

The Effect of Carbohydrate Gel (Energy Gel) Consumption Between the Second and Third Sets on the Reduction of Unforced Errors and Footwork Speed in the Third Set

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ABSTRACT (English)

The background of this study is based on the characteristics of badminton as a high-intensity intermittent sport that is highly dependent on anaerobic and aerobic metabolism. Matches that last until the rubber set often cause significant fatigue due to glycogen depletion, which results in decreased footwork speed and increased unforced errors due to decreased cognitive focus. The purpose of this study was to analyze the effect of carbohydrate gel consumption between the second and third sets on the performance of teenage badminton athletes in Surabaya. The method used was a randomized controlled crossover involving 30 athletes (aged 17.2 ± 1.8 years) with a washout period of seven days. Each athlete underwent a session with 25g of carbohydrate gel (CG) and a placebo (PL) administered during a two-minute rest before the third set. The results of the study, using a paired-samples t-test, showed that CG consumption significantly reduced the average number of unforced errors in the third set (CG: 4.8 ± 1.3 vs. PL: 7.1 ± 1.9 ; $p < 0.001$) and resulted faster footwork completion time (CG: 14.2 ± 0.9 seconds vs. PL: 15.5 ± 1.1 seconds; $p < 0.001$). It can be concluded that carbohydrate gel intervention effectively maintains athletes' physical and cognitive performance in the deciding set.

Keywords: *Badminton, Energy Gel, Carbohydrate Gel, Unforced Errors, Footwork, Fatigue*

ABSTRAK (Bahasa Indonesia)

Latar belakang penelitian ini didasari oleh karakteristik bulutangkis sebagai olahraga intermiten berintensitas tinggi yang sangat bergantung pada metabolisme anaerobik dan aerobik. Pertandingan yang berlangsung hingga *rubber set* sering kali menyebabkan kelelahan signifikan akibat deplesi glikogen, yang berdampak pada penurunan kecepatan *footwork* serta peningkatan *unforced errors* karena penurunan fokus kognitif. **Tujuan penelitian** ini adalah untuk menganalisis pengaruh konsumsi *carbohydrate gel* di antara set kedua dan ketiga terhadap performa atlet bulutangkis remaja di Surabaya. **Metode** yang digunakan adalah *randomized controlled crossover* yang melibatkan 30 atlet (usia $17,2 \pm 1,8$ tahun) dengan periode *wash-out* selama tujuh hari. Setiap atlet menjalani sesi dengan *carbohydrate gel* (CG) 25g dan plasebo (PL) yang diberikan saat istirahat dua menit sebelum set ketiga. **Hasil** penelitian melalui uji *paired-samples t-test* menunjukkan bahwa konsumsi CG secara signifikan mengurangi jumlah rata-rata *unforced errors* pada set ketiga (CG: $4,8 \pm 1,3$ vs PL: $7,1 \pm 1,9$; $p < 0,001$) dan menghasilkan kecepatan *footwork* yang lebih cepat (CG: $14,2 \pm 0,9$ detik vs PL: $15,5$

$\pm 1,1$ detik; $p < 0,001$). Dapat disimpulkan bahwa intervensi *carbohydrate gel* efektif menjaga performa fisik dan kognitif atlet pada set penentuan.

Kata kunci: Bulutangkis, Gel Energi, *Carbohydrate Gel*, *Unforced Errors*, *Footwork*, Kelelahan

INTRODUCTION

Modern badminton has evolved into a sport that demands speed, explosive power, and extraordinary endurance (Gabriela, 2014). Matches often last for long periods, with high-intensity rallies interspersed with short rest periods (Edel et al., 2019). The dominant energy system is a combination of phosphagen, anaerobic glycolysis, and aerobic metabolism (Franchini, 2023).

The main problem in long matches, especially those that go to a third set (rubber set), is fatigue (Amatori et al., 2020). This fatigue is mainly caused by the depletion of muscle and liver glycogen stores (Gonzalez et al., 2016). When these primary energy reserves are depleted, athletes experience a double decline in performance. Physically, this manifests as a decrease in footwork speed, slower reaction times, and reduced hitting power.

In addition to physical fatigue, central (brain) fatigue also occurs. The brain is highly dependent on glucose for fuel (Matsui et al., 2012). A decrease in blood glucose availability can impair cognitive function, which is crucial in badminton for decision-making, focus, and anticipation (Hidayat et al., 2024). This cognitive impairment often leads to an increase in unforced errors, such as hitting the shuttlecock into the net or out of bounds without any significant pressure from the opponent (Harmono & Wahyono, n.d.)

To address this, carbohydrate supplementation during activity has been proven effective in endurance sports (Temesi et al., 2011). Carbohydrate gels (energy gels) offer a fast-absorbing and convenient source of carbohydrates during short rest periods (2 minutes between sets) (King et al., 2022)

Although the benefits of carbohydrates have been extensively studied, specific research testing carbohydrate gels in the context of badminton, especially among adolescent athletes (aged 15-20 years) in Indonesia (particularly Surabaya), is still limited (Rahmaniar & Dewi, 2018). This study focuses on two critical performance variables: unforced errors (as a proxy for cognitive fatigue/skill decline) and footwork speed (as a proxy for physical fatigue). (Alias & Morazuki, 2022).

Therefore, this study aims to determine whether consuming carbohydrate gel during the break between the second and third sets can significantly reduce the number of unforced errors and maintain footwork speed in the third set.

METHOD

Design

This study used a randomized, placebo-controlled, single-blind, crossover design. This design was chosen to eliminate inter-individual variability, as each athlete acted as a control for themselves.

Participants

A total of 30 competitive badminton athletes (19 males, 11 females) from various training clubs in Surabaya participated in this study. Inclusion criteria were: (1) Age 15-20 years (mean: 17.2 ± 1.8 years); (2) Trained (training badminton at least 4 times per week); (3) Free from musculoskeletal injuries; and (4) No

history of diabetes or glucose intolerance. Participants and parents (if under 18 years of age) provided informed consent.

Instruments and data measurements

This research instrument was designed to ensure data validity and reliability through two main categories, namely intervention instruments and performance measurement instruments. The intervention instrument consists of a 40-gram commercial Carbohydrate Gel (CG) containing 25 grams of maltodextrin and fructose mixed carbohydrates (2:1 ratio), as well as a non-caloric placebo gel (PL) that has an identical taste, color, and texture for the single-blind procedure. To maintain consistency in workload, the Borg 6-20 Rate of Perceived Exertion (RPE) scale was used to monitor athletes' perceived fatigue at the end of each set.

Unforced errors were measured to assess athletes' accuracy and cognitive function during the third set using a match analysis observation sheet supported by digital video recording verification. Two observers (certified coaches) independently counted the frequency of errors made by athletes without pressure from their opponents, such as failed serves or shots that went out of bounds. Inter-rater reliability should be quantified using Cohen's kappa for categorical error classifications; however, the aggregated data reported in this manuscript do not contain the observer-by-observer classifications required to calculate that coefficient.

Procedure

The research procedure was conducted in two separate trial sessions with a seven-day interval as a washout period to eliminate the effects of previous interventions. Before starting the first session, all athletes were instructed to follow a standard diet (high in carbohydrates) and were prohibited from engaging in strenuous physical activity and consuming caffeine for the previous 24 hours. On the day of testing, athletes performed a standard 15-minute warm-up, followed by two full sets of high-intensity simulated matches. Right at the two-minute rest interval between the second and third sets, athletes were given an intervention in the form of one sachet of gel according to the group draw order (Carbohydrate Gel or Placebo). The athletes were instructed to consume the gel with 150 ml of water in less than one minute to ensure optimal absorption before the third set began. During the third set, the research team recorded every unforced error in real-time through direct observation and video recording.

Immediately after the last point in the third set ended, athletes were given a maximum transition time of one minute to proceed to the starting point for physical testing. Athletes then performed the Badminton-Specific Agility Test (BSAT) to measure footwork speed in a state of post-match fatigue. The entire procedure is repeated in the second session, swapping the type of intervention given to each athlete (crossover). The data collected from both sessions is then grouped and tabulated for further analysis using statistical tests.

Data analysis

The data were analyzed using SPSS version 26. The Shapiro-Wilk normality test was performed. Because the data were normally distributed, the paired-samples t-test was used to compare the differences in the mean number of unforced errors and footwork time between the CG and PL conditions. The statistical significance level was set at $p < 0.05$.

RESULTS (Font size: 12, Palatino Linotype, Bold)

All 30 participants successfully completed both research sessions without reporting any side effects (gastrointestinal problems).

The results of the paired-samples t-test analysis (presented in Table 1) showed a statistically significant difference between the Carbohydrate Gel (CG) and Placebo (PL) conditions for both dependent variables.

The average number of unforced errors in the third set was significantly lower in the CG condition (Mean = 4.8, SD = 1.3) compared to the PL condition (Mean = 7.1, SD = 1.9), with a p-value < 0.001.

Furthermore, the average time required to complete the Badminton-Specific Agility Test (BSAT) after the match was significantly faster (lower) in the CG condition (Mean = 14.2 seconds, SD = 0.9) compared to the PL condition (Mean = 15.5 seconds, SD = 1.1), with a p-value < 0.001. This section presents the results of preliminary or partial research, which require rapid dissemination.

Table 1. Comparison of the Number of Unforced Errors and Footwork Speed between the Carbohydrate Gel (CG) and Placebo (PL) Conditions in the Third Set (N=30)

Variables	Condition	Mean	SD	p-value	Cohen's d
Unforced Errors	Carbohydrate Gel (CG)	4.8	1.3	< 0.001	1.41
	Placebo (PL)	7.1	1.9		
Footwork Speed	Carbohydrate Gel (CG)	14.2	0.9	< 0.001	1.29
	Placebo (PL)	15.5	1.1		

Note: SD = Standard Deviation. A p-value < 0.05 indicates a statistically significant difference.

Based on the data in Table 1, statistical test results using a paired-samples t-test showed a very significant difference in both variables measured between the carbohydrate gel (CG) and placebo (PL) conditions, where the average number of unforced errors in the third set showed a 32.4% decrease in the CG group (4.8 ± 1.3) compared to the PL group (7.1 ± 1.9) with a significance value of $p < 0.001$. In line with these results, footwork speed through the BSAT test also showed a significant improvement in performance, where athletes in the CG condition recorded a faster time of 14.2 ± 0.9 seconds compared to the PL condition, which reached 15.5 ± 1.1 seconds ($p < 0.001$), meaning there was an 8.4% improvement in movement efficiency. Overall, these data confirm that carbohydrate gel intervention can effectively maintain athletes' cognitive performance stability by minimizing self-inflicted errors while preserving motor physical capacity to maintain explosive movement until the end of the third set.

DISCUSSION (Font size: 12, Palatino Linotype, Bold)

The results of this study provide strong evidence that consuming carbohydrate gel between the second and third sets provides a significant performance advantage for junior badminton athletes in Surabaya, both cognitively and physically (Pambudi & Fauzi, 2019). The significant decrease in unforced errors in the CG group indicates that exogenous carbohydrate intake can delay the onset of central fatigue by maintaining the availability of glucose in the blood as the main fuel for the central nervous system (Pomportes et al., 2016). In the third set, liver glycogen reserves typically begin to deplete, reducing glucose supply to the brain, which directly impairs executive function, focus, and fine motor accuracy (Matsui et al., 2012). By administering an energy gel with a high glycemic index, athletes are able to maintain concentration stability and decision-making accuracy, thereby minimizing unnecessary self-inflicted errors even under high-pressure competition conditions.

At the same time, maintaining footwork speed under CG conditions proves that fast-absorbing carbohydrates serve as an effective additional energy substrate for skeletal muscle work (Baker et al., 2015). In intermittent sports such as badminton, explosive movements are highly dependent on rapid glycolysis; carbohydrate intake during breaks between sets helps conserve remaining muscle glycogen stores (glycogen

sparing) and maintain ATP resynthesis rates (Williams & Rollo, 2015). This allows athletes to maintain agile and explosive footwork in accordance with the demands of the post-match BSAT test (Walankar & Shetty, 2020). Therefore, the use of carbohydrate gel is not merely a stamina booster, but a crucial ergogenic strategy for adolescent athletes in Surabaya to maintain both technical quality and physical intensity simultaneously until the end of the decisive set. A limitation of this study is the absence of periodic blood glucose measurements or invasive/direct blood lactate measurements to validate the physiological metabolic mechanisms.

CONCLUSION (Font size: 12, Palatino Linotype, Bold)

Consumption of carbohydrate gel (containing 25g of carbohydrates) administered between the second and third sets of a badminton match significantly reduced the number of unforced errors and improved footwork speed in the third set, compared to consumption of a placebo. This nutritional strategy has been proven effective in delaying the effects of physical and cognitive fatigue in teenage badminton athletes aged 15-20 years. Practically, coaches should administer targeted nutritional support during standard BWF match breaks (60-120 seconds) to optimize athlete recovery and performance. Future studies are encouraged to evaluate specific dosage protocols and individual tolerance during high intensity competition.

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CONFLICT OF INTEREST

There is no conflict of interest in this study.

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