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Effects of Adding Brown Sugar In Young Coconut Water Post High-Intensity Interval Training on Plasma Osmolarity, Oxygen Saturation, and Pulse Rate
Efectos de agregar azúcar moreno al agua de coco joven después del entrenamiento en intervalos de alta intensidad sobre la osmolaridad del plasma, la saturación de oxígeno y la frecuencia del pulso

*Muhammad Redy Arif Pradana, *Gadis Meinar Sari, *Bambang Purwanto, **Maharani Fatima Gandasari, *Rakhmat Nur Hidayat, ***Slamet Raharjo, ****Muhammad
*Universitas Airlangga (Indonesia), **Universitas Tanjungpura (Indonesia), ***Universitas Negeri Malang (Indonesia), ****Universitas Negeri Surabaya (Indonesia)

Abstract. This study analyzes the effect of adding brown sugar to young coconut water post-High Intensity Interval Training (HIIT) on plasma osmolarity, oxygen saturation, and pulse rate. Utilizing a pre and post-test control group design, the experiment involved 20 male subjects aged 19-22 with a normal body mass index. The participants were divided into three groups: (K_1) receiving mineral water, (K_2) receiving young coconut water, and (K_3) receiving young coconut water with added brown sugar. Each subject underwent a 30-minute ergo cycle HIIT session. Blood samples were collected at three intervals: before exercise, immediately after, and an hour post-rehydration. The results indicated plasma osmolarity levels showed no significant change from Pre-HIIT (0.939) to Post-HIIT (0.780). However, Post-Rehydration, an increase was observed across the three groups ($p=0.004$). Pulse rate measurements revealed no significant difference from Pre-HIIT (0.788) to Post-HIIT (0.411), but Post-Rehydration, a significant decrease was noted between the groups ($p=0.034$). Oxygen saturation levels remained consistent Pre-HIIT (0.902), Post-HIIT (0.602), and 1-hour post-HIIT (0.611) within the third group. In conclusion, adding brown sugar to young coconut water post-HIIT resulted in higher plasma osmolarity, did not affect oxygen saturation levels, and contributed to a lower pulse rate.
Keyword: Plasma osmolarity; oxygen saturation; pulse rate; brown sugar; young coconut water

Resumen. Este estudio analiza el efecto de agregar azúcar moreno al agua de coco joven después del entrenamiento en intervalos de alta intensidad (HIIT) sobre la osmolaridad plasmática, la saturación de oxígeno y la frecuencia del pulso. Utilizando un diseño de grupo de control previo y posterior a la prueba, en el experimento participaron 20 sujetos masculinos de entre 19 y 22 años con un índice de masa corporal natural. Los participantes se dividieron en tres grupos: (K_1) recibió agua mineral, (K_2) recibió agua de coco joven y (K_3) recibió agua de coco joven con azúcar moreno agregado. Cada sujeto se sometió a una sesión HIIT en ciclo ergo de 30 minutos. Se recogieron muestras de sangre en tres intervalos: antes del ejercicio, inmediatamente después y una hora después de la rehidratación. Los resultados indicaron que los niveles de osmolaridad plasmática no mostraron cambios significativos desde el Pre-HIIT (0.939) hasta el Post-HIIT (0.780). Sin embargo, después de la rehidratación, se observó un aumento en los tres grupos ($p=0,004$). Las mediciones de la frecuencia del pulso no revelaron diferencias significativas entre el Pre-HIIT (0.788) y el Post-HIIT (0.411), pero después de la Rehidratación, se observó una disminución significativa entre los grupos ($p=0,034$). Los niveles de saturación de oxígeno se mantuvieron constantes antes del HIIT (0.902), después del HIIT (0.602) y 1 hora después del HIIT (0.611) dentro del tercer grupo. En conclusión, agregar azúcar moreno al agua de coco joven después del HIIT resultó en una mayor osmolaridad plasmática, no afectó los niveles de saturación de oxígeno y contribuyó a una frecuencia del pulso más baja.
Palabras clave: Osmolaridad plasmática; saturación de oxígeno; la frecuencia del pulso; azúcar morena; agua de coco joven

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Gadis Meinar Sari
gadis-m-s@fk.unair.ac.id

Introduction

The quest for optimal recovery strategies post-exercise is a critical component in the domain of sports science, particularly concerning the replenishment of electrolytes and the restoration of homeostatic balance. This study investigates the integration of brown sugar into young coconut water as a post-exercise rehydration beverage and its potential implications on recovery metrics in athletes following High-Intensity Interval Training (HIIT).

Aerobic exercise, which is contingent upon the availability of oxygen in the atmosphere (Palar et al., 2015), has the capacity to enhance lung vital capacity and oxygen uptake. These physiological adaptations can lead to significant changes in the body, such as increased oxygen levels in the blood or oxygen saturation (SpO_2) (Simanjuntak et al., 2016; Pelealu et al., 2015). HIIT, a form of aerobic exercise that combines high intensity with moderate or low intensity (Vigriawan et al., 2022), has been identified as a time-efficient solution that offers similar, if not greater, health benefits compared to traditional workouts (Syamsudin et al., 2021). Its efficacy in improving cardiovascular fitness and function has made it the third most popular exercise worldwide.

Physical activity elevates body temperature, metabolic rate, and heat production, leading to electrolyte loss and reduced glycogen stores in the liver, which can contribute to fatigue and dehydration (Moreno et al., 2013). Dehydration, in turn, can diminish oxygen saturation (Aswad & Loleh, 2021), underscoring the importance of effective rehydration strategies (Ramadhan & Avandi, 2020). Fluid administration to athletes is crucial for preventing dehydration, maintaining fluid balance, and averting injuries related to excessive body heat (Krisnawati, 2011).

Electrolyte drinks are commonly used to maximize fluid rehydration post-exercise and mitigate dehydration risks

(Bahri et al., 2012). Young coconut water, a natural electrolyte drink, is rich in calcium, sodium, and sugars that aid in treating dehydration. It also contains significant amounts of carbohydrates, fats, and potassium (Siregar, 2016; Ulandari, 2021; Nasution, 2020). Brown sugar, an alternative sweetener, is rich in micronutrients that can optimize muscle, heart, and lung performance (Ramadhan & Avandi, 2020), and is composed of monosaccharides that can be directly absorbed by the body to produce energy (Tanuwijaya et al., 2017; Maryani et al., 2021).

Previous research by Syafriani et al. (2019) compared coconut water mixed with palm sugar to isotonic drinks, finding that the former maintained glucose levels effectively and was a safer consumption choice. Dehydration was assessed using urine specific gravity, with plasma osmolarity and pulse rate serving as recovery indicators (Lutfi, 2019; Kusuma et al., 2020). Despite theoretical discussions on sports rehydration (Rubiono & Setiawan, 2020), studies on the effects of adding brown sugar to young coconut water post-HIIT on plasma osmolarity, oxygen saturation, and pulse rate are lacking. This study aims to fill this gap by analyzing the impact of brown sugar-enhanced young coconut water on these recovery metrics post-HIIT.

Material and Methods

Study design

The research method was a true-experimental with a pretest-posttest control group design. The research objective was to analyze the effect of adding brown sugar to young coconut water after high-intensity interval training (HIIT). The research subjects were divided into three treatment groups, namely group one (negative control) mineral water, the second group (positive control) only being given young coconut water, and group three (treatment group) being given brown sugar young coconut water.

Participants

The research subjects were 20 people, aged 19-22 years with a body mass index of 19-24 kg/m^2, and had normal vital signs including body temperature, blood pressure, heart rate and oxygen saturation selected to participate in the study. The research population was students of the Faculty of Sports Science, State University of Malang. The technique for selecting research subjects used consecutive sampling, while the technique for dividing subjects into groups used random sampling. Subjects were randomly divided into three groups, namely K_1 (group 1, n=6), K_2 (group 2, n=7), and K_3 (group 3, n=7). The place of research was the Sports Science Laboratory, Faculty of Sports Science, State University of Malang with a room temperature of 26±1 °C and a humidity level of 50-70%.

Ethical clearance statement

Before participating, subjects received verbal and written information about the research and all subjects stated that they were willing to voluntarily participate in the research by filling out and signing informed consent consciously. All procedures of this study complied with the World Medical Association Declaration of Helsinki on the ethical conduct of research involving human subjects and were approved by the Health Research Ethics Committee of the Faculty of Medicine, Airlangga University, Surabaya number 20/EC.KEPK.FKUA/2023.

Procedures and measures

Subjects fasted ± 8 hours before exercise, then examined blood samples, oxygen saturation, pulse rate, and drinking. Take a 3 ml blood sample to pretest plasma osmolarity, SpO_2, and pulse rate before high-intensity interval training (HIIT). Research subjects were given sugar water at a rate of 80gr, dissolved in 250 ml of mineral water, and given 30 minutes before the HIIT intervention.

Subjects were given high-intensity interval training intervention treatment. HIIT workouts consist of pedaling on a high-intensity 80-90% HR Max ergo cycle for 30 minutes. The workout breakdown was 20 minutes core work (30 seconds sprint (80-90% HR Max), 90 seconds active recovery or slow cycling (50-60% HR Max), do 10 reps), and warm-up and cool-down were each carried out for 5 minutes (Setiawan et al., 2024). Polar H10 heart ratesensor was used to control intensity during exercise (Yunus et al., 2024). After HIIT, 3 ml of blood samples were taken from the research subjects and used as the first post-test data (after the HIIT intervention).

Blood sampling after HIIT aims to measure plasma osmolarity, pulse rate measurement, and post-exercise oxygen saturation. After blood sampling, the research subjects were given a drinking intervention according to the group, additional mineral water, and 1-hour of rest. The second posttest was taking blood (after being given a drink) after one hour of rest. Blood collection as much as 3 ml.

Urea levels were measured using the Nuclear magnetic resonance spectroscopy (NMR) method (Liu et al., 2012), while sodium levels were measured using the Ion Selective Electrode (ISE) method (Refardt et al., 2019). Blood glucose levels were checked using Accu Check Performa (Rejeki et al., 2023). Meanwhile, oxygen saturation and pulse rate were measured using the Beurer PO 30 Pulse Oximeter (Pranoto et al., 2023).

Statistical analysis

Statistical analysis used SPSS version 22. The amount of data distribution was analyzed using descriptive statistics. The normality test used the Shapiro-Wilk test ($p \geq 0.05$). Homogeneity test using the Levene test ($p \geq 0.05$). Analysis of differences in levels of urea and sodium, plasma osmolarity, oxygen saturation, and pulse rate between groups used one-way ANOVA with a significant level ($p \leq 0.05$) and continued with the Least Significant Difference (LSD) post hoc test with a significance level ($p \leq 0.05$).

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Results

Descriptive statistical analysis of baseline data on the characteristics of the study subjects in each group can be seen in Table 1.

Table 1.
Analysis of descriptive data on subject characteristics

Variable	K_1 (*n*=6)	K_2 (*n*=7)	K_3 (*n*=7)	*p*-value
Age (years)	21.00±1.27	20.72±1.11	21.00±1.16	0.875
Height (m)	1.64±0.05	1.66±0.05	1.68±0.04	0.233
Weight (kg)	62.17±6.20	61.07±4.66	64.54±7.04	0.559
BMI (kg/m^2)	23.06±1.24	22.12±1.39	22.74±1.78	0.522
SBP (mmHg)	114.50±9.09	119.00±4.36	117.57±6.73	0.503
DBP (mmHg)	74.17±7.19	68.71±5.12	68.43±4.54	0.156
RHR (bpm)	73.83±3.76	70.14±12.32	70.43±11.49	0.778
SpO2 (%)	97.67±1.21	97.43±1.51	97.71±0.95	0.902
BT (°C)	35.25±0.39	35.53±0.76	35.27±0.88	0.736

Notes. BMI: Body Mass Index, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, RHR: Resting Pulse rate, SpO_2, Oxygen Saturation, BT: Body Temperature, K_1: Negative Control Group (mineral water); K2: Positive Control Group (coconut water);K3: Treatment Group (coconut water + brown sugar). Data are presented as mean ± standard deviation (SD). The p-value was obtained using the One-way ANOVA test.

The results of the descriptive statistics show that the characteristics of the research subjects in each group have almost the same average. The one-way ANOVA test showed that there was no significant difference in the mean baseline data between groups (K_1 vs K_2 vs K_3) ($p \geq 0.05$). The study results showed that there was an average increase in sodium levels in each group which can be seen in Table 2.

Table 2.
Statistical analysis of average sodium levels (K_1 vs. K_2 vs. K_3)

Assessment	Sodium Levels (mmol/L)			*p*-value
	K_1 (*n*=6)	K_2 (*n*=7)	K_3 (*n*=7)	
Pre-HIIT	97.20±51.20	99.30±42.30	100.50±52.40	0.992
Post-HIIT	179.10±47.40	199.10±56.10	205.00±54.80	0.669
Post-Rehydration	175.60±56.10	215.10±48.30	278.10±33.70*†	0.003

Notes. K_1: Negative Control Group (mineral water), K_2: Positive Control Group (coconut water),K_3: Treatment Group (coconut water + brown sugar). Data are presented as mean ± standard deviation (SD). The p-value was obtained using the One-way ANOVA test, and continued with the LSD post hoc test. (*) Shows a significant difference in the increase in sodium levels with K_1 ($p \leq 0.05$). (†) Showed a significant difference in the increase in sodium levels with K_2 ($p \leq 0.05$).

The analysis shows that the average Pre-HIIT sodium levels are almost the same. The average Post-HIIT and Post-Rehydration K_3 sodium levels were higher than those of K_1 and K_2 sodium (table 2). The normality test showed that the distribution of sodium levels in Pre-HIIT, post-HIIT, and Post-Rehydration was normal (p≥0.05). Homogeneity test showed that Pre-HIIT, post-HIIT, and Post-Rehydration sodium levels were homogeneous (p≥0.05). The results of the one-way ANOVA test showed no significant difference in the average Pre-HIIT and Post-HIIT sodium levels (p≥0.05). The average post-rehydration sodium levels showed an increase (p≤0.05). The results of the LSD posthoc test showed a significant increase in the average post-rehydration sodium levels of K_3 and K_1 (p=0.001), K_3 and K_2 (p=0.021). K_2 and K_1 did not show a significant increase (p=0.144). The study results showed that there was a decrease in the average urea level in each group which can be seen in Table 3.

Table 3.
Results of urea levels (K_1 vs. K_2 vs. K_3)

Assessment	Urea Levels (mmol/L)			*p*-value
	K_1 (*n*=6)	K_2 (*n*=7)	K_3 (*n*=7)	
Pre-HIIT	16.51±4.89	15.86±6.23	16.18±4.85	0.977
Post-HIIT	18.25±4.99	14.28±3.41	15.30±4.03	0.236
Post-Rehidrasi	18.10±1.44	11.99±3.51*	7.97±1.39*†	0.000

Notes. K_1: Negative Control Group (mineral water), K_2: Positive Control Group (coconut water),K_3: Treatment Group (coconut water + brown sugar). Data are presented as mean ± standard deviation (SD). The p-value was obtained using the One-way ANOVA test, and continued with the LSD post hoc test. (*) Shows a significant difference in the decrease in urea levels with K_1 ($p \leq 0.05$). (†) Showed a significant difference in the reduction of urea levels with K_2 ($p \leq 0.05$).

The results of the data analysis showed that the average Pre-HIIT urea levels were almost the same. The average post-HIIT and post-rehydration levels of K_3 were lower than those of K1 and K_2 (Table 3). The normality test showed that the data distribution for pre-HIIT, post-HIIT, and post-rehydration was normal (p≥0.05). The homogeneity test showed that the average distribution of urea levels between Pre-HIIT, Post-HIIT, and Post-Rehydration was homogeneous (p≥0.05). The results of one-way ANOVA showed that there was no difference in the average urea levels in Pre-HIIT and Post-HIIT (p≥0.05). Post-rehydration urea levels showed a significant decrease (p≤0.05). LSD posthoc test results showed the average post-rehydration urea levels between K_3 and K_1 (p=0.000), K_3 and K_2 (p=0.006), and K_2 and K_1 (p=0.000). The results showed that there was an average increase in blood glucose levels in each group which can be shown in Table 4.

Table 4.
Statistical results of average blood glucose levels (K_1 vs. K_2 vs. K_3)

Assessment	Glucose Blood Levels (mg/dL)			*p*-value
	K_1 (*n*=6)	K_2 (*n*=7)	K_3 (*n*=7)	
Pre-HIIT	96.33±3.82	93.14±4.22	96.14±2.60	0.217
Post-HIIT	95.33±12.69	92.85±7.86	95.00±7.63	0.874
Post-Rehydration	92.50±8.96	94.57±10.22	110.57±13.85*†	0.018

Notes. K_1: Negative Control Group (mineral water), K_2: Positive Control Group (coconut water),K_3: Treatment Group (coconut water + brown sugar). Data are presented as mean ± standard deviation (SD). The p-value was obtained using the One-way ANOVA test, and continued with the LSD post hoc test. (*) Shows a significant difference in the increase in blood glucose levels with K1 ($p \leq 0.05$). (†) Showed a significant difference in blood glucose levels with K2 ($p \leq 0.05$).

The results showed that Pre-HIIT blood glucose levels had almost the same average. The mean post-HIIT and post-rehydration K_3 blood glucose levels were higher than K_1 and K_2 (table 4). The normality test showed that the average distribution of pre-HIIT, post-HIIT, and post-rehydration blood glucose levels was normal (p≥0.05). Homogeneity test showed that the average distribution of pre-HIIT, post-HIIT, and post-rehydration blood glucose levels was homogeneous (p≥0.05). The one-way-ANOVA test showed no significant difference in the mean pre-HIIT and post-HIIT blood glucose levels in the 3 groups (p≥0.05). The average post-rehydration blood glucose level showed an increase in all three groups (p≤0.05). LSD posthoc test showed a significant increase in the average blood glucose levels after rehydration K_3 with K_1 (p=0.011), K_3 with K_2 (p=0.017).

K_2 and K_1 did not show an average increase in blood glucose levels (p=0.746). Plasma osmolarity analysis showed an average increase in each group which is shown in Table 5.

Table 5.
Results of average plasma osmolarity (K_1 vs. K_2 vs. K_3)

Assessment	Plasma Osmolarity (mmol/L)			*p*-value
	K_1 (*n*=6)	K_2 (*n*=7)	K_3 (*n*=7)	
Pre-HIIT	213.00±98.60	208.00±84.80	226.00±101.90	0.939
Post-HIIT	367.00±94.70	408.00±112.50	403.00±120.90	0.780
Post-Rehydration	362.00±112.10	439.00±97.10	564.00±68.60*†	0.004

Notes. K_1: Negative Control Group (mineral water), K_2: Positive Control Group (coconut water), K_3: Treatment Group (coconut water + brown sugar). Data are presented as mean ± standard deviation (SD). The p-value was obtained using the One-way ANOVA test, and continued with the LSD post hoc test. (*) Showed a significant difference in increased plasma osmolarity with K1 ($p \geq 0.05$). (†) Showed a significant difference in increased plasma osmolarity with K_2 ($p \leq 0.05$).

Data analysis showed that the average Pre-HIIT plasma osmolarity of each group was almost the same. Post-HIIT and post-rehydration plasma osmolarity mean K_3 was higher than K_1 and K_2 (table 5). The normality test showed that the average distribution of Pre-HIIT, Post-HIIT, and Post-Rehydration plasma osmolarity data was normal ($p \geq 0.05$). The homogeneity test showed that the average pre-HIIT, post-HIIT, and post-rehydration plasma osmolarity distributions were homogeneous ($p \geq 0.05$). One way ANOVA test showed no difference in mean pre-HIIT and post-HIIT plasma osmolarity between the three groups (p≥0.05). The average post-rehydration plasma osmolarity increased in all three groups (p≤0.01). The results of the LSD posthoc test showed that there was an increase in the average post-rehydration plasma osmolarity of K3 with K1 (p=0.001) and K3 with K2 (p=0.023). K2 and K1 did not show an increase in the average plasma osmolarity (p=0.156). The results showed that there was an increase in the average pulse rate in each group which can be seen in Table 6.

Results of average pulse rate (K_1 vs. K_2 vs. K_3)

Table 6.
Results of average pulse rate (K_1 vs. K_2 vs. K_3)

Assessment	Pulse rate (bpm)			*p*-value
	K_1 (*n*=6)	K_2 (*n*=7)	K_3 (*n*=7)	
Pre-HIIT	73.00±3.76	70.00±12.30	70.00±11.40	0.778
Post-HIIT	138.00±16.70	148.00±15.40	139.00±13.00*	0.411
Post-Rehydration	87.00±8.73	87.00 ±5.55	74.00±12.40*†	0.034

Notes. K_1: Negative control group (mineral water), K_2: Positive control group (coconut water), K_3: Treatment group (coconut water + brown sugar). Data are presented as mean ± standard deviation (SD). The p-value was obtained using the One-way ANOVA test and continued with the LSD post hoc test. (*) Shows a significant difference in the decrease in pulse rate with K_1 ($p \leq 0.05$). (†) Shows a significant difference in the decrease in pulse rate with K2 ($p \leq 0.05$).

Data analysis shows that the average Pre-HIIT pulse rate is almost the same. The average pulse rate of Post-HIIT and Post-Rehydration K_3 is lower than that of K_1 and K_2 (Table 6). The normality test showed that the average Pre-HIIT, Post-HIIT, and Post-Rehydration pulses were normal (p≥0.05). The homogeneity test showed that the average Pre-HIIT, Post-HIIT, and Post-Rehydration pulses were homogeneous (p≥0.05). The one-way-ANOVA test showed no difference in the average Pre-HIIT and Post-HIIT pulse rates (p≥0.05). The average post-rehydration pulse rate decreased in the three groups (p≤0.05). LSD posthoc test decreased pulse rate after rehydration K_3 and K_1 (p=0.026), K_3 and K_2 (p=0.023). K_2 and K_1 did not show a significant decrease (p=0.971). The results of the study showed an increase in the average oxygen saturation in each group is shown in Table 7.

Table 7.
Results of oxygen saturation (K_1 vs. K_2 vs. K_3)

Assessment	Oxygen Saturation (%)			*p*-value
	K_1 (*n*=6)	K_2 (*n*=7)	K_3 (*n*=7)	
Pre-HIIT	97.67±1.21	97.43±1.51	97.71±0.95	0.902
Post-HIIT	95.83±1.17	96.57±1.51	96.00±1.41	0.602
Post-Rehydration	98.33±0.82	97.86±1.21	98.29±0.76	0.611

Notes. K_1: Negative control group (mineral water), K_2: Positive control group (coconut water), K_3: Treatment group (coconut water + brown sugar). Data are presented as mean ± standard deviation (SD). The p-value was obtained using the One-way ANOVA test and continued with the LSD post hoc test. (*) Shows a significant difference in the increase in oxygen saturation with K_1 ($p \leq 0.001$). (†) Shows a significant difference in the increase in oxygen saturation with K_2 ($p \leq 0.05$).

Data analysis showed that the mean Pre-HIIT oxygen saturation was almost the same. The average oxygen saturation of Post-HIIT and Post-Rehydration K_3 was higher than that of K_1 and K_2 (Table 7). The normality test showed that the average pre-HIIT, post-HIIT, and post-rehydration oxygen saturations were normal (p≥0.05). The homogeneity test showed that the average pre-HIIT, post-HIIT, and post-rehydration oxygen saturation was homogeneous (p≥0.05). One-way ANOVA test showed no difference in mean Pre-HIIT, Post-HIIT, and Post-Rehydration oxygen saturation between the three groups ($p \geq 0.05$).

Discussion

The results of one-way ANOVA found no difference in mean plasma osmolarity between Pre-HIIT and Post-HIIT in the three groups ($p \geq 0.05$). The mean post-HIIT plasma osmolarity increased in the third group ($p \leq 0.01$). These results indicate that the effect of adding brown sugar to young coconut water after high-intensity interval training has an impact on plasma osmolarity. This result is in line with Penggalih et al. (2015) who proved that subjects who consumed young coconut water experienced changes in plasma osmolarity values after 2 hours of rehydration. Research by Saat et al. (2002) found that carbohydrate-electrolyte drinks can maintain plasma osmolarity during exercise.

The primary mechanism supporting these findings is the osmotic effect of carbohydrates. Brown sugar, being a carbohydrate, can enhance water absorption in the intestines, thus contributing to increased plasma osmolarity. This is supported by Saat et al. (2002), who found that carbohydrate-electrolyte drinks could maintain plasma osmolarity during exercise. Additionally, the high potassium content in young coconut water may aid in restoring intracellular fluid balance, further influencing plasma osmolarity levels. The research provides robust empirical support for the efficacy of natural rehydration methods post-physical exertion. It also sheds light on the positive impact that incorporating brown sugar into these rehydration solutions can have on enhancing recovery and maintaining optimal hydration levels.

Water or body fluid is part of the body because 55-60% of an adult's body weight, or 70% of the body, does not contain fat (lean body mass). Exercise with a long duration causes the body to lose many fluids through sweat (Ardiana, 2019). Young coconut water does not contain artificial sweeteners and has balanced blood levels. The ions in young coconut water can replace the body's electrolytes released through sweat, such as sodium, potassium, magnesium, and calcium, as a post-exercise rehydration drink (Ramadhan & Avandi, 2020).

Young coconut water is a drink that contains substances that the body needs when doing sports activities. The advantage of young coconut water is that it can hydrate more than mineral water drinks and is isotonic because it contains high potassium (Putra & Kusuma, 2020). Potassium is an intracellular cation that plays a role in regulating pulse rate and muscle function. $K+$ intake is needed to replace $K+$ lost from urine and sweat because isotonic control of $K+$ ions does not have a conversion mechanism like Na ions. There are similarities between young coconut water electrolytes and the body, which can replace lost fluids. Young coconut water and palm sugar water contain carbohydrates which can delay fatigue due to dehydration. Adequate consumption of mineral water can meet the body's fluid needs.

The concentration of potassium in the body is maintained by adjusting the intake of potassium. The amount of potassium excreted in the urine will slow fatigue and maintain hydration status. Provision of brown sugar water containing simple carbohydrates in it can be converted into glucose and stored in muscle glycogen to be used as energy so as to reduce fatigue and improve hydration status after sports activities. Brown sugar water also contains simple carbohydrates and a low glucose index. Carbohydrates are considered the main source of energy during exercise. Carbohydrates through metabolic processes are converted into glucose. Excess glucose will be converted into glycogen which is stored in the liver and muscles. Muscle glycogen will be used during activities and glycogen in the liver will be released if muscle glycogen runs out. Muscle glycogen plays an important role in delaying fatigue and increasing fitness (Putra & Kusuma, 2020).

Dehydration causes blood volume to decrease due to lack of water. The two are different terms because of their effect on plasma osmolarity, which results in a decrease in blood volume. Increases and decreases in blood volume have clinical complications. Hypovolemia occurs through bleeding, sodium depletion, water loss, and plasma loss (Bhave & Neilson, 2011). Decreased circulating volume affects the renal receptors and impacts renin. The renin enzyme secreted by the kidneys converts the hormone angiotensin into angiotensin I and II. Angiotensin II increases aldosterone secretion. The adrenal glands produce aldosterone to regulate blood pressure and electrolytes. Excess aldosterone production causes a decrease in GFR (glomerular filtration rate), increase in sodium (Na), and water reabsorption (Molitoris, 2022).

Plasma osmolarity aims to determine water and electrolyte imbalances, assess the ability of the kidneys to concentrate urine, and ADH (Antidiuretic Hormone) abnormalities. Body osmolarity is an indicator of fluid balance (Rambert, 2014). The stimulus for ADH release during exercise is an increase in osmolarity. The release of sweat and water vapor causes the osmolarity pressure to increase. Exercise affects intravascular water and electrolyte balance and increases plasma osmolarity and ADH due to fluid loss through hyper-sweating and hyperpnea at increased osmolarity (Suprida, 2014). An increase in blood osmolarity due to exercise causes the body to lose many body fluids through sweat (respiration), and an increase in ionic concentration occurs. Plasma osmolarity increases because sweat is relatively hypotonic to plasma (Penggalih et al., 2015).

Rehydration using plain water causes blood dilution due to decreased blood and urine osmolarity. Rehydration of carbohydrate-electrolyte drinks increases the osmolarity level (Saat et al., 2002; Ismail et al., 2007). Water contains carbohydrates and electrolytes to maintain body fluid balance. Brown sugar has a high level of simple carbohydrates, which contain glucose, sucrose, and fructose. Brown sugar can be categorized as a producer of energy in the body. Brown sugar also contains minerals needed for metabolic processes and to optimize the work of the muscles, heart, and lungs, such as calcium, phosphorus, iron, and Cu (Azlan et al., 2020). The recommended drink contains electrolytes and carbohydrates 2.5-6.9%. The mineral and sugar content in young coconut water is isotonic, making it ideal for rehydration and refreshment after exercise (Tih et al., 2017).

The results of the difference test in the average oxygen saturation (SpO_2) using one-way ANOVA showed that there was no significant difference between the average SpO_2 Pre-HIIT, Post-HIIT, and Post-Rehydration ($p \geq 0.05$). The results showed that adding brown sugar to young coconut water after high-intensity interval training had no effect on increasing oxygen saturation (SpO_2). These results are in line with Utami's study (2008) which proved that there was no significant difference in oxygen saturation (SpO_2) and decreased serum levels of pH, PCO2, HCO3-, and TCO2 after administration of water oxygen to post-exercise subjects. Ellyana research (2011) proves that there is no significant increase in oxygen saturation (SpO_2) after drinking mineral water.

The body will experience acidosis during exercise due to the accumulation of lactic acid in anaerobic metabolism due to unmet oxygen needs (Ellyana, 2011). Acidosis is a medical condition when the blood in the body contains too much acid. The kidneys will produce acidic urine when the body experiences acidosis. Oxygen in water is expected to meet oxygen needs during exercise so that the body does not experience acidosis (Guyton & Hall., 2006; Vanderlei et al., 2014).

Oxygen absorbed through breathing can enter and be absorbed by the body through the digestive tract of food substances. Oxygen absorption occurs rapidly in the intestine, and this process increases blood saturation in the hepatic portal vein and aorta. The absorption of the drink enters the capillaries of the mucous membranes of the digestive tract and then into the portal vein and enters the liver circulation, so that increased blood can reach the organs through the hematogenous route by hemoglobin from the lungs to the tissues (Rhoades & Bell, 2009; Tirajoh et al., 2016).

The process of absorption of water in the intestine takes 15 minutes, and the process of absorption of food takes up to 4 hours. Oxygen absorption in the small intestine is possible because this section is only covered by a single layer of cylindrical epithelial cells so that oxygen enters through the epithelial membrane which limits the lumen of the small intestine by passive diffusion (Tirajoh et al., 2016).

The results of the difference in average pulse using the one-way ANOVA test showed no significant difference between the average Pre-HIIT and Post-HIIT pulse rates ($p \geq 0.05$), while the average Post-Rehydration pulse showed a significant difference. decrease between the three groups ($p \leq 0.01$). These results indicate that the addition of brown sugar to young coconut water after high-intensity interval training has a relative effect on a decrease in pulse rate. Research of Nasution (2020) proves that consuming 350 ml of coconut water 30 minutes before and after physical activity helps speed up the decrease in pulse rate. The study of Ramadhan & Avandi (2020) stated that there was a decrease in pulse rate after exercise in research subjects who were given young coconut water and brown sugar water.

Young coconut water is proven to reduce pulse by up to 21% after being given HIIT (high-intensity interval training) and can help recovery (Nugraha & Kusuma, 2019). Young coconut water can lower the pulse faster after physical exercise because coconut water contains electrolyte fluids that can replace fluids lost through sweat. (Nasution, 2020). Young coconut water contains 17% potassium (291 mg per 100 ml), 15% magnesium, and 10% vitamin C. This content in young coconut water can reduce the pulse rate after physical exercise (Yusuf et al., 2020). Young coconut water has a carbohydrate content of 3.6%, the highest electrolyte content is potassium ± 220 mg, while the sodium content is ± 105 mg (Alfiyana & Murwabani, 2012).

Brown sugar has an energy content of 368 kcal, 95 grams of carbohydrates, 75 mg of calcium, 35 mg of phosphorus, and 3 mg of iron, and contains vitamins A, B1, and C (Ardiana, 2019). Brown sugar has high levels of simple carbohydrates containing glucose, sucrose, and fructose. Brown sugar can be a source of energy for the body. Brown sugar also contains minerals needed for metabolic processes and to optimize the work of the muscles, heart, and lungs, such as calcium, phosphorus, iron, and Cu. Providing carbohydrate drinks while exercising helps improve fitness, quenches thirst, and accelerates rehydration and replenishment of energy for the body. Providing drinks containing 6-8% carbohydrates during training or matches will help improve athlete performance by delaying fatigue (Tanuwijaya et al., 2017).

Potassium in young coconut water and brown sugar can balance the function of sodium in blood pressure imbalances. Potassium reduces blood pressure through the mechanism of natriuresis in the kidneys, endothelium-dependent vasodilation, and central effects through the mechanism of renin-angiotensin-aldosterone (RAA) and increases Na pumps, which reduce sympathetic nerve activity (Farapti & Sayogo, 2014). Potassium can reduce systolic and diastolic blood pressure by inhibiting the release of renin so that it can help increase sodium and water excretion. The mineral content in the form of potassium can maintain the elasticity of blood vessel walls, minimize blood vessel narrowing and renin secretion, decrease Aldosterone, and have the effect of activating Na-K in the form of potassium, which comes from the extracellular fluid to the cells, and sodium when activated. So that potassium can restore the pulse after physical activity (Yusuf et al., 2020).

This article adds to the scientific literature by demonstrating the potential benefits of a natural rehydration strategy involving young coconut water and brown sugar. It challenges the conventional reliance on artificial sports drinks and opens avenues for further research into alternative hydration solutions that are more aligned with the body's natural electrolyte balance. Research is limited to plasma osmolarity, sodium, urea, and blood glucose, and recommended research on the brown sugar in young coconut water on potassium. Research is only the high-intensity interval training method on plasma osmolarity, sodium, blood glucose, and urea. Further research on the effects of brown sugar in young coconut water before exercise.

Conclusions

The study's primary outcome reveals that the incorporation of brown sugar into young coconut water following high-intensity interval training significantly elevates plasma osmolarity levels. This suggests a potential for improved hydration strategies in athletic recovery. While the addition of brown sugar did not markedly affect oxygen saturation (SpO_2), it did contribute to a reduction in pulse rate post-exercise. These findings indicate that brown sugar could be a beneficial component in post-exercise rehydration solutions, potentially aiding in quicker cardiovascular recovery. This aligns with the study's objectives to explore innovative rehydration methods that support rapid physiological restoration and performance enhancement post-exercise.

Conflict of Interest

The authors declare that they have no competing interests.

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Datos de los/as autores/as y traductor/a:

Muhammad Redy Arif Pradana	muhammad.redy.arif-2019@fk.unair.ac.id	Autor/a
Gadis Meinar Sari	gadis-m-s@fk.unair.ac.id	Autor/a
Bambang Purwanto	bpaifo@gmail.com	Autor/a
Maharani Fatima Gandasari	maharani.fatima@fkip.untan.ac.id	Autor/a
Rakhmat Nur Hidayat	rakhmatnur27@gmail.com	Autor/a
Slamet Raharjo	slamet.raharjo.fik@um.ac.id	Autor/a
Muhammad	muhammad@unesa.ac.id	Autor/a
Rahmatya Ikhwanurrosida	lingolinkpro@gmail.com	Traductor/a