Journal of Applied Life Sciences International

17(3): 1-12, 2018; Article no.JALSI.41498
ISSN: 2394-1103

The Effect of Different Beverages on Acute Regeneration and Performance during Interval Running

K. Baum[1*]

[1]Institute of Physiology and Anatomy, German Sport University Cologne, Germany.

Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/JALSI/2018/41498
Editor(s):
(1) Purnachandra Nagaraju Ganji, Department of Hematology and Medical Oncology, Emory University School of Medicine, USA.
Reviewers:
(1) Rosendo Balois Morales, Universidad Autonoma de Nayarit, Mexico.
(2) Faika Şanal Karahan, Necmettin Erbakan University, Turkey.
Complete Peer review History: http://www.sciencedomain.org/review-history/24671

Original Research Article

Received 3rd March 2018
Accepted 12th May 2018
Published 18th May 2018

ABSTRACT

Purpose: Field studies show, that in several sports a major part of athletes are seriously dehydrated and carbohydrate depleted after a match. Therefore, during sports-game competitions, it is of great importance to optimize short-term regeneration such as fluid and carbohydrate replacement within breaks. In the present study, the influence of taste and composition of beverages on self-selected drink volumes and the resulting performance capacity was investigated during a simulated game.
Methods: 11 athletes (3 female, 8 male) performed 5 treadmill-spiroergometries with a break of at least one week between tests. Test 1 consisted of a stepwise increase in speed (1,5 km x h^{-1} every 4 minutes, starting from 8-5 km x h^{-1}) in order to determine maximal speed (v_{max}) and maximal physiologic data. The subsequent tests were applied in random order and consisted of two 30 min. interval runs with speeds depending on individual v_{max} of test 1. In the 15 min. break between the halves, subjects were offered one of four different beverages to drink ad libitum (Mineral water = MWT, a zero-alcohol beer with 6,4 % carbohydrate content (CHO) = PIT, a zero-alcohol beer with 7,5 % CHO = WET, a 10 % CHO caffeinated beverage = CCT). After the second half, subjects run at 90 % of v_{max} until exhaustion.
Main Results: About one third of the sweat loss was compensated by the halftime drink. The volume of the ingested fluid ranged between 0,43 $\pm$ 0,19 L and 0,51 $\pm$ 0,24 L (mean $\pm$ SD) with no

*Corresponding author: E-mail: baum@professor-baum.de;

significant differences between beverages. Spiroergometric parameters, as well as lactic acid concentrations, showed no obvious differences between tests 2 to 5. By contrast, running time to exhaustion was significantly longer in WET as compared to MWT and CCT (P=0,05).

Discussion: Taste and composition of a beverage appear to be no important influences on drink volume during competition. It is speculated that the differences in running time originate from different sources, a glycogen depletion in MWT and a decreased gastric emptying rate in CCT.

Conclusions: In sports-game competitions, besides predetermined breaks also impromtu breaks have to be used in order to counteract dehydration. In order to substitute sweat and carbohydrates during and after exercise in a balanced way, zero-alcohol beer is a promising candidate.

Keywords: Sports; exercise; athletes; dehydration; sweat loss; carbohydrates; zero-alcohol beer.

1. INTRODUCTION

In sports competitions which are interrupted by recovery periods such as the predetermined breaks in soccer, basketball, handball, or ice hockey, acute regeneration strategies become of great importance. The physiological demands of these sports are characterized by interval loads. High-intensities like sprints, rapid direction changes, tackles, or jumps alternate with intermediate to low activities. At the end of a match, fatigue symptoms were reported in professional soccer [1,2], handball [3,4], ice hockey [5,6], and basketball players [7,8].

Already a moderate fluid loss of 1,5 to 2 % of body weight is able to decline physical performance in soccer [9], ice hockey [10,11], and basketball players [7,8]. Furthermore, Saltin [12] could prove that after a soccer match the muscular glycogen store of the vastus lateralis was lowered by 91%. A more recent study in soccer players performing a friendly match yielded a glycogen reduction of 43% [13]. However, in that study, a histochemical analysis showed that approximately 50% of all fibers were almost depleted or even totally depleted of carbohydrates. Therefore, both the substitution of fluid loss and the refilling of carbohydrate stores are regarded as significant contributors to overcome or at least to reduce the obtained decreases in overall performance. Meanwhile, there exists considerable evidence that carbohydrate containing drinks improve performance in team sports [6,8,14,15,16,17]. However, most studies dealing with the effect of fluid replacement during or in between exercise follow protocols with certain fluid volumes, which is far away from real-life training and match conditions. So it may not be surprising that there is a mismatch between scientific knowledge and players drink behavior. Real-live research showed that a large proportion of soccer players become dehydrated during training and competition [17,18,19]. A recent study showed that dehydration is also common in athletes of other sports [20]. Besides the physiological need to drink, other factors like taste, believe, or habits may play an important role. In adult athletes, one of the most popular drinks after training or competition is beer [21,22]. Meanwhile, zero-alcohol forms offer the taste of a beer as well as its carbohydrate content but without the diuretic and other deteriorating effects of alcohol.

In the present study, we investigated two different zero-alcohol beers in comparison to mineral water and a popular soft drink as fluid replacements during exercise. We addressed two primary outcomes: First, does the taste influence the volume of fluid ingested during the break of a simulated team-sports game and, secondly, what is the influence of these drinks on performance?

2. MATERIALS AND METHODS

The present study followed all the relevant national regulations and the tenets of the Declaration of Helsinki and was approved by the ethical committee of the Sport University Cologne, Germany.

2.1 General Overview

The empirical part of the study took place from the 19th of September to the 22th of December 2017. All tests were performed by means of a spiroergometry on a treadmill. Room temperature and humidity amounted to 22,3 ± 0,4°C and 39 ± 4%, respectively. Each subject had to perform five tests separated by at least one week. Initially, all subjects performed a stepwise incremental speed test (IST). The remaining four tests followed an identical protocol except for the kind of a half-time beverage. They were applied in random order. Subjects had to run in an interval mode two times 30 minutes separated by a break of 15 minutes, during which one of four fluids was offered ad libitum. One minute after the second half, subjects run at 90% of their maximal IST speed until exhaustion.

2.2 Subjects

Subjects were recruited via local announcements. If the inclusion and exclusion criteria were met, subjects were included in the study after oral and written informed consent. The inclusion and exclusion criteria were as follows:

Inclusion criteria:

- age between 18 and 55 years,
- a history of at least 3 times training per week on a regular basis over the last two years,
- willing to run until exhaustion in each test.

Exclusion criteria:

- cardiovascular and pulmonary diseases,
- other diseases limiting running until exhaustion,
- actual orthopedic problems,
- a longer than 5 days journey during the experimental period.

Subjects were encouraged to follow their normal training habits but had to rest one day before each test. If possible, experiments were conducted individually on the same day of the week.

Initially 12 subjects (3 female, 9 male) participated in the study (Table. 1). One male subject (ID 04, Table. 1) was excluded from final analysis with suspected exercise induced asthma. He reported "difficulties to sufficiently breath" and "a thightness in the chest" as limiting factors in some but not all tests. An analysis of the initial incremental test yielded an unusual high ratio of physiologic dead space over tidal volume at exhaustion (28%) combined with a low maximal ventilation (88 L / min, for comparison to the other male subjects see Tables 1 and 2).

2.3 Incremental Speed Test

After 3 minutes of rest, subjects run on a treadmill (hp-cosmos mercury®, h/p/cosmos sports & medical gmbh, Unterhaching, Germany) for 4 minutes per stage interrupted by 30 seconds in order to draw a blood sample. The initial velocity amounted to 8,5 km x h^{-1} and was increased by 1,5 km x h^{-1} every 4,5 minute until subjective exhaustion.

2.3.1 Measurements

Ventilation (Vent), oxygen uptake (VO_2), and CO_2 release (VCO_2) were measured breath by breath with a spirometry system (Zan 680 nSpire Health, Oberthulba, Germany). Peak values were calculated offline for the last 30 s before exhaustion. Lactic acid concentration ([lac]) was determined at rest and in the 30 s breaks between each speed by means of arterialized blood taken from an ear lobe (Accutrend lactate analyser, Roche Diagnostics, Mannheim, Germany). Blood glucose concentration ([gluc]) was analysed before and two minutes after exercise also by means of arterialized blood taken from an ear lobe (Accutrend plus® system, Roche Diagnostics, Mannheim, Germany). Heart rate was monitored at rest and for the last 20 s of each load via a heart rate monitor

Table 1. Anthropometric data and weekly training volume of subjects

ID	Sex	Age (years)	Height (m)	Mass (kg)	Training per week (h)
01	m	28	1,9	84,8	6
02	m	23	1,81	83,4	20
03	m	42	1,9	88	8
04	m	22	1,82	85,8	8
05	f	51	1,73	64,4	3
06	m	22	1,75	82	5
07	m	24	1,93	92,6	7
08	f	22	1,73	70,9	11
09	m	28	1,84	81,1	7
10	m	23	1,74	67,6	6
11	m	36	1,87	85,1	7
12	f	29	1,66	66	9

m = male, f =female

(FT60, Polar Electro, Lake Success, New York). Body temperature was measured sublingual before and immediately after the end of exercise (Bosotherm flex, Bosch&Sohn ltd, Jungingen, Germany). Body mass was measured before and after exercise by means of an electronic balance (accuracy ± 100g, Eie import ltd, Sattfeld, Austria). The difference in body weight before and after exercise was used as a measure of sweat-loss.

2.4 Interval Test

The speed profile of the two halves was identical (Fig. 1). The maximal speed of IST was taken as 100% (v_{max}) if the stage was fully completed. Otherwise, linear interpolation was used. The profile was developed in preliminary tests, which aimed to be able to finish the first half and to get seriously exhausted or even unable to complete the second half.

15 s before changes in velocity, subjects were verbally informed. The final speed of each change was achieved within 8 s.

Beside all parameters of IST, the rating of perceived effort was monitored three times during each half (see Fig. 1, arrows).

As a measure of sweat loss, the difference in body mass before and after exercise added by the volume of the ingested halftime drink was used. Immediately after completing the first half, subjects were released from the spirometry-mask and rested in a chair for 12 minutes. In this phase, subjects could drink one of the following fluids ad libitum:

- Mineral water (MWT, Gerolsteiner medium, 0 % carbohydrate content)
- Zero-alcohol pilsner beer (PIT, Krombacher Pils 0,0%,6,4 % carbohydrate content)
- Zero-alcohol wheat beer (WET, Krombacher Weizen 0,0%, 7,5 % carbohydrate content)
- Caffeinated soft drink (CCT, Coca Cola, 10 % carbohydrate content)

The mineral water was manufactured by Gerolsteiner Brunnen GmbH & Co KG, Gerolstein, Germany, the two beers by Bernhard Schadeberg GmbH & Co KG, Krombach, Germany, and the soft drink by Coca Cola Erfrischungsgetränke GmbH, Köln, Germany.

In order to minimize disturbances during recovery, no measurements were performed within the break.

Here, after 12 minutes of rest, the breathing-mask was instrumented again and the second half started after 3 min. quiet standing. If subjects were able to complete the 30 min., [lac] and [gluc] samples were drawn within 30 s of rest and, thereafter, subjects run at 90% v_{max} until exhaustion.

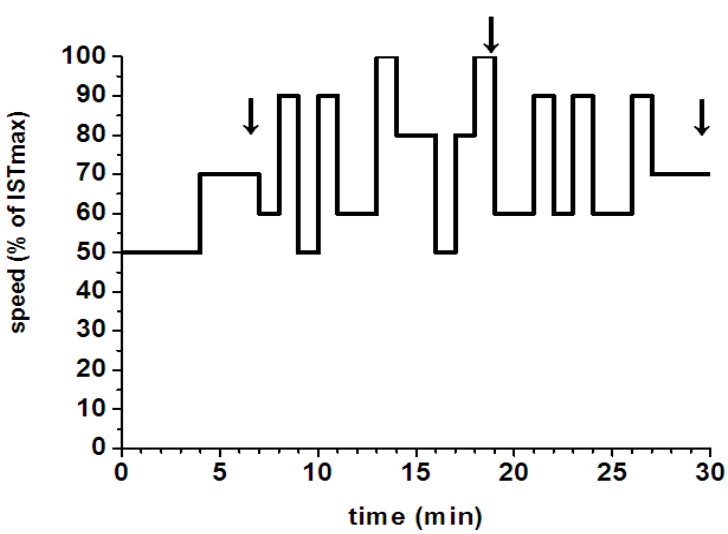

Fig. 1. Speed protocol of a half of the interval tests. Arrows indicate the time of rating of perceived effort (Borg-Scale)

Immediately after each test, subjects rated the beverage according to a school grading system, where 1 = very good, 2 = good, 3 = satisfying, 4 = sufficient, 5 = inadaequate, 6 = unsatisfactory. The following aspects were considered:

- suitability as a thirst quencher during training or competition
- suitability as a thirst quencher after training or competition
- effect of the drink on performance
- taste.

2.4.1 Randomization of interval tests

Prior to all tests, each subject chose one of 12 closed envelopes including the order of tests. Overall, each trial was equally distributed over the examination days 2 to 5.

2.5 Statistics

If not otherwise stated data are expressed as mean and standard deviation (mean ± SD). In IST, non-parametric friedman test followed by Wilcoxon tests was used for beverage-assessments. One-way ANOVA was applied to running time with the factor trial, two-way ANOVA to [gluc], [lac], and body temperature with factors trial and time. Three-way ANOVA was performed for all other parameters with factors trial, time, and half followed by Bonferroni test for multiple comparisons. Correlations were analyzed applying a Spearman Rank coefficient. Statistical significance was set to an alpha level of 0.05. All statistical analyses have been performed with IBM SPSS statistics 25.

3. RESULTS

3.1 Incremental Speed Test

The mean maximal velocity amounted to 15,5 ± 1,9 km x h^{-1}, the corresponding physiologic parameters were 191 ± 10,6 min^{-1} for heart rate, 124 ± 27,4 L x min^{-1} for ventilation, 3,2 ± 0,7 L x min^{-1} for oxygen uptake, and 9,2 ± 2,2 mmol x L^{-1} for [lac]. Body temperature rose from 36,0 ± 0,3°C at rest to 36,7 ± 0,5 ^{0}C immediately after the run. Blood [gluc] increased from a baseline value of 90±7,8 mg x 100 mL^{-1} to 116 ± 14,4 mg x 100 mL^{-1} after exhaustion. Individual maximal data can be depicted from Table. 2.

3.2 Interval tests

3.2.1 Running distance and time to exhaustion

The distance covered within one half amounted to 5380 ± 635 m with a minimum of 4520 m and a maximum of 6600 m. All subjects were able to complete the first half. From the total number of 44 tests, in 12 runs exhaustion occurred within or immediately after finishing the second half. That was obtained in 5 trials in MWT, 5 trials in CCT, and 2 trials in PIT. The mean running times of the second half are presented in Fig. 2. The longest running time until exhaustion could be obtained in WET. Compared to WET, the differences to other trials became significant for MWT and CCT.

3.2.2 Drinking volume and sweat loss

The calculated sweat loss and the drink volumes did not differ significantly between trials and are

Table 2. Individual maximal values obtained in the incremental speed test

ID	speed (km x h^{-1})	heart rate (min^{-1})	Ventilation (L x min^{-1})	VO2 (L x min^{-1})	rel. VO2 (mL x (kg x min)$^{-1}$)	[lac] (mmol x L^{-1})	VD/ VT (%)
01	17,5	210	162	2,79	32,8	10,6	20,3
02	16	199	136	3,93	47,4	7	26,3
03	19	184	144	4,22	47,9	7,2	20,8
05	13	176	86	2,42	41	7,9	26,2
06	13,8	190	115	2,69	32,8	12,1	23,7
07	17,5	181	162	4,25	45,7	12,8	23,2
08	13	184	97	2,13	30,4	6,3	25,3
09	16	200	141	3,6	44,5	10,7	22,5
10	16	198	128	3,28	49	11,1	23,1
11	14,5	179	115	3,85	45,3	8,9	24,2
12	14,5	202	77	2,45	37,7	7,1	24,3

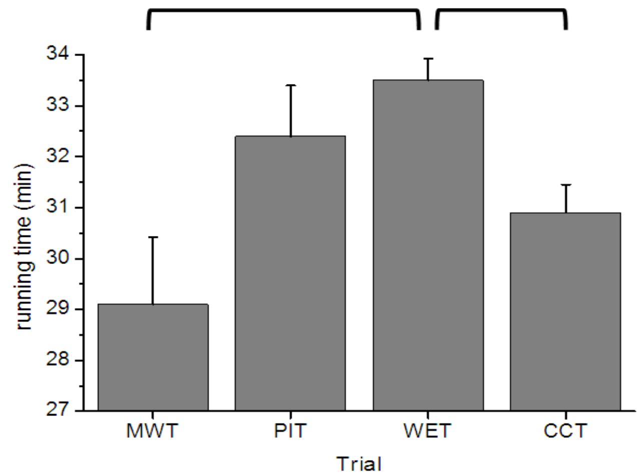

Fig. 2. Running time of the second half. Significant differences (P=0,05) between trials are indicated by brackets. Mean ± SE

Table 3. Sweat loss and halftime drink volume

Trial	Sweat loss (L)	Drink volume (L)
MWT	1,44 ± 0,71	0,49 ± 0,17
WET	1,53 ± 0,59	0,43 ± 0,19
PIT	1,33 ± 0,58	0,48 ± 0,22
CCT	1,36 ± 0,55	0,51 ± 0,24

Mean ± SD.

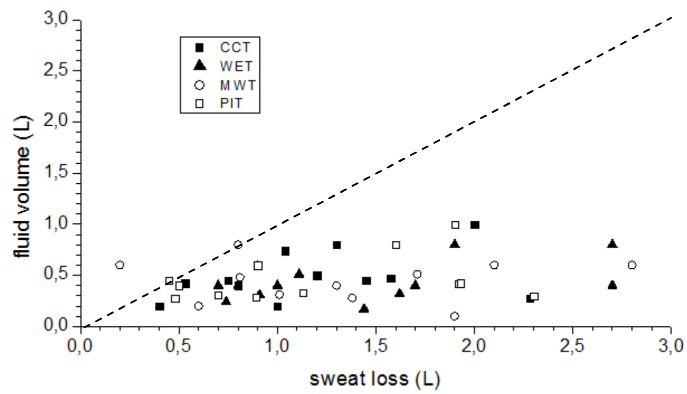

Fig. 3. Relationship between sweat loss and ingested fluid volume. Dotted Line represents points of identity

given in Table. 3. Fig. 3 shows the relationship between drink volumes and sweat losses for all trials with a weak, non-significant positive correlation (Pearssons R = 0,27).

3.2.3 Blood glucose concentration

Mean blood [gluc] at rest were in a range between 92 mg x 100 ml^{-1} and 99 mg x 100 ml^{-1}. [gluc] at exhaustion were higher in WET and CCT in all subjects as compared to a mean decrease in MWT and PIT (Fig. 4). However, the statistical analysis just missed significance (factor trial: P = 0,054; factor time: P = 0,073).

3.2.4 Lactic acid concentration

Mean resting values of about 1,5 mmol x L^{-1} increased significantly to 3,2 to 4 mmol x L^{-1}.

Running were finally stopped at concentrations between 4,6 mmol x L^{-1} and 5,4 mmol x L^{-1}. An influence of the beverage could not be obtained (Fig. 5).

3.2.5 Oxygen uptake

The intraindividual oxygen uptake pattern was neither influenced by the number of halves nor by the kind of beverage but nearly constant in each half. Peak values occurred in the 18th minute with a mean of 3,24 ± 0,68 L x min^{-1}, which is nearly identical to the maximal oxygen uptake of IST. The mean oxygen uptake during exercise amounted to 2,54 ± 0,41 L x min^{-1}, corresponding to 79 ± 13 % of $VO_{2\ max}$.

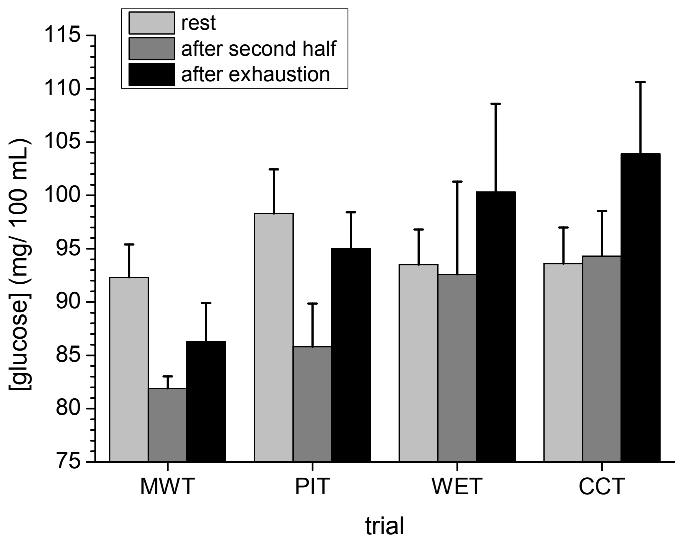

Fig. 4. Blood glucose concentration at rest, immediately after the second half and after exhaustion. Mean±SE

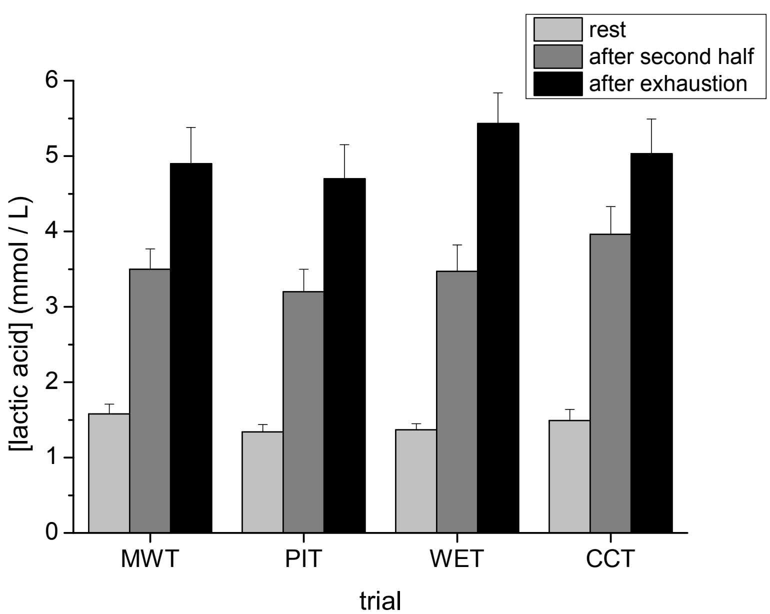

Fig. 5. Blood lactic acid concentration at rest, immediately after the second half and after exhaustion. Mean ± SE

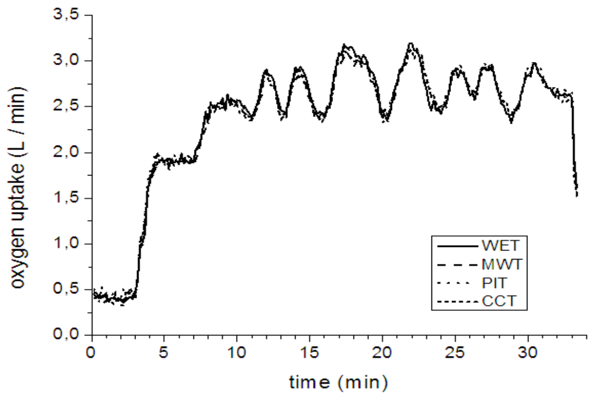

Fig. 6. Mean Oxygen uptakes of the first halves of the four trials. Exercise started after 3 min. of quiet standing. For better reading the standard deviation is not shown

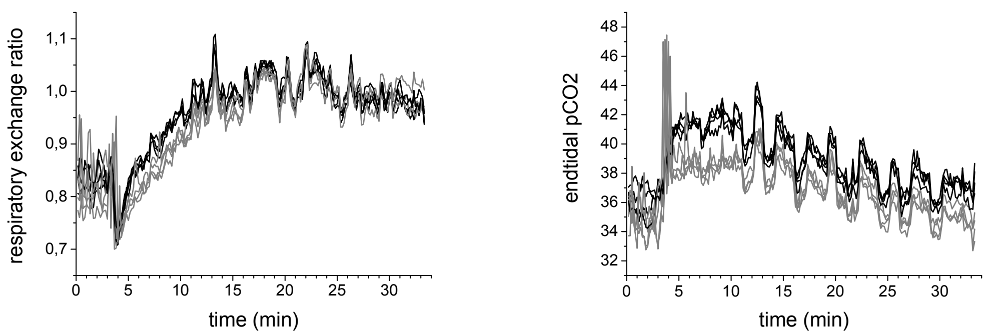

Fig. 7. Respiratory exchange ratio (left) and endtidal pCO2 in the first (black lines) and second halves (grey lines). For better reading standard deviations are not shown

3.2.6 Respiratory exchange ratio and endtidal CO_2 partial pressure

Both respiratory exchange ratio and endtidal CO2 partial pressure (pCO_2) of both halves were not influenced by the trial (Fig. 7). Compared to the first halves, in all trials, pCO_2 was significantly reduced throughout the exercise phase except the first two minutes while in RER a systematic reduction occurred in the first 10min of exercise. The overshoots in pCO2 during the initial 2 min of running in the second halves were due to belching, which could be obtained in all trials.

3.2.7 Heart rate and rate of perceived effort

Heart rate (HR) and rate of perceived effort (RPE) were signifantly influenced by time but independent of trial. Compared to the first half, in the second half values at rest were significantly increased by 23 to 28 min^{-1} (104 $\pm$ 7 min^{-1} vs. 77 $\pm$ 8 min^{-1}, 98 $\pm$ 11 min^{-1} vs. 74 $\pm$ 10 min^{-1}, 102 $\pm$ 14 min^{-1} vs. 79 $\pm$ 11 min^{-1}, 101 $\pm$ 10 min^{-1} vs. 73 $\pm$ 6 min^{-1} for CCT, WET, MWT, and PIT, respectively). During exercise, HR of the second halves was higher throughout the 30 min. in a range from 6 to 10 min^{-1}. Peak HR in all trials occurred in the 18th min. of exercise (171 $\pm$ 10 min^{-1} to 173 $\pm$ 7 min^{-1} in the first half, 177 $\pm$ 11 min^{-1} to 180 $\pm$ 9 min^{-1} in the second half). RPE followed a similar pattern and can be depicted from Fig. 8.

3.2.8 Assessment of the beverages

The assessments of beverage´s suitability as a thirst quencher during and after training or competition, their subjective effect on performance, and the taste are presented in fig. 9. Significant differences occurred for the roles as thirst quencher during and after exercise as indicated in Fig. 9. There was no correlation between any of these parameters and drink volume.

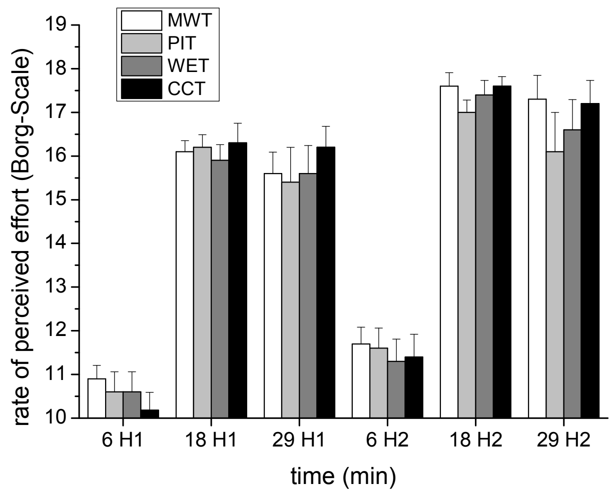

Fig. 8. Rate of perceived effort evaluated with the Borg-Scale at three times (6 = 6. Min, 18 = 18 min., 29 = 29 min.) in half 1 (H1) and half 2 (H2). Mean±SE

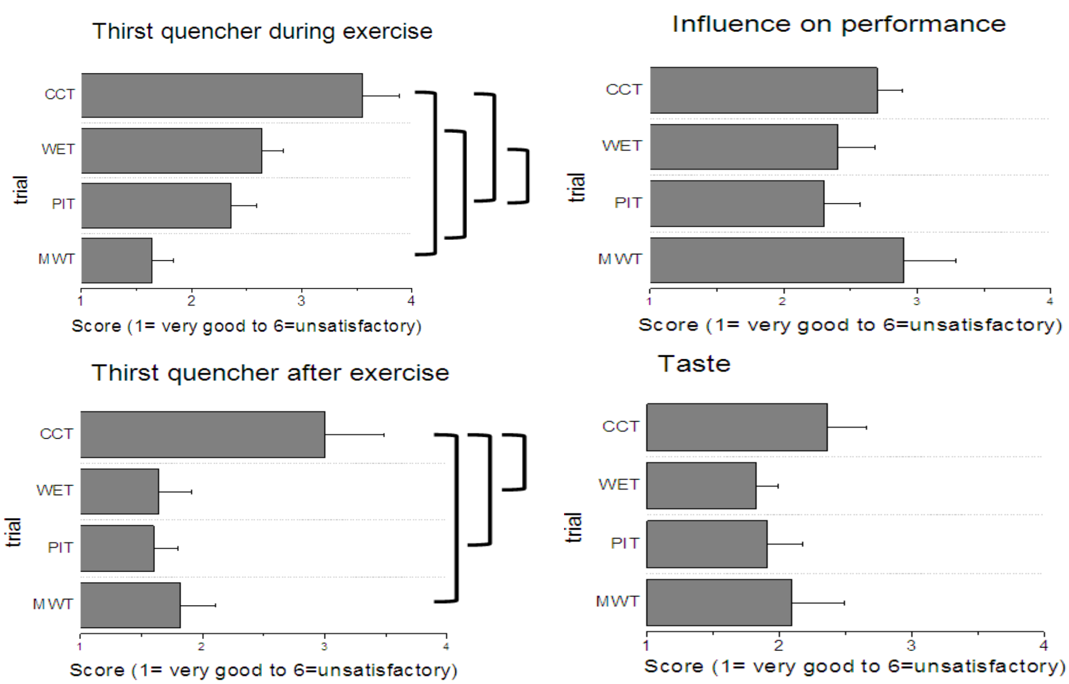

Fig. 9. Assessment of the beverage offered in the four trials. Mean ± SD. Significant differences are indicated by brackets. Mean ± SE

4. DISCUSSION

In the present investigation, we used the term "zero-alcohol beer". At first sight, that may sound unusual to some extent. However, the two zero-alcohol beers investigated in the actual study really do not contain ethanol. The more familiar term "non-alcoholic beer" would be misleading to some extent, since in those beers an alcohol content of up to 0,5% is allowed by German law.

The main findings of the present study are 1) neither the taste nor the composition of the beverages had a noticeable influence on the ingested fluid volume, 2) zero-alcohol beer was superior to mineral water and a 10%

carbohydrate caffeinated beverage for maintaining performance.

ad 1) The present dada show that the quantity of self-chosen rehydration in athletes appears to be largely independent of the kind of fluid. Neither the huge difference in carbohydrate content from 0 % to 10 % nor the associated sweetness/taste led to a preferable fluid ingestion of one beverage. Desbrow and coworkers [23] speculated that non-alcoholic beer may be a potential candidate for adequate fluid replacement during exercise because beer is traditionally associated with post-match celebrations [22] and, therefore, athletes are familiar with its taste in a positive way. In contrast to their speculation, in our study the drink volumes of both beer trials failed to be superior to the other beverages. Instead, the intra-individually ingested volumes were quite constant between trials. Furthermore, only a non-significant, weak correlation could be obtained between sweat loss and drink volume. With the obtained Spearman r of 0,27 and a resulting r^2=0,073 just 7% of the variability in drink volume can be accounted for by sweat volume. Therefore, other variables such as learned behavior or stomach filling play an important role. With the present data, we are unable to make a decision about the leading factor. If it holds for stomach filling, impromptu breaks e.g. substitutions and time-outs have to be regarded as mandatory drink-phases to ensure an adequate hydration at the final stage of competitions.

Ad 2) As stated above, the obtained significant differences in running time to exhaustion cannot be explained by differences in the volume of fluid ingestion. Furthermore, the nearly identical oxygen uptakes and RER of the four trials speak for comparable metabolic situations. Different underlying mechanisms may be responsible for the differences between WET and MWT on the one hand and WET and CCT on the other hand. A probable cause for the first is a partial depletion of glycogen stores within exercising muscles. The total running distance covered in our trials is comparable to those obtained during real soccer competitions [24] and was primarily realized via the carbohydrate (CHO) metabolic pathway as indicated by RER. It is known that under this condition the glycogen stores are remarkably reduced [12]. That fits to the [gluc] in our investigation, which was lowest at the end of MWT. Therefore, at least a partial depletion of CHO may be responsible for the early exhaustion obtained in MWT.

By contrast, [gluc] at the end of CCT was even slightly higher than in WET. A performance limiting effect of caffeine appears unlikely since in recent studies physical performance was even increased by caffeine consumption in both female and male soccer players [25,26]. However, in these investigations, a caffeine content of 3 mg per kg body mass was applied while in the present study it was well below 1 mg per kg body weight. Therefore, the positive effect of caffeine may have been negligible or superposed by negative effects. According to the data of Bartoli et al. [27] it can be speculated that in CCT gastric emptying rate (GER) was lower due to the critical high CHO content of the beverage. The authors compared four different sports drinks containing 0%, 4%, 6%, and 8% CHO. While GER for the first three beverages was in the same range it was significant reduced for the 8% CHO trial. Furthermore, the osmolality was not as important as the energy content of the fluid. It may be speculated that in our study the 7,5 % CHO content as it is in the zero-alcohol wheat-beer corresponds to a well-balanced combination of fluid and energy replacement during high intensity exercise. That is supported by the ranking of the other trials with the 6,5 % CHO solution (zero-alcohol pilsener beer), the 10% CHO solution (Coca-Cola), and the 0% CHO solution (Mineral water) at the second, third, and fourth place, respectively.

During sports competitions, there may be a conflict between the wish of athletes to reduce thirst and the need to cope with the two physiological demands of carbohydrate refilling and fluid ingestion. As an example, Logan-Sprenger et al. [10] found that ice hockey players only drink water during the periods. In the present assessments, mineral water as a thirst quencher was also significantly favored, while the obtained influence of the beverages on performance capacity was just reflected by the trend. In order to optimize physical performance, it can be concluded that the kind of drink during training and, especially, during competition should not depend on athlete´s habits but coaches should educate and support athletes in this area, too.

We did not compare zero-alcohol beer with commercially available or self-prepared sports drinks containing similar CHO contents. Further studies are encouraged to provide a deeper insight into the effectiveness of different sports beverages.

5. CONCLUSION

Zero-alcohol beer should be considered as a successful tool for the fast and effective restoration of both carbohydrates and fluid during and after high intensity sports. Although it was tested in the situation of high interval running, that probably will hold for classic endurance activities like jogging and cycling.

ETHICAL APPROVAL

All experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards lai down in the 1964 Declaration of Helsinki.

NOTE

The study was supported by a grant of Krombacher Brauerei, Bernhard Schadeberg GmbH & Co KG. The funder had no role in the design, conduct, analysis and interpretation of data.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Bangsbo J, Iaia FM, Krustrup P. Metabolic response and fatigue in soccer. Int J Sports Physiol Perform. 2007;2:111-127.
2. Krustrup P, Zebis M, Jensen JM, Mohr M. Game-induced fatigue patterns in elite female soccer. J Strength Cond Res. 2010;24:437-441.
3. Póvoas SC, Ascensão AA, Magalhães J, Seabra AF, Krustrup P, Soares JM, Rebelo AN. Analysis of fatigue development during elite male handball matches. J Strength Cond Res. 2014;28:2640-2648.
4. Thorlund JB, Michalsik LB, Madsen K, Aagaard P. Acute fatigue-induced changes in muscle mechanical properties and neuromuscular activity in elite handball players following a handball match. Scand J Med Sci Sports. 2008;18:462-472.
5. Stevens ST, Lassonde M, de Beaumont L, Keenan JP. In-game fatigue influences concussions in national hockey league players. Res Sports Med. 2008;16:68-74.
6. Linseman ME, Palmer MS, Sprenger HM, Spriet LL. Maintaining hydration with a carbohydrate-electrolyte solution improves performance, thermoregulation, and fatigue during an ice hockey scrimmage. Appl Physiol Nutr Metab. 2014;39:1214-1221.
7. Baker LB, Dougherty KA, Chow M, Kenney WL. Progressive dehydration causes a progressive decline in basketball skill performance. Med Sci Sports Exerc. 2007;39:1114-1123.
8. Dougherty KA, Baker LB, Chow M, Kenney WL. Two percent dehydration impairs and six percent carbohydrate drink improves boys basketball skills. Med Sci Sports Exerc. 2006;38:1650-1658.
9. Edwards AM, Mann ME, Marfell-Jones MJ, Rankin DM, Noakes TD, Shillington DP. Influence of moderate dehydration on soccer performance: Physiological responses to 45 min of outdoor match-play and the immediate subsequent performance of sport-specific and mental concentration tests. Br J Sports Med. 2007;41:385-391.
10. Logan-Sprenger HM, Palmer MS, Spriet LL. Estimated fluid and sodium balance and drink preferences in elite male junior players during an ice hockey game. Appl Physiol Nutr Metab. 2011;36:145-152.
11. Palmer MS, Spriet LL. Sweat rate, salt loss, and fluid intake during an intense on-ice practice in elite Canadian male junior hockey players. Appl Physiol Nutr Metab. 2008;33:263-271.
12. Saltin B. Metabolic fundamentals in exercise. Med Sci Sports Exerc. 1973;5:137-146.
13. Krustrup P, Mohr M, Steensberg A, Bencke J, Kjaer M, Bangsbo J. Muscle and blood metabolites during a soccer game: implications for sprint performance. Med Sci Sports Exerc. 2006;38:1165-1174.
14. Shephard RJ. Meeting carbohydrate and fluid needs in soccer. Can J Sport Sci. 1990;(15):165-171.
15. Maughan RJ, Leiper JB. Fluid replacement requirements in soccer. J Sports Sci. 1994;12:S29-S34.
16. Guerra I, Chaves R, Barros T, Tirapegui J. The influence of fluid ingestion on performance of soccer players during a match. J Sports Sci Med. 2004;3:198-202.

17. Palmer MS, Heigenhauser G, Duong M), Spriet LL. Ingesting a sports drink enhances simulated ice hockey performance while reducing perceived effort. Int J Sports Med. 2017;38:1061-1069.
18. Aragon-Vargas LF, Moncada-Jimenez J, Hernandez-Elizondo J, Barrenechea A, Monge-Alvarado M. Evaluation of pre-game hydration status, heat stress, and fluid balance during professional soccer competition in the heat. Eur J Sports Sci 2009:9: 269-276.
19. Da Silva RP, Mundel T, Natali AJ, Filho MG, Alfenas RC, Lima JR, Belfort FG, Lopes PR, Marins JC. Pre game hydration status, sweat loss, and fluid intake in elite Brazilian young male soccer players during competition. J Sports Sci 2012;30:37-42.
20. Magee PJ, Gallagher AM, McCormack JM. High prevalence of dehydration and inadequate nutritional knowledge among university and club level athletes. Int J Sport Nutr Exerc Metab. 2017;27:158-168.
21. Burke LM, Read RS. A study of dietary patterns of elite Australian football players. Can J Sport Sci 1988;13:15-19.
22. Dietze PM, Fitzgerald JL, Jenkinson RA. Drinking by professional Australian Football Leage (AFL) players: Prevalence and correlates of risk. Med J Austr; 189:479-483.
23. Desbow B, Murray D, Leveritt M (2013) Beer as a sports drink? Manipulating beer´s ingredients to replace lost fluid. Int J Sports Exerc Metab 2013;23: 593-600.
24. Hoppe MW, Slomka M, Baumgart C, Weber H, Freiwald J. Match running performance and success across a season in German Bundesliga Soccer Teams. Int J Sports Med. 2015;36:563-566.
25. Lara B, Gonzalez-Millán C, Salinero JJ, Abian-Vicen J, Areces F, Barbero-Alvarez JC, Muñoz V, Portillo LJ, Gonzalez-Rave JM, Del Coso J. Caffeine-containing energy drink improves physical performance in female soccer players. Amino Acids. 2014;46:1385-1392.
26. Del Coso J, Muñoz-Fernández VE, Muñoz G, Fernández-Elías VE, Ortega JF, Hamouti N, Barbero JC, Muñoz-Guerra J. Effects of a caffeine-containing energy drink on simulated soccer performance. PLoS One. 2012;7:e31380.
27. Bartoli, W P, Horn M K, Murray R. Delayed gastric emptying during exercise with repeated ingestion of 8% carbohydrate solution. Med Sci Sports Exerc, 1995;27 (Suppl. 77)

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/24671