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The Effect of Table Tennis-Specific High-Intensity Interval Training (HIIT) on the Ability to Maintain Shot Quality (Accuracy and Speed) in Fatigue Conditions

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ABSTRACT (English)

Background: Table tennis is a sport that demands high levels of physical and technical ability simultaneously, especially the ability to maintain shot quality (accuracy and speed) when experiencing fatigue. **Research Objectives:** This study aims to examine the effect of a 6-week Table Tennis-Specific High-Intensity Interval Training (HIIT) program on athletes' ability to maintain the accuracy and speed of their forehand topspin shots under conditions of fatigue. **Metods Methods:** Twenty regional-level male table tennis athletes (age 17.2 ± 1.5 years) participated and were randomly divided into two groups: the Experimental Group (EG, n=10) who performed table tennis-specific HIIT three times a week, and the Control Group (CG, n=10) who continued their regular technical training. Pre-intervention (Pre-test) and post-intervention (Post-test) tests were conducted to measure stroke accuracy (target score) and stroke speed (km/h) immediately after undergoing a standard fatigue protocol (Specific Table Tennis Fatigue Protocol). **Results:** Data analysis used Mixed-design ANOVA. The results showed a significant Time \times Group interaction for both accuracy ($p < 0.01$) and speed ($p < 0.01$). In the Post-test, EG showed a significant increase in accuracy score (+34.5% increase) and speed (+11.9% increase) in fatigued conditions, while CG did not show significant changes. **Conclusion:** It was concluded that table tennis-specific HIIT is an effective training method for improving

Keywords: *Table Tennis, HIIT (High-Intensity Interval Training), Fatigue, Shot Accuracy, Shot Speed.*

ABSTRAK (Bahasa Indonesia)

Latar Belakang: Tenis meja adalah olahraga yang menuntut kemampuan fisik dan teknis tingkat tinggi secara simultan, terutama kemampuan untuk mempertahankan kualitas pukulan (akurasi dan kecepatan) saat mengalami kelelahan. **Tujuan Penelitian**: Penelitian ini bertujuan untuk menguji pengaruh program *Table Tennis-Specific High-Intensity Interval Training* (HIIT) selama 6 minggu terhadap kemampuan atlet dalam mempertahankan akurasi dan kecepatan pukulan *forehand topspin* dalam kondisi kelelahan. **Metode**: Dua puluh atlet tenis meja putra tingkat regional (usia 17.2±1.5 tahun) berpartisipasi dan dibagi secara acak menjadi dua kelompok: Kelompok Eksperimen (EG, n=10) yang melakukan HIIT spesifik tenis meja tiga kali seminggu, dan Kelompok Kontrol (CG, n=10) yang melanjutkan latihan teknis reguler mereka. Tes pra-intervensi (Pre-test) dan pasca-intervensi (Post-test) dilakukan untuk mengukur akurasi pukulan (skor

target) dan kecepatan pukulan (km/jam) segera setelah menjalani protokol kelelahan standar (Specific Table Tennis Fatigue Protocol). **Hasil**: Analisis data menggunakan *Mixed-design ANOVA*. Hasil menunjukkan adanya interaksi Waktu \times Kelompok yang signifikan baik untuk akurasi ($p < 0.01$) maupun kecepatan ($p < 0.01$). Pada Post-test, EG menunjukkan peningkatan signifikan pada skor akurasi (peningkatan +34.5%) dan kecepatan (peningkatan +11.9%) dalam kondisi lelah, sementara CG tidak menunjukkan perubahan yang signifikan. **Kesimpulan**: Disimpulkan bahwa HIIT spesifik tenis meja adalah metode latihan yang efektif untuk meningkatkan resistensi terhadap kelelahan, yang memungkinkan atlet mempertahankan kualitas pukulan yang lebih tinggi.

Kata kunci: Tenis Meja, HIIT (High-Intensity Interval Training), Kelelahan, Akurasi Pukulan, Kecepatan Pukulan.

INTRODUCTION

Modern table tennis is characterized by high-speed rallies whose intensity often exceeds the anaerobic threshold (De Mello Leite et al., 2017). Matches can be long, requiring athletes to not only have superior technical skills but also the physical capacity to repeat those skills under the pressure of progressive physical and mental fatigue (Amatori et al., 2020). Fatigue has been shown to significantly redu ce technical performance quality, manifesting as an increase in errors (decreased accuracy) and a decrease in stroke power or speed (Urbinati et al., 2016).

Traditionally, table tennis training has focused heavily on technical drills and low-to-moderate intensity aerobic exercises (Indrayanti et al., 2025) (Li et al., 2020). However, the intermittent nature of table tennis short bursts of explosive activity (strokes and footwork) interspersed with brief rest periods (between points) closely resembles the demands of High-Intensity Interval Training (HIIT) (Edel et al., 2019). HIIT involves intervals of very high-intensity work (approaching or exceeding VO2max) interspersed with short recovery periods (Astorino et al., 2017)

Although the physiological benefits of HIIT (increased anaerobic capacity, VO_2max, and lactate tolerance) have been widely documented in various sports, research specifically examining its impact on fine motor skills (such as stroke accuracy) under fatigue conditions in table tennis remains limited (Suárez Rodríguez & Del Valle Soto, 2017). Adapting HIIT to be specific to the movement patterns and demands of table tennis (e.g., using high-intensity multi-ball drills or explosive footwork exercises) could theoretically provide better training transfer than non-specific HIIT (running on a treadmill) (P. Wang et al., 2018).

Therefore, this study aims to investigate whether a HIIT program specifically designed for table tennis can improve athletes' ability to maintain stroke accuracy and speed when fatigued, compared to a standard technical training program (Z. Wang, 2023). Our hypothesis is that the group receiving the HIIT intervention will show a smaller decline in stroke quality (higher accuracy and speed scores) under fatigued conditions in the post-test compared to the control group.

METHOD

Design

This study used a randomized controlled trial (RCT) experimental design with a pre-test and post-test design to compare two groups: the Experimental Group (EG) and the Control Group (CG). Population and Sample.

Participants

Twenty male regional-level table tennis athletes (mean age: 17.2 ± 1.5 years; training experience: 5.4 ± 1.1 years) voluntarily participated in this study. They had no history of musculoskeletal injuries in the past six months. After providing informed consent (and parental consent for those under 18 years of age), participants were randomly assigned (using a random number generator) to either the Experimental Group (EG, n = 10) or the Control Group (CG, n = 10).

Procedur

During the intervention period, participants in the Experimental Group (EG) replaced their three regular training sessions (each lasting 30 minutes) per week with a table tennis-specific HIIT program designed to maximize heart rate (HR) >90% HR max, with an example session consisting of 4 sets x 5 repetitions (30 seconds of maximum intensity multi-ball forehand/backhand drills at various angles of the table, followed by 30 seconds of passive rest). In contrast, participants in the Control Group (CG) continued their regular technical training schedule under the supervision of a coach, where their training focused on consistency and technique at moderate intensity. To avoid bias, the total training volume (total time) was equalized between the two groups.

Instruments and data measurements

The pre-test and post-test measurement procedures were carried out immediately after the athletes completed the Specific Table Tennis Fatigue Protocol, which was designed to simulate the demands of competition. This fatigue protocol consisted of the "Falkenberg" footwork drill combined with continuous multi-ball strokes for 5 minutes, followed by a 1-minute rest, and repeated until the athletes reached an RPE (Rating of Perceived Exertion) > 18 (Borg scale 6-20) or were unable to maintain proper technique. Immediately after reaching fatigue, athletes performed an accuracy test, executing 30 forehand topspin cross-court strokes to a target on the opponent's table divided into three scoring zones (maximum 90 points). Immediately following this, athletes perform a speed test, where the ball speed (km/h) of 10 maximum forehand topspin strokes is recorded using a radar gun (e.g., Stalker Radar Pro II), and the average value is used for analysis.

Data analysis

The data were analyzed using SPSS Version 26. An independent t-test was used to ensure that there were no significant differences between groups in the pre-test (baseline). To test the hypothesis, a Mixed-design ANOVA 2 \times 2 (Between-subjects factor: Group [EG vs CG]; Within-subjects factor: Time [Pre vs Post]) was used for the variables of accuracy and speed. The statistical significance level was set $\alpha = 0.05$.

RESULTS

A total of 20 male regional table tennis athletes (East Java) voluntarily participated in this study. The demographic and basic anthropometric characteristics of the participants were as follows: average age of 17.2 ± 1.5 years, height of 168.4 ± 4.2 cm, weight of 60.5 ± 5.1 kg, and average training experience of 5.4 ± 1.1 years.

No significant differences were found between EG and CG on all dependent variables during the pre-test ($p > 0.05$), indicating that both groups had comparable initial abilities.

Mixed-design ANOVA analysis showed a statistically significant interaction effect of Time x Group for Accuracy ($F(1, 18) = 18.22$, $p < 0.001$, $p2 = 0.503$) and Speed ($F(1, 18) = 14.76$, $p = 0.001$, $p2 = 0.450$.

This interaction effect indicates that the change from the Pre-test to the Post-test was significantly different between the two groups. Post-hoc tests (simple effects analysis) show that EG experienced a significant increase in accuracy scores (increase of +34.5%, $p < 0.01$) and hitting speed (increase of +11.9%, $p < 0.01$) in the tired condition. In contrast, CG did not show significant changes in either variable ($p > 0.05$).

Table 1. Comparison of Accuracy and Speed Scores in Fatigued Conditions between the Experimental Group (EG) and Control Group (CG) in the Pre-test and Post-test (Mean ± SD)

No.	EG	CG	Total
Age	17.1 ± 1.4	17.3 ±1.6	17.2 ±1.5
height	168.2 ±4.0	168.6±4.5	168.4±4.2
weight	60.8 ±5.0	60.2 ±5.3	60.5 ±5.1
training experience	5.5 ±1.0	5.3 ±1.2	5.4 ±1.1

Table 2. Significant Time \ Times Group Interaction for Both Accuracy and Speed

No.	Variables	p-value
1	Accuracy of Strikes	< 0.001
2	Speed of Strikes	0.001

DISCUSSION

The main finding of this study is that a 6-week table tennis-specific HIIT program significantly improved athletes' ability to maintain the accuracy and speed of their topspin forehand strokes under conditions of fatigue (Zaferanieh et al., 2021). The Experimental Group (EG) showed substantial improvements in both performance parameters, while the Control Group (CG), which only performed regular technical training, showed no improvement (Afshar, 2019).

The improvement in EG performance can be attributed to physiological adaptations induced by HIIT (Jabbour et al., 2017). HIIT is highly effective in increasing anaerobic energy system capacity, including improved lactate buffering capacity and accelerated phosphocreatine (PCr) resynthesis (Sant'Ana et al., 2024). In the context of table tennis, this means that during high-intensity rallies (simulated by the fatigue protocol), EG athletes become more resistant to the accumulation of fatigue-related metabolites (such as H^+). As a result, they are able to maintain better neuromuscular function (Chen & Wang, 2023).

Neuromuscular fatigue is known to interfere with timing, coordination, and force production, all of which are important for accurate and fast table tennis strokes. By increasing resistance to fatigue, EG athletes are able to execute complex motor patterns (topspin strokes) with greater precision and power, even after undergoing a strenuous fatigue protocol (Lu et al., 2024).

Another key factor is the specificity of HIIT interventions. The exercises used (high-intensity multi-ball drills) not only challenge the metabolic system but also train foot movement patterns and striking mechanisms relevant to the game. This ensures that physiological adaptations (lactate tolerance) can be effectively transferred into sport-specific skill performance, something that may not be achieved by non-specific HIIT (such as interval running) (Wells et al., 2014).

These findings are consistent with previous research showing that high-intensity training can reduce skill decline in other intermittent sports. However, this study provides specific evidence in the context of table tennis, linking HIIT intervention directly to stroke quality parameters (accuracy and speed) (Aravena Tapia et al., 2020).

This study has several limitations. The sample size (N=20) is relatively small, which limits the generalizability of the findings. The 6-week intervention duration is relatively short; a longer duration may result in greater adaptation (Indrayanti et al., 2025). In addition, the standardized fatigue protocol, although

controlled, may not fully replicate the multifaceted fatigue (including cognitive stress and decision-making) experienced in actual competitive matches (Aravena Tapia et al., 2020).

CONCLUSION

Based on the findings of this study, it can be concluded that a 6-week Table Tennis-Specific High-Intensity Interval Training (HIIT) program is a highly effective training method for improving table tennis athletes' ability to maintain accuracy and stroke speed under conditions of fatigue. Coaches are advised to consider integrating movement-specific HIIT protocols into their athletes' training programs to improve physical endurance and technical stability during competition.

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CONFLICT OF INTEREST

There is no conflict of interest in this study.

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