AMERICAN UNIVERSITY OF BEIRUT

INFLUENCE OF DIFFERENT SPORTS ON THE TASTE PERCEPTION AND ACCEPTABILITY OF A COMMERCIAL SPORTS DRINK AMONG UNIVERSITY ATHLETE STUDENTS

by
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AN ABSTRACT OF THE THESIS OF

Jana Ahmad Daher for Master of Science
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Title: Influence of Different Sports on the Taste Perception and Acceptability of a Commercial Sports Drink Among University Athlete Students.

Sports drinks are essential in improving athletic performance through replenishing nutrients and electrolytes lost during physical activity. It has been previously suggested that the perception and acceptability of fluids is influenced by exercise and significantly varies between exercise and non-exercise situations. The study investigates the influence of different types of sports on the taste perception and acceptability of Gatorade, a commercial sports drink, before and after exercise.

A sample of Gatorade – Red Orange Flavor was evaluated by 34 male university athletes (20 weightlifters, 14 runners) recruited from the American University of Beirut (AUB) at two time points: pre and post exercise. Urine samples collected from the participants 30 minutes before and immediately after exercising were analyzed to test for hydration. Sensory testing examined the change in the intensity of sweetness, saltiness, sourness, and the thirst-quenching ability of the drink as well as its acceptability pre and post exercise with respect to the type of sport practiced. Participants were asked to rate their level of exertion and fatigue using a Borg Rating of Perceived Exertion (RPE) scale immediately after exercising.

Results indicated that the acceptability of the drink increased as the hydration status of the athletes decreased. No major change was found in the perception of the sensory attributes between exercise and non-exercise conditions. However, there were differences between the two sports groups in the ratings of the thirst-quenching ability of the drink where runners' ratings increased after exercise while weightlifters' ratings decreased after exercise.

These findings suggest that exercise has a larger effect on the acceptability and overall liking of the beverage compared to other sensory attributes. An enhanced liking of the beverage is key for optimal replenishment of lost fluids and electrolytes after exercise.

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CHAPTER I

INTRODUCTION

Sports drinks help athletes and physically active individuals replace fluids and electrolytes lost during exercise and provide them with an energy boost to replenish endogenous stores. They usually include water, simple carbohydrates, and electrolytes. Gatorade was the first sports drink to be introduced to the market in 1967. Sports drinks improve athletic performance, sustain exercise capacity, and maintain body fluid homeostasis.

The body loses 1 to 2L of water per hour during exercise which makes sports drinks consumption essential to avoid progressive hypo-hydration. Dehydration appears to be prevalent among athletes. Many studies demonstrated a high number of athletes starting exercise in a sub-optimal hydration state in addition to following inadequate rehydration strategies. This can have harmful effects on athletes’ health and can lead to a compromised performance.

Studies suggest that exercise influences the sensory perception and overall liking of fluids with a significant variation between exercise and non-exercise conditions. The acceptability of the drink has, in turn, a high influence on the consumption of the beverage and consequently on the hydration status of the body.

The objectives of this work were to investigate the influence of different types of sports on the taste perception and acceptability of Gatorade, a commercial sports drink, pre and post exercise.

CHAPTER II

LITERATURE REVIEW

A. Sports Drinks

Sports drinks are beverages intended to provide athletes with nutrients needed to improve athletic performance and compensate for nutrient, electrolyte, and fluid loss before, during, or after training or competition. They maintain body-fluid balance (Garth and Burke, 2013) and prevent dehydration (James *et al*., 2017), improve endurance performance (Australian Institute of Sports (AIS), 2017), and provide energy (Oria and Greenwood, 2008). It is claimed that sports drinks have a psychological effect on performance. Sports drinks can delay the sensation of fatigue (Silva and Paiva, 2015) and cognitively influence the perception of exertion (Silva *et al*., 2019). Friedman and Elliot (2008) showed that the mere exposure of popular sports drinks increased endurance in some tasks.

1. History

The history of sports drinks dates back to 1965 when the assistant coach of the University of Florida football team, Dwayne Douglas, approached a group of kidney specialists at the university, led by Dr. Robert Cade, to question why the athletes lost so much weight during games and training but did not urinate frequently (Kays and Philips-Han, 2003). Cade speculated that due to excessive sweating, players were dehydrated especially that lost fluids and electrolytes were not sufficiently replenished (Cade *et al*., 1972). Blood tests confirmed that the players suffered from low blood volume, imbalanced electrolytes, and low blood glucose levels. The research team then formulated a beverage comprised of water, salt, and sugar. They aimed to ensure adequate hydration, replenish key nutrient components lost during games, and provide energy (Driskell *et al*., 1999). Lemon juice was then added to flavor the drink because the players could not stomach its initial formulation (Kays and Philips-Han, 2003). Improvements in the weight loss issue were observed and the number of players hospitalized due to heat exhaustion decreased as well. The drink became popular after the team won the Orange Bowl game for the 1st time in 1966 (Galaz, 2019). The drink was then named “Gatorade’’ after the UF football team “The Gators’’ being the first drink developed specifically to support athletes during training (Burdette, 2015). Other teams started ordering Gatorade to improve their performance and endurance. Multinational companies started formulating their own sports drink products after the fast growth of Gatorade. Since then, the sports drinks industry has grown into a multibillion dollar making industry (Mintel, 2012).

2. Types

There are three types of commercially available sports drinks. They are classified based on their sugar and electrolyte content.

a. Isotonic

Isotonic sports drinks contain similar levels of sugars and electrolytes compared to the human body. The predominant aim of isotonic beverages is to rapidly restore lost fluids, electrolytes, and offer an energy boost (Colakoglu *et al*., 2016). Most commercial sports drinks are isotonic containing around 8% carbohydrates (Chatterjee and Abraham, 2019).

b. Hypertonic

Hypertonic sports beverages contain high amounts of carbohydrates and electrolytes compared to the human body. They are suitable for long-duration sports and normally consumed after exercise to replenish muscle glycogen stores and restore electrolytes (Raizel *et al.*, 2019). However, they are thought to cause gastrointestinal distress due to the increased water flow in the intestines caused by their high sugar content (De Oliveira and Burini, 2014).

c. Hypotonic

Hypotonic sports drinks contain the least amounts of carbohydrates and electrolytes. Studies suggest that hypotonic drinks result in better fluid absorption compared to isotonic drinks while having a similar effect on performance (Bonetti *et al*., 2010). They are normally consumed by athletes who require large amounts of fluids. However, hypotonic sports drinks are better consumed during short-duration performances because they might not cover the required carbohydrate intake for long performances (Rowlands *et al*., 2011).

3. Ingredients

The fundamental ingredients of sports drinks are water, carbohydrates, and electrolytes.

a. Water

The main component of sports drinks is water. During exercise, water is lost mainly through sweating (Maughan, 1998) in addition to electrolytes such as sodium, potassium, and to lesser extent calcium, magnesium, and iron (Hussain *et al*., 2017). Exercising in hot environments exacerbates sweating thus leading to higher fluid loss and interfering with body metabolic functions (Sawka *et al*., 2007). In extreme cases, severe dehydration and hyperthermia can lead to a heat stroke (Navarro *et al*., 2017). Fluid loss (more than 2% body weight) can lead to a compromised cognitive function (Shirreffs and Sawka, 2011) and impaired performance (McDermott *et al*., 2017). During exercise, the body loses 1 to 2L of water per hour which makes sports drinks consumption essential to avoid progressive hypo-hydration (Ali *et al*., 2011). Drinking enough fluids during exercise helps maintain body-fluid homeostasis and sustains exercise capacity (Maughan and Shirreffs, 2010).

b. <u>Carbohydrates</u>

Carbohydrates enhance athletic performance and reduce fatigue through providing energy for the muscles and the brain and postponing the utilization of muscle glycogen (Burke *et al*., 2011). They are essential in all types of sports of different intensities and durations (Academy of Nutrition and Dietetics, American College of Sports Medicine, and Dietitians of Canada, 2016). They also contribute to the flavor and the palatability of the beverage (Cater *et al*., 2004) which is associated with an improved performance (Burke and Maughan, 2015; Jeukendrup and Chambers, 2010). Sports drinks formulations include a mix of different types of sugars such as glucose, fructose, sucrose, galactose, and sometimes maltodextrins (Rowlands *et al*., 2015). In the small intestine, glucose is transported by a sodium-dependent glucose transporter or SGLT1 whereas fructose is transported by GLUT5 transporter (Jeukendrup and Moseley, 2010). The fact that different monosaccharides are transported via different routes in the intestinal mucosa maximizes carbohydrates and fluid absorption which enhances gastric emptying (De Oliveira and Burini, 2014). Sugars also enhance the intestinal absorption of both sodium and water (Mathers and Wolever, 2009); however, a high sugar content can delay gastric emptying (Stricker *et al*., 2009). According to the Academy of Nutrition and Dietetics, the carbohydrate content of a sports drink should range between 6-8 % to ensure an optimal absorption of water and electrolytes. The sugar and acid contents of sports drinks can impose a risk of dental enamel erosion and tooth decay (Lintner, 2016).

c. Electrolytes

Electrolytes replenish the minerals lost during exercise due to excessive sweating of sodium and to a lesser extent potassium, calcium, and magnesium. Sodium balances body fluids, regulates nerve conduction, and acid-base balance. Its main function is to maintain the thirst sensation so that the athletes consume more fluids and consequently stay hydrated (Kreider *et al*., 2010; Thomas *et al*., 2016). It also promotes renal fluid retention (American College of Sports Medicine, 2007). Exercise-associated muscle cramps can be a direct result of hyponatremia (low sodium blood levels), especially when exercising at a high intensity or in a humid or hot environment (Armstrong *et al*., 2007). This, in addition to heat exhaustion, can be avoided by drinking enough sports drinks to ensure fluid replenishment. A sports-drink sodium content of 25 mmol/L increases fluid consumption but a sodium level exceeding this can result in problematic fluid retention (American College of Sports Medicine, 2007; Australian Institute of Sport (AIS), 2017). Potassium also enhances the hydration status and prevents cramps since it acts as a main intracellular electrolyte (Moreno-Rojas *et al*., 2016) and aids in muscle contraction. Magnesium and calcium promote the overall athletic performance through maintaining normal muscle functioning (Kreider *et al*., 2010).

B. Effect of Palatability on Consumption

The acceptability of sports drinks has been shown to have behavioral consequences with regard to beverage consumption during exercising. Athletes are more likely to increase their fluid consumption if they perceive the drink as pleasant (Maughan *et al*., 1997). This helps in preventing voluntary dehydration and in supplying the athlete's body with lost fluids and electrolytes thus enhancing the overall physical performance (Wilmore *et al*., 1998). Wilmore *et al*. (1998) studied the relationship between taste preference and fluid consumption during and after exercising by analyzing the fluid intake based on the preference of fifteen runners and triathletes who were given two sports drinks of different sugar contents and water *ad libitum*. They concluded that the most preferred drink was consumed significantly more than the least preferred drink during exercise and that the perceived liking of a beverage is substantial for adequate hydration during exercise. These findings are consistent with those of Passe *et al*. (2000) where there also was a relationship between the hedonic value and the voluntary fluid intake during exercise. It is suggested that preference and consumption are stimulated by a feedback process caused by a complex thirst mechanism (Horio and Kawamura, 1998). Flavoring or lower temperature water was reported to improve fluid consumption during exercising (Szlyk *et al*., 1989). Therefore, the palatability of the sports drink can impact the hydration status of the athlete due to its positive effect on the consumption of fluids and consequently replenishing all electrolytes and water lost through sweat and urine at a later stage (Maughan *et al*., 1997; 1996).

C. Effect of Exercise on Palatability

Exercise, in turn, has been shown to impact the acceptability of beverages thus subsequently affecting fluid intake. Passe *et al*. (2000) demonstrated that a significant hedonic shift can occur during prolonged exercise where a disliked carbohydrate-electrolyte beverage changed in terms of liking from the sedentary to exercise state which increased voluntary fluid consumption as well. Prolonged exercise was also shown to cause a preference for sweet and sour tastes after exercise without affecting the taste threshold sensation (Horio and Kawamura, 1998). However, the preference may vary for different sweet substances. Horio (2004) investigated the effect of exercise on various sweet beverages of different concentrations of sucrose, glucose, stevioside, D-sorbitol, eryhtriyol, and sachharin using a hedonic rating scale. The acceptability ratings of all solutions increased post-exercise but did not change for saccharin at all tested concentrations. This was attributed to the non-caloric content of saccharin since preference for energy-containing sweet solutions may be expected to be higher after exercise even though stevioside and erythritol contribute little or no energy at the used levels. These hedonic changes are accompanied with temporal changes in the perception of different sensory attributes during exercise. Ali *et al*. (2011) studied the changes in sensory perceptions of different formulations of sports beverages pre, during and after exercising in recreational runners. Ratings of sweetness scored higher during exercise compared to before and after physical activity. Ratings of overall acceptability and thirst-quenching ability increased as the duration of exercise increased for all beverages including water. Appleton (2005) showed that the perceived pleasantness of fluids increased after exercise.

It has been previously suggested that the physiological characteristics of the consumers can affect the perceived pleasantness of any food or fluid item (Rogers, 1999). This is directly related to the theory of "physiological usefulness" which suggests that any food item which is physiologically beneficial to a person will be perceived as highly pleasant (Appleton, 2005). Leshem *et al*. (1999) showed that preference for salt increases after 1 hour of exercise. There is an increased salt preference, which is caused by the decreased levels of sodium in the body (Beauchamp *et al*., 1990; Takamata *et al*., 1994) and by the activation of sodium retention hormones (Leshem *et al*., 1999) through exercise-induced hypovolemia (Maughan and Leiper, 1995). Wald and Leshem (2003) showed that the preference of untasted salt was proportional to the amount of sweat lost during exercising, and that a rewarding physiological state was induced after replenishment of exercise-induced sodium loss. This theory was also used in other studies to explain the increased preference for saltier drinks post exercising (Passe *et al*., 2000; Appleton, 2005).

D. Hydration

The hydration status is critical for optimal athletic performance. During exercise, thermoregulation is primarily maintained through sweating (Casa *et al*., 2000). Sweating losses vary considerably among athletes, depending on the type, intensity and duration of exercise, and weather conditions (American College of Sports Medicine, 2007; Sawka *et al*., 2005). Sweating results in the loss of body fluids and electrolytes that are of prime importance for optimal performance (Casa *et al*., 2000). Failure to sufficiently replace lost fluids and maintain water balance leads to progressive dehydration and consequently compromised athletic performance (Binkley *et al*., 2002). Exercising in hot climates (> 30°C) exacerbates the situation and increases the risk of exertional heat illness like cramps, heat exhaustion or heat stroke (Casa, 1999). Many studies reported that most athletes start exercise in a suboptimal hydration state (Rivera-Brown *et al*., 2012; Castro-Sepulveda *et al*., 2015; Kiitam *et al*., 2018) and get dehydrated even more during practice (Arnaoutis *et al*., 2015). Dehydration has detrimental effects on the human body. Dehydration compromises endocrine and excretory systems, alters thermoregulation, and negatively affects the cardiovascular system resulting in suppressed physical performance and cognitive function (Mielgo-Ayuso *et al*., 2015). The onset of significant dehydration is preventable, or at least modifiable, when fluid intake parallels sweat losses (Sawka *et al*., 2005). Exercising results in increased water requirements (Sawka *et al*., 1996); however, sweating rates and consequently water needs vary significantly among athletes even under standardized conditions (Maughan *et al*., 2004). Therefore, there is no single drinking regimen that is best for all athletes and all exercise conditions. The American College of Sports Medicine (2007) recommends the development of an individualized fluid replacement program that maintains hydration at less than 2% body mass reduction of the pre-exercise mass. A hydration program should consider the individual's sweat loss rate, exercise dynamics, drinking opportunities and environmental conditions (Casa *et al*., 2000). Athletes can monitor their sweat losses by routine measurements of body mass before and after exercise, with corrections for fluid consumption or urination (Maughan and Shirreffs, 2010). Starting exercise in a hypohydrated state, which is common in the athletic community, can amplify performance decrements (Maughan *et al*., 2007). An athlete should slowly drink beverages (5-7ml/kg body weight) at least four hours before exercising (American College of Sports Medicine, 2007). After exercise, normal food consumption and sufficient intake of water or another beverage can restore deficient fluids and electrolytes (Institute of Medicine, 2005). Furthermore, sodium consumption during recovery periods helps in thirst stimulation and fluid retention (Ray *et al*., 1998).

There is no scientific consensus for how to best assess hydration status of athletes since all hydration assessment techniques vary greatly in their applicability due to methodological limitations (Cheuvront and Sawka, 2005). Armstrong *et al*. (1998) have studied the relationship between urine color and specific gravity and have developed a urine color chart that can be used to assess hydration status when a high precision might not be needed. Measuring specific gravity requires the use of a refractometer which is inexpensive, portable, and does not require electric supply. Moreover, measurement of osmolarity is not very common due to methodological limitations (Maughan and Shirreffs, 2010).

E. Types of Exercises – Mitchell's Classification

The most common classification of sports categorizes them into aerobic and anaerobic based on the type of muscle metabolism. Another classification, followed in this study, was proposed by Jere Mitchell, M.D in 2005. Mitchell classified sports according to the type and intensity of exercise. They are classified as dynamic or static then further grouped into either low, moderate, or high intensity, as shown in Figure 1. Static and dynamic correspond to the mechanical action of the muscles involved. Dynamic exercise involves changes in muscle length and little need for intramuscular force while static exercise involves the development of large intramuscular force and relatively small changes in muscle length. All sports include both static and dynamic components but at variable levels. Distance running has high dynamic and low static components while weightlifting has low dynamic and high static demands. While being a widely accepted method for classifying sports, Mitchell's classification has two limitations. It does not take into account the athlete's position in the sport (Beaumont *et al*., 2017). A goalkeeper and a midfielder in soccer, for example, experience different dynamic and static loading although they are playing the same sport. Moreover, it does not take into account differences between athletes, who practice the same type of sport, amongst themselves (Beaumont *et al*., 2017). In elite level sports, athletes take on additional training and conditioning that accompany their competition training. This may lead to differences between the static and dynamic components.

CHAPTER III

MATERIALS AND METHODS

A. Samples

The commercial sports drink Gatorade® (500ml) was used in the study based on its popularity among athletes and its availability in the local market. Red-orange flavor was used instead of other flavors due to its general overall liking and absence of any strong flavor, as judged in informal taste tests by members of the project's research team, and to ensure against possible floor or ceiling effects due to extreme low or high liking. Gatorade bottles were stored for a maximum of 72 h in a refrigerator at 4 °C. Samples were prepared on the same day of testing and served at 5-10℃. Fifty ml of the sports drink were served in plastic sensory cups (locally purchased).

B. Subjects

A total of 34 male athletes – 20 weightlifters and 14 runners (mean ± SD; age 20.8±1.7 years, height 1.76±0.04 m, body mass 77.5±9.7 kg) aged between 18 and 24 years participated in this study. They were recruited from the Charles Hostler Student Center at the American University of Beirut (AUB). They were selected based on being non-smokers to ensure against any taste abnormalities. The screening questionnaire is provided in Appendix II. The subjects were briefed about the study's procedure and requirements before confirming their participation. Written informed consent was obtained from all subjects prior to participation. The study was approved by the Institutional Review Board of the American University of Beirut, Lebanon.

As illustrated in Figure 1, sports are classified as dynamic or static and then further grouped into either low, moderate, or high intensity according to the Mitchell's classification (Mitchell *et al*., 2005). Athletes were divided into two groups according to the low and high intensity classification of dynamic sports.

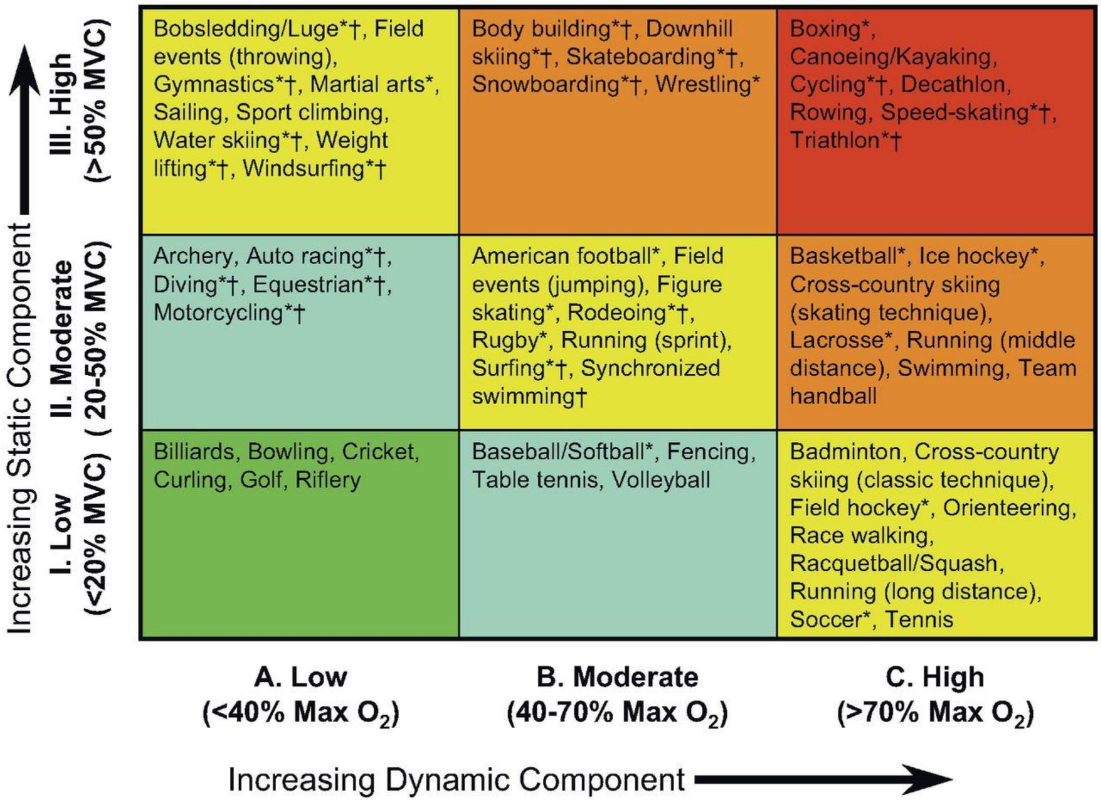

Fig. 1. Classification of sports
Source: Mitchell, J.H., Haskell, W., Snell, P., and Van Camp, S.P. (2005). "Task Force 8: classification of sports". *Journal of the American College of Cardiology, 45*(8), 1364-1367.

C. Experimental Procedure

The experimental procedure of the study is summarized in Figure 2:

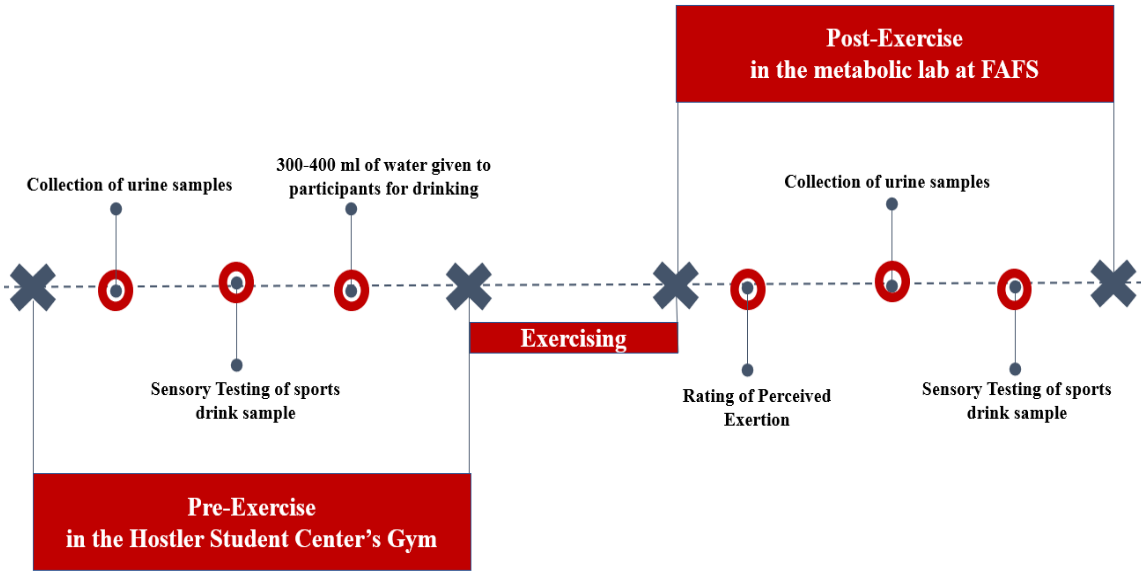

Fig. 2. Summary of experimental procedure

Data collection was separated into three different phases: pre-exercise, exercise, and post-exercise. Upon arrival to the Charles Hostler Student Center's gym, athletes were asked to provide a urine specimen. They then performed the pre-exercise sensory evaluation session and were asked to drink 300-400 ml of water before starting to ensure that the effect of dehydration will only be due to exercising. Fifty ml of red-orange flavored Gatorade was given to the subjects in 50 ml clear plastic cups. They could consume the solutions in stage while recording their responses on a tablet (Samsung, model SM-T510). Each athlete exercised for 30 to 45 min according to his sport category (running or weightlifting). Following completion of the exercise, subjects rated their perceived exertion and were asked to provide another urine sample. The athletes were then provided with another 50 ml sample of red-orange flavored Gatorade to perform a similar sensory evaluation session to the above.

D. Urinalysis

Urinalysis was performed to test for the hydration status of the athletes. Urine samples were collected from the participants 30 min before and immediately after exercising. To determine the overall concentration of the urine, samples were analyzed using two methods. First, the color of the urine specimens was compared to an eight-color scale developed by Armstrong *et al*. (1994; Appendix I, Figure A1) in a well-lit room. Furthermore, the specific gravity of the urine specimens, which is another indication of urine concentration, was measured using a refractometer (ATAGO, USA). The lower the specific gravity, the less concentrated is the urine sample, and the lighter in color it is and vice versa. The color of the urine and its specific gravity are directly correlated with the hydration level of the athlete (Armstrong *et al*., 1994; Stover *et al*., 2006).

E. Sensory Testing

Participants were given the sports drink before and immediately after exercising. During the session, participants were asked to rate the sports drink according to each of the perceived intensities of sweetness, sourness and saltiness on a 15 cm line scale that starts from "Not at All" and ends with "Very". The thirst-quenching sensation experienced from consuming the drink was also rated on a 15 cm line scale with "Not at All" and "Very" being the anchor words corresponding to its low and high ends, respectively. Drinking of 300-400 ml of water before exercising to ensure that the effect of dehydration will only be due to exercising, allows us to properly assess the thirst-quenching attribute in the sensory test taking place after exercising. Additionally, the athletes assessed the overall acceptability of the drink using both a 9-point Hedonic scale and the Food Action Rating Test (FACT; Schutz, 1965), as well as the acceptability for the intensity of sweetness, sourness and saltiness of the product using the Just About Right (JAR; Lawless & Heymann, 2010) scale. The developed sensory ballot, which includes intensity rating, JAR scale and acceptability testing, as well as the FACT questionnaire are provided in Appendix III. Sensory testing was done using *Compusense s*oftware.

F. Rating of Perceived Exertion

The level of effort and fatigue experienced by the athletes due to exercising was measured using the Borg Rating of Perceived Exertion (RPE) scale. The participants were asked to rate their exertion based on the scale, summarized in Appendix I, Figure A2), after exercising. This scale gives an indication about the intensity of exertion due to the activity (Borg, 1982). It is anchored by simple verbal expressions and ranges from 0 to 10.

G. Body Composition and Anthropometry

The athletes' anthropometric measurements were recorded in the metabolic lab at AUB (Room 408, 1st floor, Faculty of Agriculture and Food Sciences, Wing B). Height was measured to the nearest 0.5 cm using a Seca stadiometer (Seca model 213, Germany) while subjects were bare-footed. Weight, percent body fat and lean body mass were measured using a bioelectric impedance analysis (Inbody 770).

H. Statistical Analysis

SPSS, a statistical software (version 23, IBM Corporation, Armonk, NY, USA), was used to perform regression analysis, whereby the sensory attribute was the response variable, and the sport category (runners vs. weightlifters), subject, time (pre vs. post) and the sport x time 2-way interaction were predictor variables. The level of hydration (as measured by the refractometer) and perceived exertion were also used as continuous variables in the model. Moreover, regression trend lines were devised for significant continuous variables to discern the nature of the trend (positive or negative relationship between the x and y variables) and the magnitude of the change (slope of line).

CHAPTER IV

RESULTS

Table 1 shows the regression analysis results table. Subject was significant for most response variables, but it is not of major practical significance since it accounts for differences between subjects. Sport was only significant for the thirst-quenching variable, which implies a significant difference between the two sport categories in the thirst-quenching ability of the drink. Time (Pre vs. Post) was not significant for any response variable. Hydration, which was measured by a refractometer, was significant for the hedonic and for the Food Action Rating scale ratings. The perceived exertion was significant for the JAR sourness, JAR saltiness, and hedonic ratings.

Table 1. Regression analysis result table

	Subject		*Sport*		*Time*	
	Coefficient	*t-value*	*Coefficient*	*t-value*	*Coefficient*	*t-value*
Sweetness	0.176	0.621	-0.300	-0.648	-0.046	-0.090
Sourness	-0.194	-0.665	0.016	0.035	-0.483	-0.931
Saltiness	-0.399	-1.389	0.696	1.489	0.388	0.758
Thirst Quenching	-0.874***	-3.198	0.939**	2.110	0.358	0.736
JAR Sweetness	0.736**	2.579	-0.617	-1.326	-0.030	-0.060
JAR Sourness	-0.747***	-2.712	0.576	1.284	-0.686	-1.400
JAR Saltiness	-0.372	-1.316	0.493	1.071	-0.404	-0.804
Hedonic	-0.745***	-2.820	0.536	1.246	-0.371	-0.787
Food Action Rating Scale	0.678**	2.454	-0.445	-0.989	0.028	0.057
	Hydration		Perceived Exertion		Sport x Time	
	Coefficient	*t-value*	*Coefficient*	*t-value*	*Coefficient*	*t-value*
Sweetness	-0.107	-0.823	0.253	1.145	0.001	0.002
Sourness	0.074	0.554	0.131	0.580	0.568	0.966
Saltiness	0.107	0.816	0.210	0.942	-0.455	-0.784
Thirst Quenching	0.114	0.916	0.098	0.461	-0.484	-0.878
JAR Sweetness	0.013	0.098	0.003	0.013	-0.062	-0.107
JAR Sourness	0.114	0.903	0.465**	2.173	0.462	0.831
JAR Saltiness	-0.050	-0.390	0.505**	2.299	0.100	0.175
Hedonic	0.267**	2.205	0.482**	2.346	-0.053	-0.100
Food Action Rating Scale	-0.283**	-2.239	-0.201	-0.936	0.026	0.046

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table A1, Appendix IV illustrates the mean ± SD sensory data for red-orange flavored Gatorade before and after exercise rated by runners and weightlifters.

A. Sensory Properties Ratings Before and After Exercise

1. Sweetness

Ratings of sweetness for red-orange flavored Gatorade increased after exercise in both types of sports. Ratings were higher in runners compared to weightlifters both pre and post exercising Figure 3. However, differences were not statistically significant Table 1.

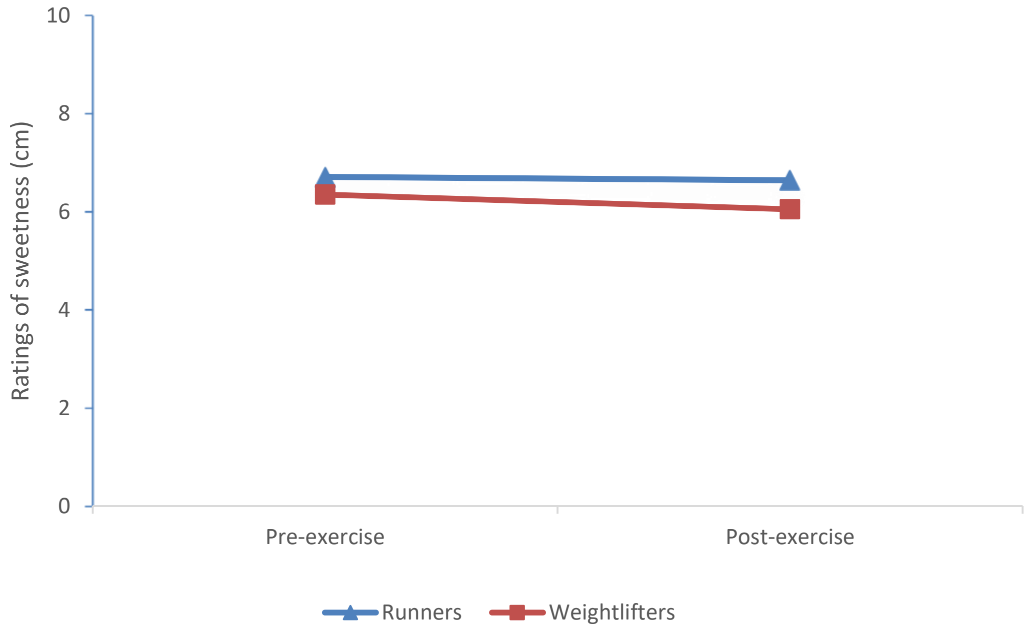

Fig. 3. Mean ratings of sweetness before and following exercise by runners and weightlifters

2. Sourness

There were no statistically significant differences in sourness ratings before and after exercise. However, weightlifters perceived the drink as more sour after exercising while runners perceived it as less sour compared to pre-exercising Figure 4. A relationship between athletes' perceived exertion and sourness just-about-right (JAR) scale ratings was found to be significant Table 1. The trend line (Figure 5) shows that as the perceived exertion of the athletes increased, their JAR sourness ratings increased, which is explained as a desire for the drink to be less sour. However, although it is significant, there is no significant practical implication given that the line is almost horizontal and both values are close to a rating of 4, which is the JAR mark.

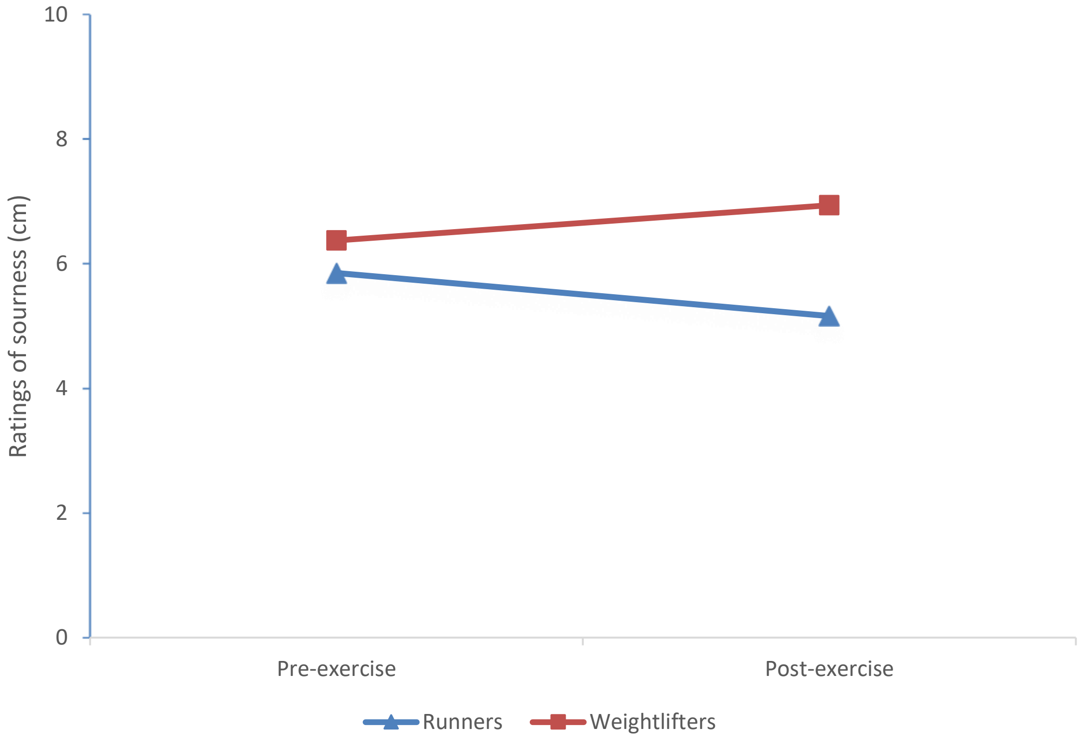

Fig. 4. Mean ratings of sourness before and following exercise by runners and weightlifters

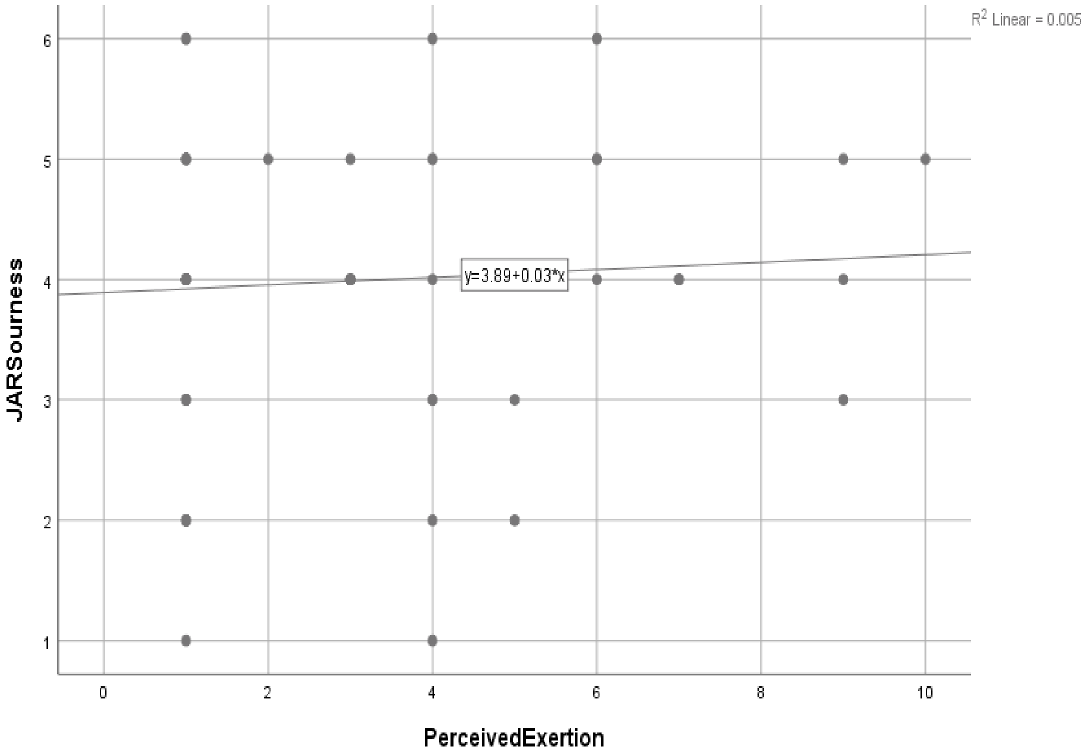

Fig. 5. Perceived exertion versus just-about-right sourness ratings trend line

3. Saltiness

In both sport groups, saltiness ratings increased from pre to after exercise Figure 6, but the changes were not statistically significant Table 1**.** The perceived exertion of the athletes was found to have a positive, statistically significant relationship with the just-about-right saltiness ratings of both groups. As the perceived exertion of the athletes increased, the just-about-right saltiness ratings increased by almost one point on the exertion scale, Figure 7.

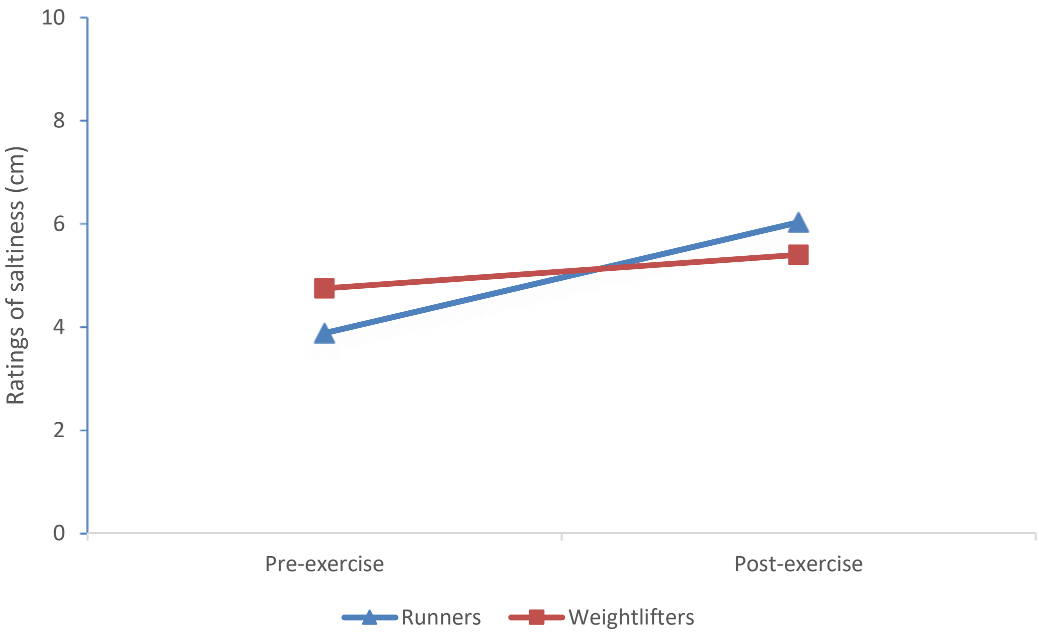

Fig. 6. Mean ratings of saltiness before and following exercise by runners and weightlifters

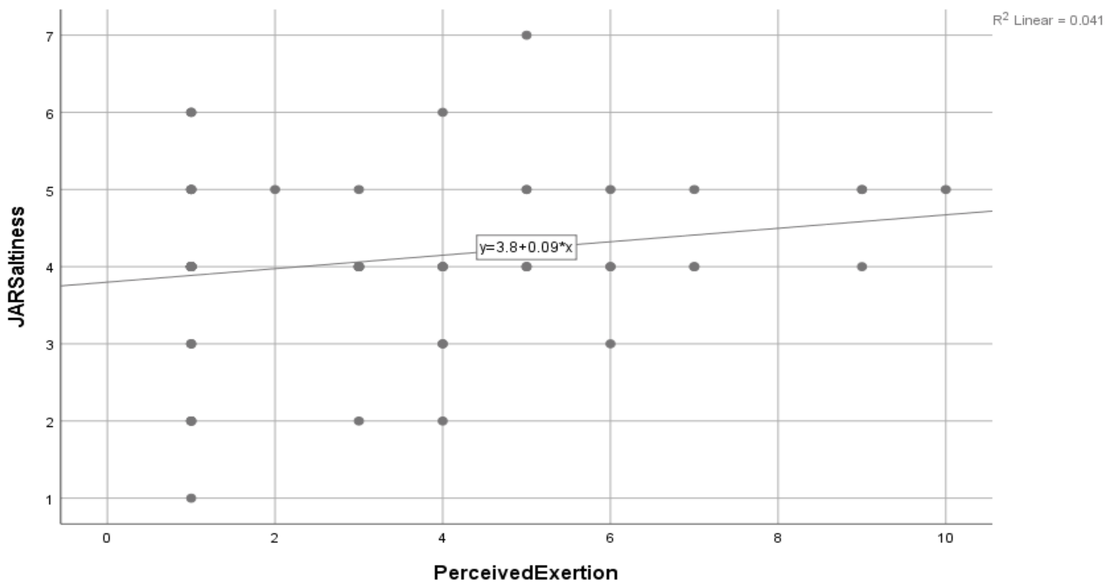

Fig. 7. Perceived exertion versus just-about-right saltiness ratings trend line

4. Thirst-quenching Ability

The ratings of the sports drink's thirst-quenching ability were higher in runners post exercise but lower in weightlifters Figure 8. However, the differences were not statistically significant Table 1.

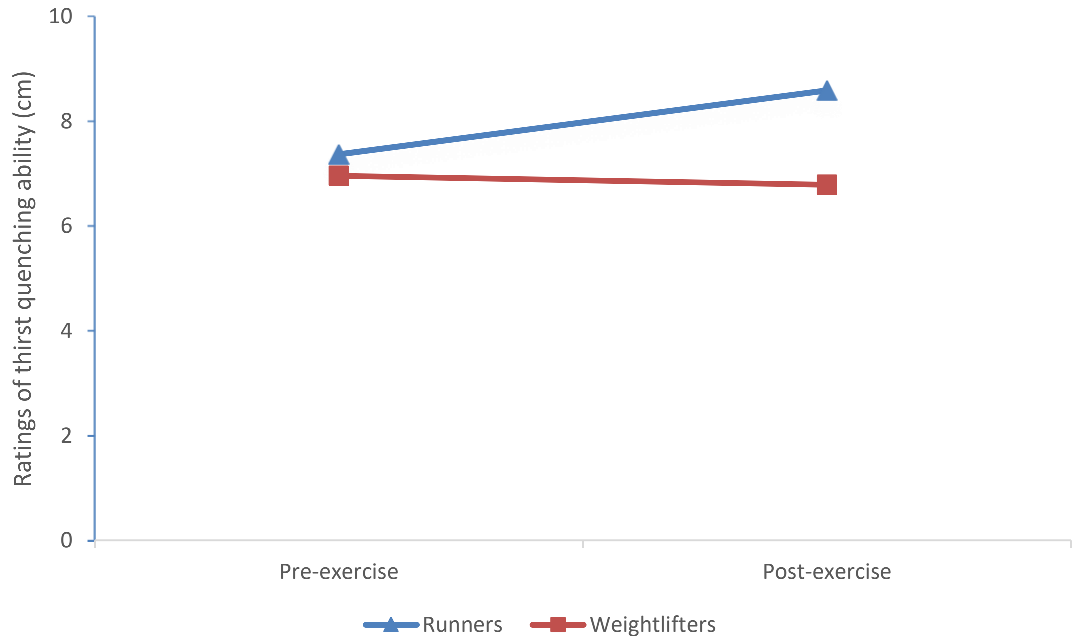

Fig. 8. Mean ratings of thirst-quenching ability before and following exercise by runners and weightlifters

5. Overall Liking

There were no statistically significant changes in the overall liking of the sports drink before and after exercise Table 1, means in Figure 9. The perceived exertion of the athletes was found to have a positive, statistically significant relationship with the hedonic/overall liking ratings of both groups. As the perceived exertion of the athletes increased, the hedonic ratings increased which implies a higher liking for the beverage after exercising Figure 10.

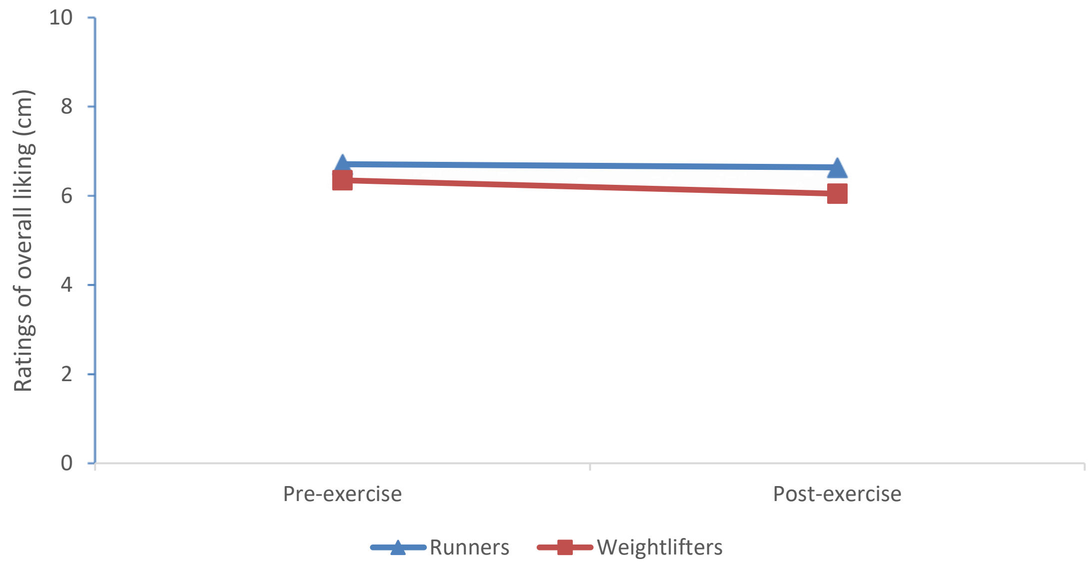

Fig. 9. Mean ratings of overall liking before and following exercise by runners and weightlifters

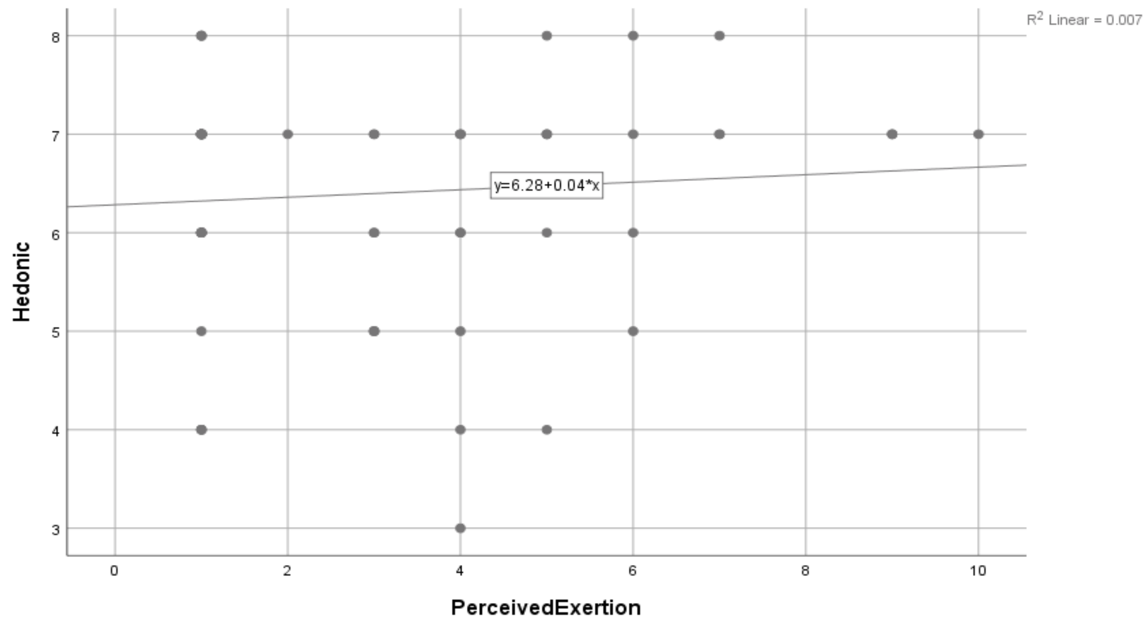

Fig. 10. Perceived exertion versus hedonic ratings trend line

B. Correlation between Hydration Status and Sensory Response Variables

Statistical analysis showed a positive correlation between hydration (refractometer) and hedonic ratings. Higher refractometer readings reflect lower hydration. The trend line in Figure 11 shows that when athletes are dehydrated, their liking for the sports drink increases.

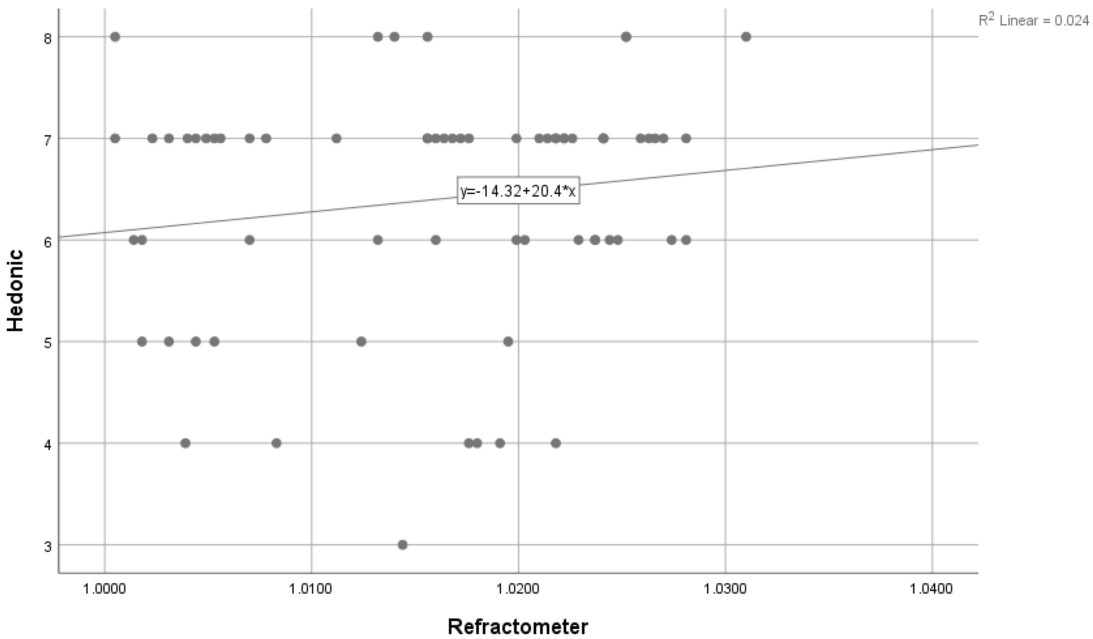

Fig. 11. Hydration (Refractometer) versus hedonic ratings trend line

Consistently, Figure 12 illustrates a negative correlation between hydration and Food Action Rating Scale (FACT) responses. High values of the FACT scale (Appendix III) imply low liking of the beverage. Likewise, low values of the refractometer reflect a good hydration status. Therefore, the negative correlation can be explained in higher liking of the beverage as hydration decreases.

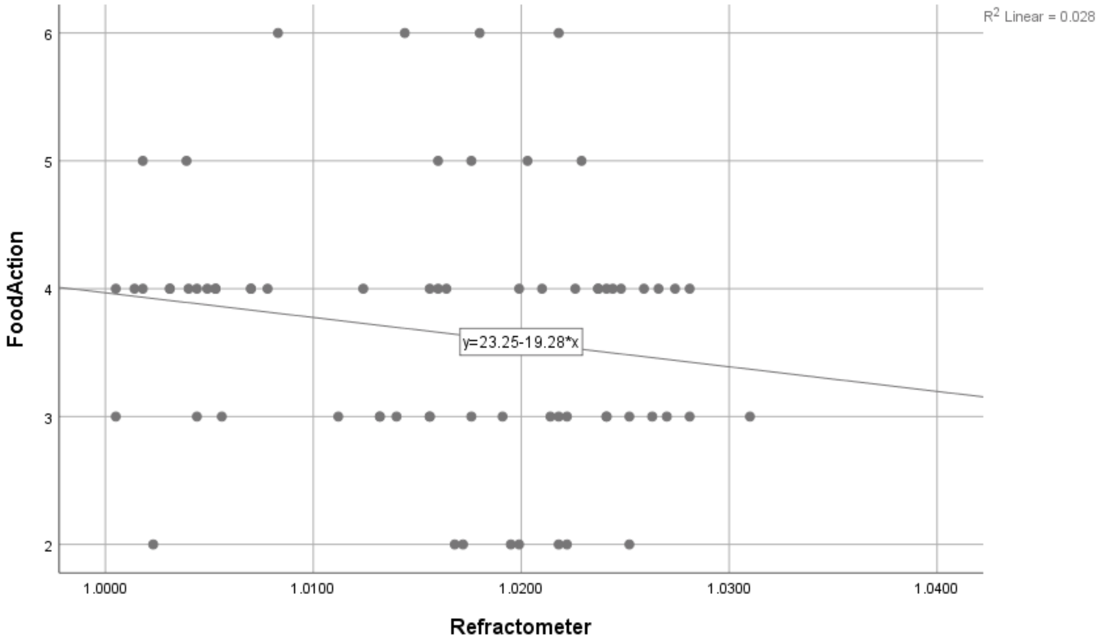

Fig. 12. Hydration (Refractometer) versus food action ratings trend line

CHAPTER V

DISUCSSION

The aim of this study was to examine the effect of different types of exercise on the taste perception and acceptability of Gatorade, a commercial sports drink, pre and post exercise. Ratings of sweetness increased in both sport categories after exercise, but the increase was not significant. Changes in perceptions of sweetness following exercise have previously been reported. Appleton (2005) reported increased sweetness ratings after exercise and Passe *et al*. (2000) also found higher sweetness ratings between sedentary and exercise conditions. Some studies have observed a difference in the perception of sweet taste in low concentrations (Westertep-Plantenga *et al*., 1997). This has been linked to the “physiological usefulness” theory which suggests that the perceived pleasantness of a certain fluid of food increases when there is a physiological need for it (Appleton, 2005). This means the body perceives a certain stimulus as highly pleasant when it is in a physiological need for it (Cabanac, 1971).

The changes in the taste perception of sourness have had different trends in the two sport categories as weightlifters have perceived the drink as more sour after exercise but runners felt the opposite. However, the changes were not significant. Very few studies examined this sensory attribute, but some have reported that human preference for sourness increased after physical activity (Horio and Kawamura, 1998). As for thirst quenching, Ali *et al*. (2011) reported that there was no significant effect of activity on thirst-quenching ratings.

The theory of “physiological usefulness” does not go in line with some studies including ours in terms of ratings of saltiness levels after exercise. Sodium is physiologically beneficial after exercise for thirst stimulation and fluid retention (Leshem *et al*., 2003; Ray *et al*., 1998). In this study, changes in saltiness ratings and salt intensity preference ratings after exercise in both sport categories were not significant and were consistent with the results of Ali et al, (2011), Passe *et al*. (2000) and Horio and Kawamura (1998) which also did not find a significant difference in how athletes rated saltiness levels as a function of exercise. Takamata *et al*. (1994) reported increases in the perceived pleasantness of a low osmolarity (low sodium concentration) fluid post exercise but results were not similar in fluids of higher sodium concentration. This might explain the non-significant changes in saltiness ratings supposing that the fluid was satisfying the physiological need for sodium.

Likewise, fluids would be perceived as highly pleasant when there is a physiological situation of high fluid requirement. The overall liking of Gatorade did not significantly change from pre to post exercise but there was a significant correlation between the hydration status of the athletes and the hedonic ratings. As athletes were more dehydrated, their acceptability of the drink increased. This was confirmed in their ratings of the Food Action Rating Scale (FACT). A relationship between hydration and FACT ratings also showed that as the hydration of the athletes decreases, they tend to exhibit positive actions towards the beverage. This is consistent with the findings of another study that investigated the changes in the perceived pleasantness of seven fluids of varying osmolality, electrolyte content, and energy content before and after fluid loss. The perceived pleasantness of the seven fluids was significantly higher after exercise especially in fluids of lower osmolarity and in the group with higher fluid losses (Appleton, 2005). Analysis have also shown that as the perceived exertion of the athletes increases, their hedonic ratings for the drink increase as well. It might be due to the correlation between the perceived exertion and the hydration status especially that athletes who have higher ratings of perceived exertion are probably not well hydrated.

The physiological cause behind this hedonic shift is still unclear (Passe *et al*., 2000) but some have attributed it to a feedback mechanism to the taste system (Horio and Kawamura, 1998; Horio, 2004). Indeed, overall liking is affected by complex sensory and psychological factors (Ali *et al*., 2011).

We conclude that a hedonic shift can occur under the influence of exercise, which has an important impact on fluid replacement after exercise (Horio, 2004; Passe *et al*., 2000).

CHAPTER VI

CONCLUSION

In conclusion, the present study demonstrates that a hedonic shift can occur under the influence of exercise. This can be related to the theory of physiological usefulness although this was not confirmed at the ratings for specific tastes. The acceptability of the sports drink has an important impact on fluid replacement and subsequently the hydration status of the athletes (Horio, 2004; Passe *et al*., 2000). In this study, exercise was found to have a less significant effect on the perception of the sensory attributes of the sports drink compared to its acceptability. Although this effect might be due to the acute changes in the body physiological needs, the main psychological or physiological cause behind it remains uncertain.

It is highly recommended from future studies to consider studying the physiological and psychological factors behind the changes in the acceptability and overall liking of sports drinks. Further research is needed to determine the best sports drink formulation which is most likely to undergo a positive hedonic shift under the effect of exercise which leads to an increased consumption and therefore an optimal hydration.

APPENIDIX I

URINE COLOR CHART AND BORG SCALE

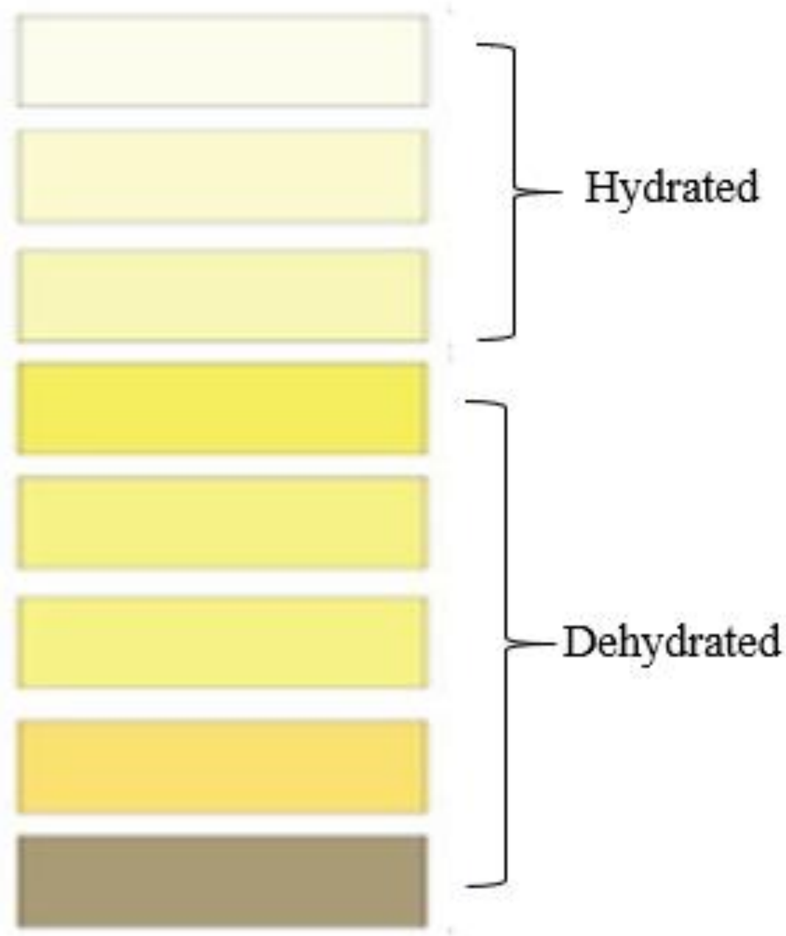

Fig. A1. Urine color chart
Source: Armstrong, L.E., Maresh, C.M., Castellani, J.W., Bergeron, M.F., Kenefick, R.W., LaGasse, K.E., and Riebe, D. (1994). "Urinary indices of hydration status". International Journal of Sport Nutrition, 4(3), 265-279.

Score	Level of Exertion
0	No exertion at all
0.5	Ver, very slight (just noticeable)
1	Very slight
2	Slight
3	Moderate
4	Somewhat severe
5	Severe
6	
7	Very severe
8	
9	Very, very severe (almost maximal)
10	Maximal

Fig. A2. Borg RPE scale
Source: G.A. Borg. (1982). "Psychophysical bases of perceived exertion". *Medicine & Science in Sports & Exercise, 14*(5), 377-381.

APPENIDIX II

SCREENING QUESTIONNAIRE

Name: ____

Date: ________________________________

1. Age: ______________________________
2. Weight: _____________________________
3. Height: _____________________________
4. Sport: ____________________________
5. Smoker: ☐ Yes ☐ No ☐ Occasional
6. Are you following any diet? ☐ Yes ☐ No
7. If yes, describe that diet.
   ____
   ____
   ____
8. Have you had any weight fluctuation over the past 3 months? ☐ Yes ☐ No
9. Are you familiar with sports drinks? ☐ Yes ☐ No
10. How often do you consume sports drinks? ☐ Never ☐ Occasionally ☐ Often

APPENIDIX III

SENSORY BALLOT

Name: ____

Date: ________________________________

Please rinse your mouth with water before starting the test.

Please rate the sample with the line scale provided for each attribute.

Sweetness: Taste elicited by sugar

NOT AT ALL VERY

Sourness: Taste elicited by citric acid

NOT AT ALL VERY

Sourness: Taste elicited by NaCl salt

NOT AT ALL VERY

Thirst Quenching: Ability of the drink to satisfy thirst

NOT AT ALL VERY

Just About Right Scale

Please rate the sample using scale provided for each attribute.

Sweetness: Taste elicited by sugar

☐	☐	☐	☐	☐	☐	☐
TOO LOW			JUST RIGHT			TOO HIGH

Sourness: Taste elicited by citric acid

☐	☐	☐	☐	☐	☐	☐
TOO LOW			JUST RIGHT			TOO HIGH

Saltiness: Taste elicited by salt

☐	☐	☐	☐	☐	☐	☐
TOO LOW			JUST RIGHT			TOO HIGH

Place rate the overall acceptability of the sample using the following scale.

1	2	3	4	5	6	7	8	9
☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like Nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Food Action Rating Test

Name: ____

Please taste the sample and tick the box that best describes how you feel about it.

- ☐ I would drink this every opportunity that I had
- ☐ I would drink this very often
- ☐ I like this and would drink it now and then
- ☐ I would drink this if available but would not go out of my way
- ☐ I don’t like this but would drink it on occasion
- ☐ I would hardly ever drink this
- ☐ I would drink this only if forced to

APPENIDIX IV

TABLE OF MEANS

Table A1. Sensory ratings of Gatorade sports drink by weightlifters and runners before and after exercise

	Pre-exercise	Post-exercise
Ratings of Sweetness (cm)		
Runners	7.52 ± 1.79	8.89 ± 2.72
Weightlifters	6.74 ± 2.65	7.46 ± 3.09
Ratings of sourness (cm)		
Runners	5.85 ± 2.53	5.16 ± 2.89
Weightlifters	6.37 ± 2.54	6.94 ± 2.76
Ratings of saltiness (cm)		
Runners	3.88 ± 2.60	6.03 ± 3.53
Weightlifters	4.75 ± 3.12	5.40 ± 3.12
Ratings of thirst-quenching (cm)		
Runners	7.37 ± 3.44	8.59 ± 3.44
Weightlifters	6.96 ± 3.49	6.79 ± 2.79
JAR Sweetness (cm)		
Runners	4.00 ± 1.10	3.86 ± 1.29
Weightlifters	4.05 ± 1.19	3.85 ± 1.22
JAR Sourness (cm)		
Runners	3.86 ± 1.02	3.71 ± 1.13
Weightlifters	4.10 ± 1.21	4.15 ± 1.08
JAR Saltiness (cm)		
Runners	3.71 ± 1.13	4.07 ± 1.43
Weightlifters	4.15 ± 1.08	4.20 ± 0.69
Ratings of overall liking (cm)		
Runners	6.71 ± 0.99	6.64 ± 1.08
Weightlifters	6.35 ± 1.22	6.05 ± 1.23

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