal of the International Society of Sports Nutrition*, 9:1-10.

[28]. Karlsson, J., & Saltin, B. (1971). Diet, muscle glycogen and endurance performance. *Journal of Applied Physiology*, 31:203-206

[29]. Kuberski, T., Roberts, A., Linehan, B., Bryden, R.N., & Teburae, M. (1979). Coconut water as rehydration fluid. *New Zealand Medical Journal*, 90(64):98-100.

[30]. Lepers, R., Hausswirth, C., Maffiuletti, N., Brisswalter, J., & Van Hoecke, J. (2000). Evidence of neuromuscular fatigue after prolonged exercise on the contractile properties of human quadriceps muscle. *Medicine and Science in Sports and Exercise*, 71:1880-1886.

[31]. Lepers, R., Pousson, M., Maffiuletti, N.A., Martin, A., & Van Hoecke, J. (2000). The effects of a prolonged running exercise on strength characteristics. *International Journal of Sports Medicine*, 21:275-280.

[32]. Madsen, K., Maclean, D.A., Kiens, B, & Christensen, D. (1996). Effects of glucose, glucose branched-chain amino acids, or placebo on bike performance over 100km. *Journal of Applied Physiology*, 81:2644.

[33]. Maughan, R.J., Bethell, L.R., & Leiper, J.B. (1996). Effects of ingested fluids on exercise capacity and on cardiovascular and metabolic responses to prolonged exercise in man. *Experimental Physiology.* 81:847-859.

[34]. Millet, G.Y., Martin, V., Lattier, G., & Ballay, Y. (2003). Mechanisms contributing to knee extensor strength loss after prolonged running exercise. *Journal of Applied Physiology*, 21:193-198.

[35]. Pescatello, L.S., Arena, R., Riebe, D., & Thompson, P.D. (2014). *ACSM's Guidelines for Exercise Testing and Prescription*. 9th ed. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins.

[36]. Saat, M., Singh, R., Sirisinghe, R.G., & Nawawi, M. (2002). Rehydration after exercise with fresh young coconut water, carbohydrate-electrolyte beverage and plain water. *Journal of Physiological Anthropology and Applied Human* Sciences, 21:93-104.

[37]. Sahlin, K., & Seger, J.Y. (1995). Effects of prolonged exercise on the contractile properties of human quadriceps muscle. *European Journal of Applied Physiology*, 71(2-3):180-186.

[38]. Sawka, M.N., Burke, L.M., Eicher, E.R., Maughan, R.J., Montain, S.J., & Stachenfeld, N.S. (2007). Exercise and fluid replacement. *American College of Sports Medicine position stand* 39:377-390.

[39]. Stellingwerff, T., Boon, H., Gijsen, A.P., Stegen, J.H.C.H., Kuipers, H., & van Loon L.JC. (2007). Carbohydrate supplementation during prolonged cycling exercise spares muscle glycogen but does not affect intramyocellular lipid use. *European Journal of Physiology*, 454(4):635-647.
[40]. Stellingwerff, T., & Cox, G.R. (2014). Systemic review: Carbohydrate supplementation on exercise performance or prolonged running exercise. *Applied Physiology*, Nutrition &b Metabolism. 39(9):998-1011.
[41]. Tsintzas, K., Liu, R., Williams, C., Campbell, I., & Gaitanos, G. (1993). The effect of carbohydrate ingestion on performance during a 30-km race. *International Journal of Sport Nutrition.* 3:127-139.
[42]. Tsintzas, O.K., William, C., Boobis, L., & Greenhaff, P. (1996). Carbohydrate ingestion and single fiber glycogen metabolism during prolonged running in man. *Journal of Applied Physiology*, 81:801-819.
[43]. Welsh, R.S., Davis, M.J., Burke, J.R., & Williams H.G. (2002). Carbohydrates and physical/mental performance during intermittent exercise to fatigue. *Medicine and Science in Sports and Exercise*, 34(4):723-731.
[44]. Von Duvillard, S.P., Arceiero, P.J., Tietjen-Smith, T., & Alford, K. (2008). Sports drinks, exercise training, and competition. *Current Sports Medicine Reports,* 7(4):202-208.