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Original Article

Effects of date extract ingestion on high-intensity cycling performance

NANDYA RIZKY NUR FEBRIANA[1], RADEN ARGARINI[2]*, IRMANTARA SUBAGIO[3], BAMBANG PURWANTO[4], NUR SHAKILA MAZALAN[5]
[1,2,4] Master of Exercise, Health and Sport Sciences, Faculty of Medicine, Universitas Airlangga, Surabaya, East Java, INDONESIA
[2,4]Department Medical Physiology and Biochemistry, Faculty of Medicine, Airlangga University, Surabaya, East Java, INDONESIA
[3]Faculty of Sports and Health Sciences, State University of Surabaya, Surabaya, East Java, INDONESIA
[5] Faculty of Education, Universiti Kebangsaan Malaysia, MALAYSIA

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Abstract:
High-intensity exercise requires substantial energy, often resulting in exhaustion and reduced performance. Fatigue during exercise can stem from various factors, including energy depletion, accumulation of lactic acid, neurological impairments, and psychological influences. Dates (*Phoenix dactylifera Linn*) are a rich source of glucose and bioactive compounds, making them potential components of energy bars designed to enhance performance. This study investigated the anti-fatigue and performance-enhancing effects of date extract during intensive cycling activities. The research used a crossover design, enrolling eight male trained inline skaters with a mean age of 19.13 (0.35) years. These individuals regularly engaged in skating sessions lasting over 1.5 h at least three days a week and had prior experience in competitive events. The participants engaged in two separate high-intensity cycling sessions: one involving date extract ingestion (1 g/kg body weight, consumed 15 min before exercise commencement) and one without. A two-day washout period separated these sessions. Blood glucose levels exhibited a significant increase 15 min after date extract ingestion (pre-exercise: 90.38 (12.93) mg/dL vs. 15-min post 124.63 (25.12) mg/dL; p = 0.002). However, blood glucose levels at the end of exercise were comparable between both conditions. Notably, blood lactate levels increased in both groups, but these values were not significantly different. Performance during high-intensity cycling was significantly enhanced in the group that consumed date extract. Both duration (794.75 (74.89) s vs. 699.88 (84.82) s; p = 0.033) and distance (8,003.72 (784.48) m vs. 6,961.3 (1,036.7) m; p = 0.04) were greater compared to those in the control group, while power and speed remained unaffected. Notably, the maximum rate of perceived exertion was reached at a more advanced stage of high-intensity exercise by the participants in the intervention group compared to those in the control group. These findings suggest that date extract ingestion improves glucose availability for energy production, delays the onset of exercise-induced fatigue, and enhances performance during high-intensity exercise.
Keywords: **Date extract; high-intensity exercise; ergogenic aid; glucose; fatigue**

Introduction

Optimal nutrition is a fundamental component of training and performance strategies for athletes, serving as a crucial factor in enhancing performance and delaying the onset of fatigue. Fatigue is a common, non-specific symptom often characterized by a sense of tiredness or diminished energy, which can hinder participation in voluntary activities. This phenomenon can be classified into two primary types: mental fatigue, which encompasses cognitive or perceptual factors, and physical fatigue, which pertains to the functioning of the motor system. In humans, muscle fatigue specifically refers to the reduced ability of a muscle or group of muscles to generate maximal force or power as a consequence of exercise (Wan et al., 2017). One aspect that warrants particular attention is the specific nutritional requirements associated with high-intensity exercise. During this type of exercise, the demand for energy in the form of adenosine triphosphate (ATP) in muscles increases in proportion to the intensity level. Consequently, ATP demands can surge well beyond 100 times above resting levels, leading to more rapid fatigue and diminished performance (Calbet et al., 2020). As a result, there is an increased reliance on plasma glucose as an energy source during high-intensity exercise. Elevated lactate concentrations are also commonly observed during high-intensity exercise as a byproduct of increased glycolytic activity, which can further contribute to fatigue (Durand et al., 2021; Hargreaves & Spriet, 2020).

Ergogenic aids encompass substances or methods that enhance energy utilization by increasing energy production, efficiency, and regulation. Examples of these aids include sugars and essential minerals such as potassium, sodium, calcium, chromium, zinc, magnesium, and selenium, each of which plays a critical role in various metabolic processes in the human body (Bucci, 2020). Ergogenic aids, including carbohydrates (CHO),

Corresponding Author: RADEN ARGARINI, E-mail: raden-a@fk.unair.ac.id

are commonly used as supplements by athletes across a wide range of sports, with the aim of improving performance and recovery. CHO supplementation has been well-established in the literature to enhance prolonged endurance exercise performance (Ramos-Campo et al., 2024). Endurance training reduces the rates of glucose production and utilization; therefore, CHO ingestion before and during exercise can enhance endurance performance. In contrast to the consistently observed beneficial effects of CHO ingestion during low-intensity exercise, the efficacy of pre-exercise CHO ingestion in high-intensity exercise or intermittent exercises, such as certain athletic competitions, cycling, and various forms of resistance training, remains less clear (Baker et al., 2015; Krings et al., 2016). CHO supplementation during high-intensity training (HIT) or high-intensity interval training (HIIT) has been examined in numerous studies using diverse training protocols. Consequently, direct comparisons between these studies are challenging owing to the involvement of different muscle groups, masses, and fiber types in various exercise modalities.

A meta-analysis study revealed that CHO interventions were associated with faster time-trial performances, indicating enhanced performance. However, subsequent subgroup analyses demonstrated that significant performance improvements were only observed in studies administering a CHO concentration ranging from 6 to 8% (Pöchmüller et al., 2016). Despite the inconclusive findings regarding CHO supplementation in high-intensity exercise, it is still plausible that such supplementation can positively impact exercise performance. Several potential mechanisms may underlie this effect. (1) CHO supplementation may increase exogenous glucose concentrations, enhancing substrate availability for the glycolytic pathway and sparing glycogen stores. This increased substrate availability could stimulate glycolysis, leading to higher lactate concentrations and improved performance (Mata et al., 2019). (2) CHO consumption or mouthwash may stimulate oral receptors, triggering the brain's pleasure and reward centers and providing a central nervous system-based mechanism for enhanced performance (Fraga et al., 2017). (3) CHO supplementation may potentially mitigate the suppression of the hypothalamic–pituitary–gonadal/adrenal axis, resulting in reduced catabolic stress and cortisol levels (Gryaznykh et al., 2021), thereby improving running performance.

The form and concentration of CHO supplementation can influence its impact on exercise performance. In most of studies the amount of carbohydrate consumed was ~30–60 g/h in the form of a 6%–7% CHO solution comprised of sucrose, glucose, and/or maltodextrin (Baker et al., 2015). However, more recent evidence suggests that simultaneously ingesting carbohydrates from multiple sources (e.g., glucose and fructose) may increase oxidation capacity by up to ~75% (Close et al., 2016). Natural products, such as honey contain mix sources of sugar (glucose ~30–35% and fructose ~35–40%) (Hills et al., 2019), can be used as ergogenic aids to either replace or minimize the reliance on synthetic compounds for managing exercise-induced fatigue. In recent years, there has been a growing literatures toward using Dates (Phoenix dactylifera Linn). This fruits are rich in various bioactive compounds and provide a wide array of macro- and micronutrients known for their potent bioactive properties (Alu'datt et al., 2025; Barakat & Alfheeaid, 2023). These attributes make dates a promising candidate for the development of functional energy bars (Barakat & Alfheeaid, 2023). Moreover, dates and their processed forms are a substantial source of glucose energy, with a glucose content, mostly in the form of sucrose, ranging between 72% and 88%. As ripening progresses, the sucrose is hydrolyzed into reduced sugars such as glucose and fructose (Habib et al., 2014). This high glucose content plays a crucial role in preventing energy deficits that may arise from strenuous physical activity and has the potential to enhance athletic performance (Ibrahim et al., 2021). In a previous animal study, Piyarom date extract exhibited anti-fatigue properties, suggesting its potential as a functional ingredient in beverages or snacks designed to counteract fatigue-related issues (Kadum et al., 2021). Additionally, the inherent sweetness and flavor of date extract could potentially satisfy the brain's reward center. This study examined the anti-fatigue and performance-enhancing effects of date extract, specifically examining its impact on intense cycling activities. Our hypothesis was that date extract ingestion would delay the onset of fatigue and improve performance during high-intensity cycling exercises. Given the widespread use and relevance of ergogenic supplements in cycling, this study aimed to provide valuable insights for athletes, trainers, and coaches aiming to understand the potential benefits of natural products, such as date extract, on cycling performance.

Materials and methods

Eight trained inline skaters, with an average age of 19.13 (SD 0.35) years, height of 1.71 (SD 0.04) m, body weight of 58.83 (SD 5.86) kg, and body mass index (BMI) of 20.27 (SD 2.42) kg/m², participated in this study. To be eligible, participants had to meet the following inclusion criteria: healthy males aged 18–21 years with a skating regimen of at least three days per week, exceeding 1.5 h per session, and involvement in regular competitions for at least the past year. Individuals who smoked, demonstrated poor tolerance to the treatment during familiarization sessions, or had recent injuries were excluded from the study. Prior to participation, all potential participants underwent an evaluation to identify any contraindications to exercise. They were provided with detailed information about the study's purpose and potential risks and provided written informed consent. Ethical approval was obtained from the Ethical Committee of the Faculty of Medicine at Universitas Airlangga (Reference Number: 75/EC/KEPK/FKUA/2024). Table 1 presents the characteristics of the study participants.

Table 1. Characteristics of subjects

	Mean ± SD
Age, years	19.13 ± 0.35
Body weight, kg	58.83 ± 5.86
Height, m	1.71 ± 0.04
BMI, kg/m^2	20.27 ± 2.42
Body composition	
Fat mass, kg	5.80 ± 3.39
Fat-free mass, kg	53.03 ± 3.45
Fat mass index, kg/m^2	2.01 ± 1.19
Fat-free mass index, kg/m^2	18.23 ± 1.51
Skeletal muscle mass	
Total, kg	25.03 ± 2.32
Right arm, kg	1.48 ± 0.18
Left arm, kg	1.33 ± 0.17
Right leg, kg	5.77 ±0.48
Left leg, kg	5.69 ± 0.38
Torso, kg	10.80 ± 1.38
Total body water, L	38.15 ± 2.83
Extracellular water, L	15.07 ± 103
ECW/TBW, %	39.53 ± 1.17
Visceral adipose tissue, L	0.81 ± 0.14
VO_2max absolute, L/min	3.27 ± 0.38
VO_2max relative, mL/kg/min	52.95 ± 8.05
Maximal power, W/kg	5.41 ± 0.80

Note: extracellular water (ECW); total body water (TBW)

The study used a randomized, two-way crossover design, as depicted in Figure 1. A two-day interval separated the experimental trials (Figure 1). Each trial was performed at a consistent time of day (starting between 1:30 and 3:30 PM) to minimize the influence of circadian variation. Participants completed two experimental exercise trials in a randomized, counterbalanced order. (1) In the control group, participants consumed a placebo (Stevia, Beeru, Natural Farm Indonesia), while (2) in the intervention group, participants consumed water containing an additional 1 g/kg body weight of date extract 15 min prior to engaging in high-intensity exercise using a Wattbike Cycle Ergometer (Wattbike Ltd, Nottingham, UK).

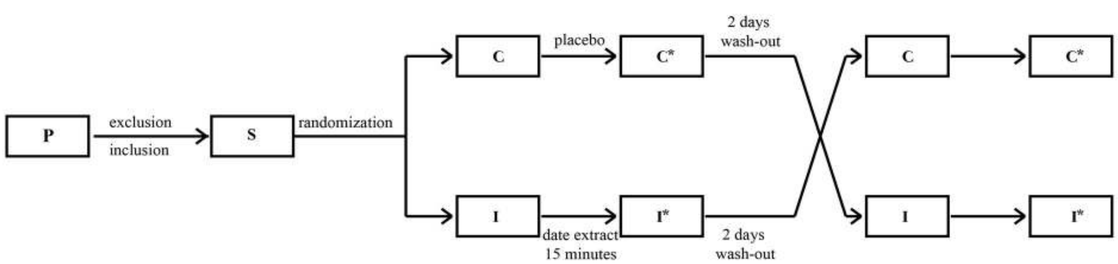

Figure 1. Experimental design

The high-intensity cycling regimen began with a 5-min warm-up at 100 W. Participants chose a pedaling frequency and gear that they could maintain during the test. Once ready, subjects cycled at a self-selected cadence that generated power appropriate to their cycling ability. The performance test began at 100 W and increased by 15 W per minute (Figure 2) until voluntary exhaustion (Kozlowski et al., 2021).

The ambient conditions were controlled at 20°C with approximately 49% relative humidity, and a fan provided standardized airflow over the cyclist. Heart rate was monitored using a heart rate monitor (Polar H10, Kempele, Finland). Performance data were recorded using the Wattbike App (Wattbike Hub version 6.4.0), which was connected to an Apple Device (iOS version 17.3) and stored during high-intensity exercise. Measured parameters included distance, average speed, and average power. Ratings of perceived exertion were recorded using the Borg Scale of Perceived Exertion at the beginning of the test and every minute during the ride (Borg, 1982).

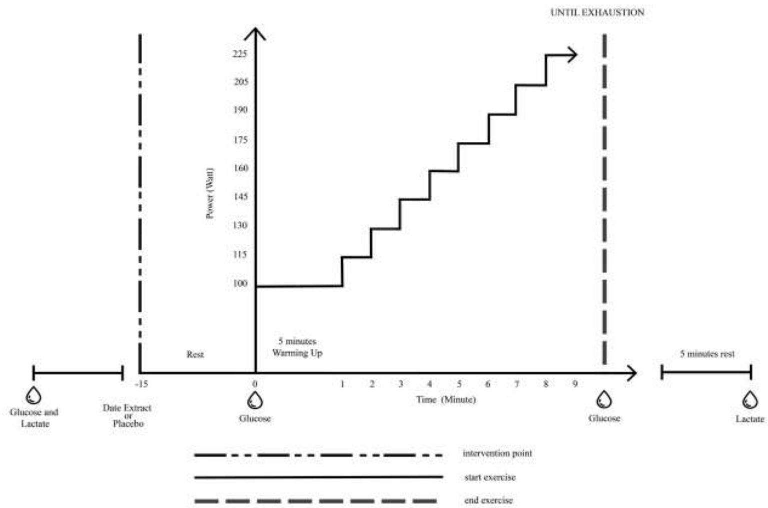

Figure 2. Timeline of date extract ingestion and exercise protocol

Date extracts were ingested 15 min before the commencement of high-intensity exercise. The dosage of date extract was 1 g/kg of body weight. The date extracts used were commercial products (Sahara, Sehat Prima Lestari, Indonesia) containing dates, glucose, fructose, and antifoam as ingredients. Water was ingested ad libitum. Blood lactate levels were measured using the Accutrend Lactate device (Sports Resource Group, Hawthorne, NY) via finger sticks, both before and 5 min after exercise. Glucose levels were assessed using the Accu-Chek device (Roche Diagnostics, Indianapolis, IN) via finger sticks before exercise, 15 min after ingesting either date extract or a placebo, and immediately after exercise.

The sample size for this study was calculated using the G*Power version 3.1 software with the F-Test Repeated Measures ANOVA (in-between interaction) formula. This formula incorporated a direct partial η^2 value of 0.186 and a power (1-β err prob) of 0.8, as reported in Kozlowski et al.'s study (Kozlowski et al., 2021). Based on these parameters, a minimum total sample size of 10 was determined to be necessary. Data analysis was performed using the Statistical Package for the Social Sciences (SPSS) software. Descriptive statistics were used to characterize the research participants and the measurement results before and after the intervention in both the control and treatment groups. Normality was assessed using the Shapiro–Wilk test (p-value > 0.05 indicating normal distribution). The homogeneity of variances was evaluated using the Levene test. For normally distributed data, a 2-way repeated-measures ANOVA was performed, followed by independent samples and paired t-tests as appropriate.

Results

Two-way repeated-measures ANOVA revealed a significant interaction effect and main effects of group and time on blood glucose levels (all $p < 0.01$). Post-hoc analysis indicated that blood glucose levels significantly increased 15 min after the date extract ingestion and remained elevated until the end of the high-intensity cycling performance (Table 1).

Blood lactate, a key indicator of fatigue during strenuous exercise, was measured at baseline and 5 min after cycling. Blood lactate levels increased at the end of exercise in both groups. However, no significant differences were observed between groups, either at baseline or after exercise (Table 2).

Table 2. Blood glucose and lactate levels before and after exercise

	Group		**P value (2-way RM ANOVA)**		
	Control	**Intervention**	**Time**	**Group**	**time*group**
Blood glucose, mg/dL					
Pre-exercise	89 + 5.40	90.38 + 12.93	<0.001	0.004	0.010
15 min after date extract/ placebo ingestion	89 + 5.24	124.63 + 25.12[ab]			
Post-exercise	124 + 17.00[c]	123.63 + 19.32			
Lactate, mmol/L					
Pre-exercise	1.99 + 0,83	2.55 + 0.39	<0.001	0.213	0.602
Post-exercise	8.67 + 1.34[b]	9.97 + 3.62[b]			

Note: Data are presented as mean ± SDs; [a] significant compared to the control group within the same group; [b]significant vs. pre-exercise within the same group; [c] significant vs. 15 min postdate extract/placebo ingestion within the same group

The findings of this study provide compelling evidence for the anti-fatigue effects of date extract during high-intensity cycling performance. Participants in the intervention group attained their maximum perceived exertion at a more advanced stage of the cycling test (Figure 3). Consistently, date extract ingestion led to improvements in cycling duration and distance. However, no significant differences were observed between groups in terms of average power or speed (Table 2).

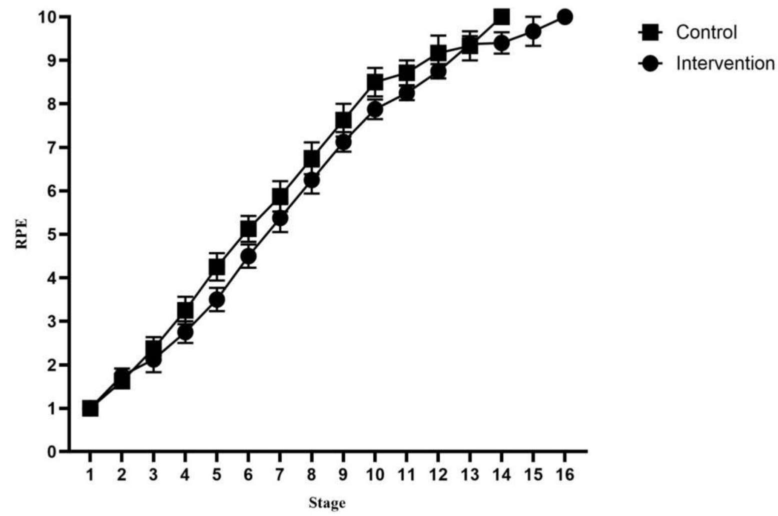

Figure 3. Rate of perceived exertion (RPE, Borg Scale 1–10) during high-intensity cycling

Table 2. High-intensity cycling performance

	Control	Intervention	Mean difference (95% CI)	P value
Time performance, s	**699.88 + 84.82**	**794.75 + 74.89**	**94.87 (9.07; 180.68)**	**0.033**
Distance, m	**6,961.3 + 1,036.7**	**8,003.72 + 784.48**	**1,042.41 (56.44; 2,028)**	**0.04**
Average power, W/kg	**2.91 + 0.29**	**3.08 + 0.29**	**0.13 (−0.09; 0.34)**	**0.237**
Average speed, km/h	**35.23 + 0.7**	**35.84 + 0.89**	**0.61 (−0.25; 1.47)**	**0.153**

Note: Data are presented as mean ± SD. s: second; m: meter; kg: kilogram; km: kilometer; h: hour; CI: confidence interval

Discussion

This study investigated the influence of date extract ingestionconsumption on performance, glucose and lactate levels, and fatigue during high-intensity cycling. The key findings of this study suggest that date extract ingestion before exercise, 1) enhances high-intensity exercise performance, 2) increases post-prandial blood glucose levels without affecting levels after exercise, and 3) prolongs the time to fatigue.

During exercise, glucose is the primary fuel source for skeletal muscles. Glycogen, broken down through glycogenolysis, provides the bulk of this energy, sustaining glycolysis for energy production. Muscle glycogen serves as the main energy source during high-intensity exercise (Flockhart & Larsen, 2024). As exercise intensity increases, circulating glucose levels rise to meet the energy demands of the working muscles. When muscles use extramuscular fuels, blood glucose levels gradually increase until exercise reaches maximal intensity (Hargreaves & Spriet, 2020; Van Loon et al., 2001). However, trained athletes exhibit distinct glucose kinetics; notably, their rate of glucose utilization is lower during intense exercise, leading to a substantial increase in plasma glucose concentration during exercise (Coggan et al., 1995). The date extract used in this study is CHO-based, containing 15.58 g of glucose per 20 g. The study revealed that date extract administration led to elevated blood glucose levels 15 min post-prandially. However, no significant differences in blood glucose levels were observed during exercise. This finding suggests that date extract administration enhances energy levels before exercise. Furthermore, the distance covered during the exercise intervention was greater than that of the control group. This improvement is attributed to increased substrate availability resulting from muscle preservation during high-intensity exercise, demonstrating the ergogenic properties of date extract.

To date, no research has investigated the effects of date extract on human performance. However, animal studies have demonstrated the potential of date extract as an ingredient in energy drinks, exhibiting effects comparable to other natural plant extracts. Date extract has been shown to enhance endurance capacity, delay fatigue, reduce blood lactate levels, and increase blood glucose levels. Moreover, lower biomarkers for muscle damage, such as creatine kinase (CK), were observed after prolonged use of date extract (Kadum et al., 2021). Another potential mechanism is that date extract may prevent excessive oxidative stress associated with fatigue resulting from high-intensity exercise training. Although animal studies have indicated that chronic supplementation of date extract does not have any toxic effects, further research in humans is warranted to establish the efficacy and safety of long-term date extract use (Kadum et al., 2021).

The degree of fatigue experienced after exercise can be assessed through various biochemical markers, including glucose, lactate, and subjective measures such as the rate of perceived exertion (RPE). Blood lactate is a critical indicator of fatigue during intense exercise and serves as a measure of existing pathology in a standard stress test (Wan et al., 2017). Lactic acid is a byproduct of glycolysis under anaerobic conditions, which is the primary metabolic pathway in muscles during exercise. Increased lactate production leads to a decrease in pH, disrupting normal metabolism and inducing fatigue (Hall & Hall, 2020). Consequently, inhibiting lactate accumulation or reducing lactate levels can have an anti-fatigue effect. The findings of this study revealed no significant differences in lactate levels between the intervention and control groups, both at baseline and after exercise. Theoretically, glucose availability during exercise can influence the metabolic pathway used for energy production, with increased glycolytic metabolism leading to greater lactic acid production (Kozlowski et al., 2021). However, similar to our findings, (Kozlowski et al., 2021) also observed no significant improvement in lactate production rate post-exercise with glucose gel ingestion. Notably, in this study, the duration of high-intensity exercise until exhaustion was considerably longer in the intervention group compared to the control group. Therefore, the lactate levels indicate that participants in both the control and intervention groups reached a similar level of exhaustion at the end of the exercise. In line with this result, we also found no significant differences in RPE scores at the end of the exercise. This finding suggests that date extract consumption delays the onset of fatigue.

Conclusions

Our study's findings indicate that consuming 1 g/kg of body weight of date extract before high-intensity cycling effectively increases post-prandial blood glucose levels and maintains them during high-intensity exercise. Furthermore, date extract ingestion enhances performance in high-intensity cycling and delays the onset of fatigue. While we did not explore the underlying mechanisms of this effect, it could potentially be mediated by the increased availability of blood glucose as a primary energy source during high-intensity exercise. Additionally, the sweetness and flavor of date extract may stimulate the reward center in the brain. However, because blood lactate levels did not differ considerably compared to the control group, it appears that all participants reached a similar level of exhaustion. Assessing lactate kinetics after date extract ingestion is crucial in future research to gain a deeper understanding of its effects. Given its potential, date extract is promising as an ingredient in energy gels or bars, offering a practical energy source for high-intensity cycling. Further studies should explore the application of date extract in other types of high-intensity exercise to strengthen the robustness and generalizability of these findings.

Conflicts of interest - The authors declare no conflicts of interest.

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