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Effect Of Badminton Sport in Improving Heart Rate Variability and Body Composition of Overweight and Obese Amateur Badminton Players – A Randomized Control Trial

Efecto del bádminton en la mejora de la variabilidad de la frecuencia cardíaca y la composición corporal de jugadores aficionados con sobrepeso y obesidad: ensayo controlado aleatorio

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Abstract

Regular physical exercise enhances autonomic function in obese individuals, as indicated by heart rate variability (HRV). While badminton, a high-intensity interval sport, may offer similar benefits, its empirical investigation remains limited. This single-blind, randomized control trial evaluated the impact of badminton on heart rate variability (HRV) and body composition in overweight and obese (BMI between 23 and 30 kg/m2) recreational players. 100 participants were randomly assigned to either a badminton intervention group or a control group. The intervention group engaged in 60-90 minutes of moderate- intensity badminton and gym-based resistance training, while the control group followed a regimen combining gym-based aerobic exercise and resistance training. Baseline and post-intervention measurements included HRV indices, total body fat percentage (TBF%), waist-hip ratio (WHR), and body mass index (BMI). Results showed significant improvements in HRV for both groups, with the intervention group exhibiting greater increases in Root Mean Square of Successive Differences (RMSSD) (41.32±10.58 to 58.06±5.57) and Standard Deviation of Normal R-R intervals (SDNN) (50.94±10.91 to 62.16±5.97) compared to the control group (RMSSD: $p = 0.026$; SDNN: $p<0.001$). Additionally, both groups experienced significant reductions in BMI and TBF%, with the intervention group showing more pronounced changes (BMI: $p<0.001$; TBF%: $p<0.001$ and WHR :$p<0.001$). The findings suggest that structured badminton training effectively enhances HRV and improves body composition in overweight and obese individuals, supporting its potential as a beneficial physical activity for this population. Future studies should explore the long-term effects of badminton on diverse populations to validate its benefits further

Keywords: *recreational sports, weight management, bmi, autonomic nerve system, hrv, badminton player, aerobic training, fat loss, weight loss and obesity.*

Resumen

El ejercicio físico regular mejora la función autonómica en personas con obesidad, tal y como indica la variabilidad de la frecuencia cardíaca (VFC). Aunque el bádminton, un deporte de alta intensidad por intervalos, puede ofrecer beneficios similares, su investigación empírica sigue siendo limitada. Este ensayo controlado aleatorio y simple ciego evaluó el impacto del bádminton en la variabilidad de la frecuencia cardíaca (VFC) y la composición corporal en jugadores recreativos con sobrepeso y obesidad (IMC entre 23 y 30 kg/m2). 100 participantes fueron asignados aleatoriamente a un grupo de intervención de bádminton o a un grupo de control. El grupo de intervención

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practicó entre 60 y 90 minutos de bádminton de intensidad moderada y entrenamiento de resistencia en el gimnasio, mientras que el grupo de control siguió un régimen que combinaba ejercicio aeróbico en el gimnasio y entrenamiento de resistencia. Las mediciones iniciales y posteriores a la intervención incluyeron índices de VFC, porcentaje de grasa corporal total (%GCT), índice cintura-cadera (ICC) e índice de masa corporal (IMC). Los resultados mostraron mejoras significativas en la VFC en ambos grupos, y el grupo de intervención presentó mayores aumentos en la media cuadrática de las diferencias sucesivas (RMSSD) (41,32 ± 10,58 a 58,06 ± 5,57) y la desviación estándar de los intervalos R-R normales (SDNN) (50,94 ± 10,91 a 62,16 ± 5,97) en comparación con el grupo de control (RMSSD: p = 0,026; SDNN: p<0,001). Además, ambos grupos experimentaron reducciones significativas en el IMC y el %GCT, con cambios más pronunciados en el grupo de intervención (IMC: p<0,001; %GT: p<0,001 y ICC :p<0,001). Los resultados sugieren que el entrenamiento estructurado de bádminton mejora eficazmente la VFC y la composición corporal en personas con sobrepeso y obesidad, lo que respalda su potencial como actividad física beneficiosa para esta población. En futuros estudios se deberían explorar los efectos a largo plazo del bádminton en diversas poblaciones para validar aún más sus beneficios.

Palabras clave: *deportes recreativos, control del peso, IMC, sistema nervioso autónomo, VFC, jugador de bádminton, entrenamiento aeróbico, pérdida de grasa, pérdida de peso y obesidad.*

INTRODUCTION

Obesity has become one of the leading health concerns worldwide, particularly after the COVID-19 pandemic. Obesity is defined as excessive accumulation or abnormal distribution of body fat that affects health (Strüven et al., 2021). Obesity is primarily diagnosed by estimating an individual's body mass index (BMI) (Strüven et al., 2021). WHO defines obesity as a BMI greater than or equal to 30 kg/m2, however, the cut-off differs with ethnicity (World Health Organization, 2020). The criteria for the Asian population to be defined as overweight is >23 to 24.9 kg/m2, and obese is >25 kg/m2 (World Health Organization, 2020).

The prevalence of overweight and obesity has dramatically increased over the last century (> 2 billion people), and it is estimated that the prevalence will double over the next decade (Rastović et al., 2019). WHO estimated that at least 2.8 million die each year as a result of being overweight or obese (World Health Organization [WHO], 2020). Obesity can be a precursor to various other illnesses and is often associated with conditions such as type 2 diabetes mellitus, cardiovascular disease, hypertension, hepatic steatosis, stroke, gallbladder issues, osteoarthritis, dyslipidemia, sleep apnea and certain types of cancer (Chung et al., 2024; Zhang et al., 2023; Rossing et al., 2024; Stedman et al., 2023; Sinha et al., 2022; Baser et al., 2024). In India, the most often associated with obesity is hypertension (Verma et al., 2024). The presence of morbidities further increases the disease burden of obesity leading to a reduction in the quality of life of an individual.

During the COVID-19 pandemic, sedentary lifestyles poor eating habits and physical inactivity were the leading risk factors for developing obesity. A WHO/Europe report showed that post the COVID-19 pandemic, there is an increased incidence of obesity among school-aged children and this was attributed predominantly to physical inactivity (WHO, 2024). The evidence warrants the need to make lifestyle modifications that can prevent and manage the rising concern of obesity.

Physical activity (PA) is a powerful modulator of cardiovascular risk associated with obesity and is one of the key factors in confronting the obesity epidemic (Perissiou et al., 2020). Correlational research in patients with obesity recommends that physical activity can benefit many essential health markers (Sinha et al., 2023). Research by Hernández- Reyes et al. showed that body fat was lower in women who exercised at moderate intensity compared to those who only ate a hypocaloric diet, but high-intensity physical activity was the most effective program for reducing body fat while maintaining muscle mass (Hernández-Reyes, 2019). This proves the need to synthesize a structured high- intensity training program that can potentially improve body composition in overweight and obese individuals.

Badminton is a racket sport for two or four individuals characterized by short-duration, high-intensity physical activity. A typical match has a rally time of 7 seconds and a rest time of 15 seconds, with an effective playing duration of 31% (Hoffmann et al., 2024). This sport is highly demanding, with an average heart rate (HR) that exceeds 90% of the player's maximum HR (Hoffmann et al., 2024). The intermittent actions throughout a game place stress on both the aerobic and anaerobic systems: 60-70% on the aerobic system and around 30% on the anaerobic system (Hoffmann et al., 2024). The unique nature of the sport brings about adaptations that benefit the overall health of an individual.

Heart rate variability (HRV) is an indicator of the autonomic nervous system of the heart (Shaffer & Ginsberg, 2017). It is measured as the beat-to-beat variations between two successive heartbeats. Higher HRV indicates a more balanced system and is generally regarded as good (Shaffer & Ginsberg, 2017). It is often considered a significant marker of the physiological status of the body (Shaffer & Ginsberg, 2017). Research has demonstrated an inverse association between obesity and HRV with lower HRV values being obtained from obese individuals (Strüven et al., 2021). Additionally, inverse relationships were found between vagal modulation and high body mass, waist

circumference, and body fat percentage (Strüven et al., 2021). Measuring HRV is also essential to evaluate the physiological effect of weight loss on the overall health of an individual.

Existing research has consistently demonstrated the benefits of physical activity in improving body composition and cardiovascular health among overweight and obese individuals (Perissiou et al, 2020; Lin et al., 2022; O'Donoghue et al., 2021). Numerous studies have highlighted the role of exercise in HRV and reducing body fat, particularly through high-intensity interval training (HIIT) and aerobic exercises (Martin-Smith et al., 2020; Fisher et al., 2015; Cao et al., 2021). However, while sports like running, cycling, and swimming have been extensively studied, the specific effects of racket sports like badminton on HRV and body composition have not been thoroughly explored (Yi et al., 2024; Jakše et al., 2024; Bagot et al., 2024; Jebb et al., 1991). This study fills a critical gap by focusing on badminton, a sport that combines high-intensity bursts with periods of rest, making it uniquely suited for improving both aerobic and anaerobic fitness. The novelty of this research lies in its focus on badminton as a structured intervention, providing empirical evidence for its effectiveness in improving HRV and body composition, which has been underexplored in the context of overweight and obese populations.

This paper aims to evaluate the effect of badminton as a sport on heart rate variability and body composition of overweight and obese amateur badminton players. The findings of this study may benefit badminton players, coaches, sports trainers, sports medicine and sports science professionals, and the general public in implementing a badminton-based program for various health benefits. The results may add to physical activity guidelines and promote badminton as a potential exercise option for weight management.

MATERIALS AND METHODS

Participants

A total of 131 amateur badminton players, defined as individuals who played badminton 1-2 days per week (more than 30 minutes), were recruited for the study. Participants were aged between 30 and 55 years, had a Body Mass Index (BMI) ranging from 23.0 to 30.0 kg/m², possessed sufficient badminton skills, and had no comorbidities, injuries, or illnesses. The participants also did not routinely engage in physical activity other than playing badminton once or twice a week. Recruitment was conducted through local badminton clubs. Ethical approval was obtained from the Saveetha Medical College and Hospital Institutional Ethics Committee (Ref. No. 014/05/23/IEC/SMCH) prior to the commencement of the study. All participants were provided with an information sheet detailing the study, after which they signed informed consent forms, confirming their voluntary participation. Participants were not involved in the design, conduct, reporting, or dissemination of the research.

The study took place at the Department of Sports Medicine and Sports Sciences, Saveetha Medical College and Hospitals, SIMATS, Chennai, India, in collaboration with badminton academies in and around Chennai. Recruitment occurred from February to May 2023, and the study was conducted between June and November 2023.

Instruments

HRV was measured using the Biosignal Plux Explorer, a wireless data acquisition system equipped with sensors to record electrocardiography from which HRV was analyzed (Figure *1A, 1B*). The HRV analysis was obtained using a company integrated software that estimates HRV values. To control for confounding factors, measurements were taken early morning in a seated position maintaining a standardized environment for both groups, HRV measurements were taken between 7:00 AM and 9:00 AM under the following conditions: a semi-dark room with a temperature of 20-22° C, after 7-8 hours of quality sleep, overnight fasting, and avoiding tea, coffee, or energy drinks for at least 2 hours prior. Participants also avoided exhaustive exercise for 24 hours before the measurement. The validity of the Biosignal Plux system was established by Sousa et al. (2015). Subcutaneous fat was measured using skinfold calipers, which enabled the calculation of TBF% using the Durnin-Womersley method. The reliability and reproducibility of this method for estimating TBF% were supported by research conducted in 1974 by Durnin & Womersley. BMI was calculated using a digital weighing scale and measuring tape, while WHR was assessed using a tape measure.

Figure 1. Image A shows the heart rate variability recorder device. Image B shows the exterior of the device (Biosignals Plux)
Note: Image A displays the device used to obtain the electrocardiography recording from which heart rate variability was analyzed.

The time and intensity of exercise prescribed were in accordance with the American College of Sports Medicine's (ACSM) long-term weight loss recommendations (Donnelly et al, 2009). 200-300 minutes a week of moderate- intensity exercise is advised by the ACSM (Donnelly et al, 2009). The training intervention lasted for 12 weeks, with participants engaging in physical activity for four days per week. The badminton/intervention group (BDT) trained in an indoor court measuring 13.4 meters in length and 5.18 meters in width. The BDT group participated in one day of moderate-intensity badminton for 60-90 minutes (starting at 60 minutes and progressively increasing to 90 minutes over the course of the intervention). Additionally, they engaged in three days of moderate-intensity badminton for 30-45 minutes per day, paired with 30-45 minutes of gym- based resistance training per day. The badminton sessions were supervised by a badminton coach with at least 3 years of experience. The training consisted of moderate-intensity singles matches, divided into 15- minute quarters (14 minutes of play followed by 1 minute of rest). A session was considered complete if participants played for at least 75% of the allotted time.

The control group followed a different exercise regimen, consisting of one day of moderate-intensity aerobic activity for 60-90 minutes (starting at 60 minutes and progressively increasing to 90 minutes; 50% gym-based aerobic training and 50% badminton), along with three days of 30-45 minutes of aerobic exercise (gym-based) per day. Similar to the intervention group, the control group also participated in 30-45 minutes of gym-based resistance training per day. The exercise intensity was progressively increased by 10% per week, adjusted by modifying repetitions, sets, or exercise difficulty. Sessions were supervised by a certified gym coach with a minimum of 3 years of experience. A session was marked as complete if participants completed 75% of the prescribed exercise. Adherence was calculated based on the total number of completed sessions. Participants who missed more than three continuous sessions were excluded from the study.

Study Design

Participants were selected using a simple random sampling technique from collaborating local badminton clubs. Screening and pre-participation evaluations were rigorously conducted to ensure adherence to the inclusion criteria. Using a stratified random sampling method, participants were assigned based on gender and BMI into either the badminton group (BDT; n=55) or the control group (CNT; n=55). Routine screening occurred every 4 weeks to ensure participants were fit to continue. During the study, two participants from the BDT group and three from the CNT group withdrew due to minor injuries or illness. Additionally, three participants from the BDT group and two from the CNT group left due to time constraints (Figure 2).

Physiological assessments included HRV analysis using time and frequency domain metrics. Body composition was evaluated by measuring total body fat percentage (TBF%), BMI, and waist-hip ratio (WHR). These assessments were conducted at baseline, at the 4th and 8th weeks during the intervention, and upon completion at the 12th week. Due to the nature of the intervention, blinding the participants was not possible. However, the researchers and data analysts were blinded to the participants' group allocation.

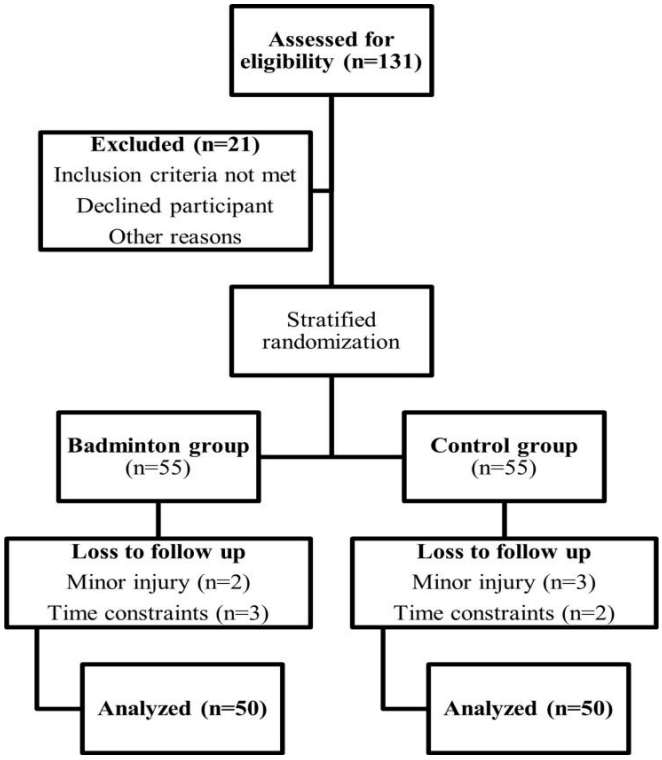

Figure 2. Study design

Note: Figure show the overall study design. Participants were assigned to badminton (BDT; n=55) or control (CNT; n=55) groups based on gender and body mass index.

During the trial, two from BDT and three from CNT withdrew due to minor injuries or illnesses, while three from BDT and two from CNT left due to time constraints.

RESULTS

Demographics

The study examined a range of variables, including age, RMSSD, SDNN, LF, HF, LF/HF, SD1/SD2, BMI, TBF, and WHR across two groups: BDT and CNT. The mean age of the total population was 41.97 +/- 6.72 (n=100). The mean age of participants in the BDT group was 41.96 years (+/- 7.15), and in the CNT group, the mean

age was 41.98 years (+/- 6.35). There were 30 males and 20 females in each group. There was no significant difference in age between the groups (p = 0.988), indicating a well-matched population in terms of age (Table 1). Independent t-test used to analyze the baseline data revealed no statistical significance between the two group's RMSSD, SDNN, HF, LF/HF, SD1/SD2, BMI, TBF% or WHR as well (Table 1)

Table 1
Comparison of baseline data of the population

Variable	Group	Mean	Std. Deviation	P value
AGE	BDT	41.9600	7.14845	.988
	CNT	41.9800	6.35189	
RMSSD	BDT	44.3400	10.25911	.064
	CNT	48.2800	10.75334	
SDNN	BDT	50.9400	10.91228	.541
	CNT	52.4000	12.80465	
LF	BDT	53.1000	10.42025	.000
	CNT	62.4000	13.58270	
HF	BDT	39.5200	14.35588	.831
	CNT	40.1200	13.61967	
LF/HF	BDT	1.6200	1.10454	.474
	CNT	1.7600	.82214	
SD1/SD2	BDT	1.1054	.40197	.611
	CNT	1.1446	.36436	
BMI	BDT	26.8146	2.06995	.806
	CNT	26.7237	1.59516	
TBF	BDT	24.7926	2.48938	.608
	CNT	24.5620	1.95541	
WHR	BDT	.9664	.08889	.740
	CNT	.9616	.04979	

Note: Independent t-test showing no statistical significance between the two group's RMSSD, SDNN, HF, LF/HF, SD1/SD2, BMI, TBF% or WHR RMSSD, Root mean square of successive differences between normal heartbeats; SDNN, Standard deviation of NN intervals; LF, Low frequency; HF, High frequency; SD1, Standard deviation 1; SD2, Standard deviation 2; BMI, Body mass index; TBF%, Total body fat percentage; WHR, Waist hip ratio.

RMSSD

The BDT group had a mean RMSSD of 44.34 +/- 10.26, while the CNT group showed a slightly higher mean of 48.28 +/- 10.75. Over 12 weeks, RMSSD increased significantly in both groups, with the BDT group showing a rise from 44.34 at baseline to 58.06 by the end of 12 weeks. In comparison, the CNT group showed a smaller increase, from 48.28 at baseline to 55.92 at the 12-week mark (Table 2; Figure 3). MANOVA revealed a signification time and time-by-group interaction (both p's < 0.001). The main effect of treatment was also found to be statistically significant (p<0.001).

Table 2
Descriptive statistics of RMSSD

GROUP	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
BDT	Baseline	44.340	1.486	41.391	47.289
	End of 12 weeks	58.060	.886	56.302	59.818
CNT	Baseline	48.280	1.486	45.331	51.229
	End of 12 weeks	55.920	.886	54.162	57.678

Note: RMSSD, Root mean square of successive differences between normal heartbeats; Std., Standard; BDT, Badminton intervention group; CNT, Control group

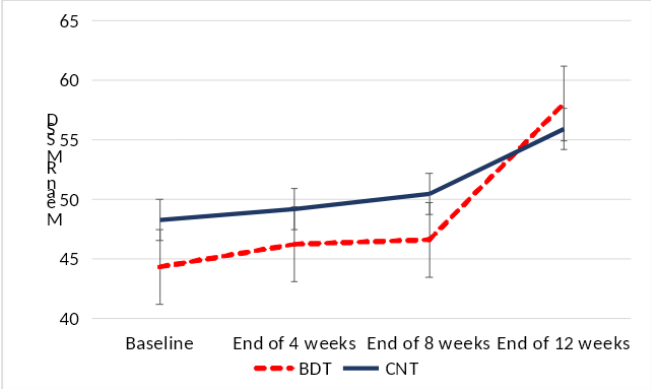

Figure 3. Mean RMSSD of BDT and CNT group across time
Note: The figure shows the mean value of RMSSD plotted against various time points.
RMSSD, Root mean square of successive differences between normal heartbeats; BDT, Badminton intervention group; CNT, Control group

SDNN

Similarly, SDNN values, which reflect overall variability in heart rate, also improved in both groups. The BDT group exhibited a baseline SDNN of 50.94, which increased to 62.16 by week 12 (Table 3). The CNT group showed a smaller improvement, increasing from 52.40 at baseline to 58.98 at the end of the study (Table 3; Figure 4). MANOVA revealed significant values for time, time-by-group, and the main effect of treatment indicating that the intervention may have had a more profound impact on heart rate variability in the BDT group (all p's <0.001).

Table 3
Descriptive statistics of SDNN

GROUP	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
BDT	Baseline	50.940	1.682	47.601	54.279
	End of 12 weeks	62.160	.915	60.345	63.975
CNT	Baseline	52.400	1.682	49.061	55.739
	End of 12 weeks	58.980	.915	57.165	60.795

Note: SDNN, Standard deviation of NN intervals; Std., Standard, BDT, Badminton intervention group; CNT, Control group

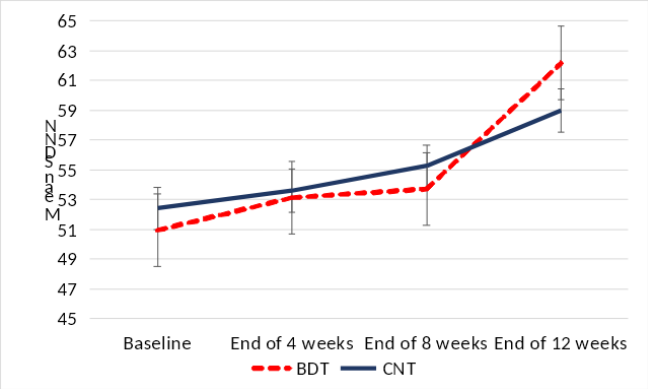

Figure 4. Mean SDNN of BDT and CNT group across time
Note: The figure shows the mean value of SDNN plotted against various time points. SDNN, Standard deviation of NN intervals; BDT, Badminton intervention group; CNT, Control group.

LF, HF and LF/HF

The LF component of heart rate variability, often linked to sympathetic activity, was significantly higher in the CNT group (62.40 +/- 13.58) compared to the BDT group (53.10 +/- 10.42) at baseline ($p < 0.001$). Over time, LF values decreased in both groups, but the difference remained significant throughout the study. HF, associated with parasympathetic activity, remained relatively stable in both groups, with minimal fluctuations.

The LF/HF ratio, an indicator of the balance between sympathetic and parasympathetic activity, showed no significant differences between the groups at baseline ($p = 0.474$). Both the BDT and CNT groups exhibited similar reductions in the LF/HF ratio over the 12 weeks, with the BDT group decreasing from 1.62 to 1.05, while the CNT group decreased from 1.76 to 1.05. MANOVA tested for time, time-by-group interaction and overall main effect of treatment indicate significant differences between the groups (all p's <0.001). These changes suggest a shift toward greater parasympathetic dominance over time, particularly in the BDT group (Table 4) (Figure 5).

Table 4
Descriptive statistics of LF/HF

GROUP	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
BDT	Baseline	1.620	.138	1.347	1.893
	End of 12 weeks	1.053	.051	.952	1.154
CNT	Baseline	1.760	.138	1.487	2.033
	End of 12 weeks	1.055	.051	.954	1.156

LF, Low frequency; HF, High frequency; Std., Standard, BDT, Badminton intervention group; CNT, Control group

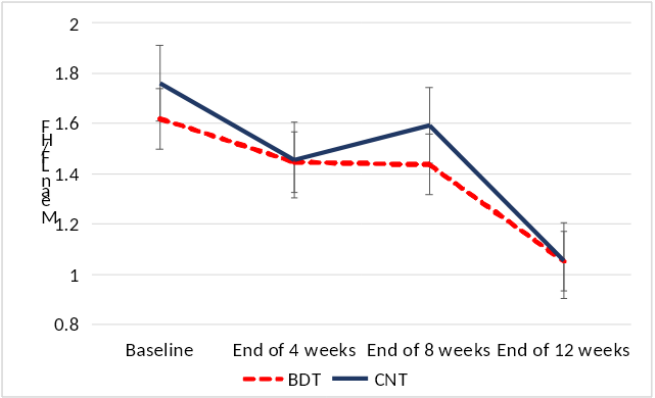

Figure 5. Mean LF/HF of BDT and CNT group across time
Note: The figure shows the mean value of LF/HF plotted against various time points. LF, Low frequency; HF, High frequency; BDT, Badminton intervention group; CNT, Control group

SD1/SD2

The SD1/SD2 ratio also showed no significant difference between the groups at baseline ($p = 0.611$). However, both groups demonstrated increases in the SD1/SD2 ratio over time, with the BDT group rising from 1.105 at baseline to 1.316 at week 12 (Table 5). The CNT group also showed an increase, though smaller in magnitude, from 1.145 to 1.179 (Table 5). These MANOVA results for time, time-by-group interaction and overall main effect of treatment indicate an overall improvement in heart rate variability, particularly in the BDT group (all p's <0.001)(Figure 6).

Table 5
Descriptive statistics of SD1/SD2

GROUP	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
BDT	Baseline	1.105	.054	.998	1.213
	End of 12 weeks	1.316	.064	1.188	1.443
CNT	Baseline	1.145	.054	1.037	1.252
	End of 12 weeks	1.179	.064	1.051	1.306

Note: SD1, Standard deviation 1; SD2, Standard deviation 2; Std., Standard, BDT, Badminton intervention group; CNT, Control group

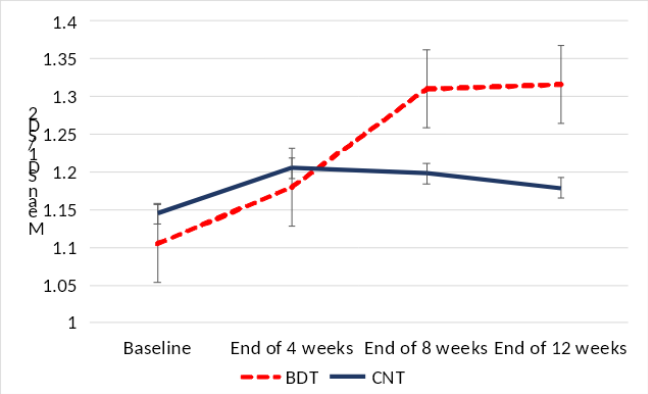

Figure 6. Mean SD1/SD2 of BDT and CNT group across time
Note: The figure shows the mean value of SD1/SD2 plotted against various time points. SD1, Standard deviation 1; SD2, Standard deviation 2; BDT, Badminton intervention group; CNT, Control group

BMI

There was no significant difference in BMI between the groups at baseline (p = 0.806). The BDT group had a mean BMI of 26.81 +/- 2.07 and the CNT group had a mean BMI of 26.72 +/- 1.60 (Table 6). Over the 12 weeks, both groups showed a reduction in BMI (both p's < 0.001), with the BDT group showing a more pronounced decrease from 26.82 at baseline to 24.27 at week 12 (Table 6). Similarly, the CNT group exhibited a reduction in BMI from 26.72 to 24.83 over the same period. Statistical analysis using MANOVA for time, time-by-group interaction and main effect of treatment showed significantly lower values in the BDT group (all p's <0.001) (Figure 7).

Table 6
Descriptive statistics of BMI

GROUP	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
BDT	Baseline	26.815	.261	26.296	27.333
	End of 12 weeks	24.274	.259	23.760	24.788
CNT	Baseline	26.724	.261	26.205	27.242
	End of 12 weeks	24.827	.259	24.312	25.341

Note: BMI, Body mass index; Std., Standard; BDT, Badminton intervention group; CNT, Control group

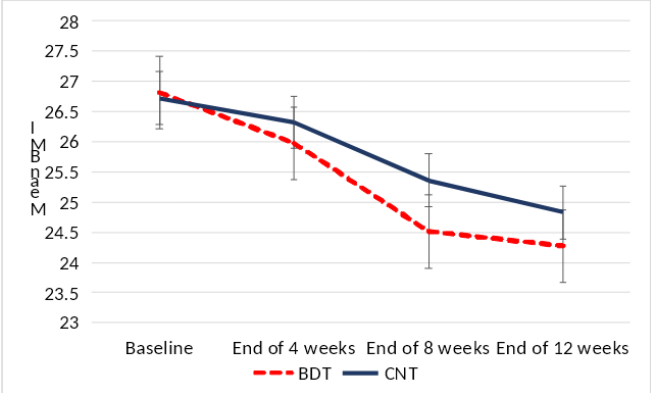

Figure 7. Mean BMI of BDT and CNT group across time
Note: The figure shows the mean value of BMI plotted against various time points. BMI, Body mass index; BDT, Badminton intervention group; CNT, Control group

TBF%

TBF% also decreased in both groups over time. The BDT group exhibited a substantial reduction from 24.79% at baseline to 20.63% by week 12 (p <0.001), while the CNT group showed a decrease from 24.56% to 21.31% (p <0.001)(Table 7). Although both groups experienced reductions in TBF, the BDT group appeared to show a more significant improvement as indexed by MOVA for time and time-by-group interaction and main effect of treatment (all p's <0.001) (Figure 8).

Table 7
Descriptive statistics of TBF%

GROUP	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
BDT	Baseline	24.793	.317	24.164	25.421
	End of 12 weeks	20.629	.336	19.961	21.296
INT	Baseline	24.562	.317	23.934	25.190
	End of 12 weeks	21.312	.336	20.645	21.980

Note: TBF%, Total body fat percentage, Std., Standard; BDT, Badminton intervention group; CNT, Control group

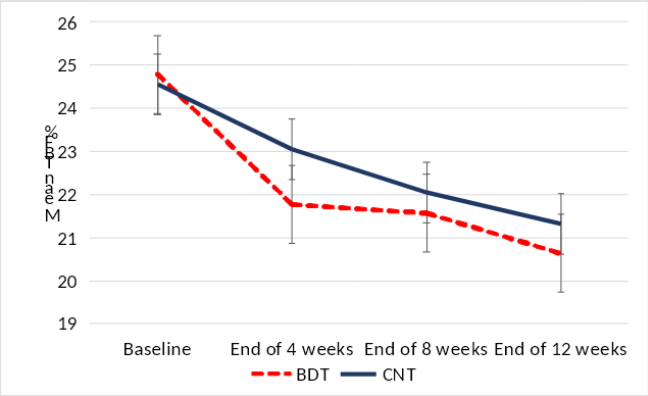

Figure 8. Mean TBF% of BDT and CNT group across time
Note: The figure shows the mean value of TBF% plotted against various time points. TBF%, Total body fat percentage; BDT, Badminton intervention group; CNT, Control group

Table 8
Descriptive statistics of WHR

GROUP	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
BDT	Baseline	.966	.010	.946	.987
	End of 4 weeks	.945	.010	.931	.964
CNT	Baseline	.962	.010	.941	.982
	End of 12 weeks	.918	.010	.898	.938

Note: WHR, Waist hip ratio; Std., Standard; BDT, Badminton intervention group; CNT, Control group

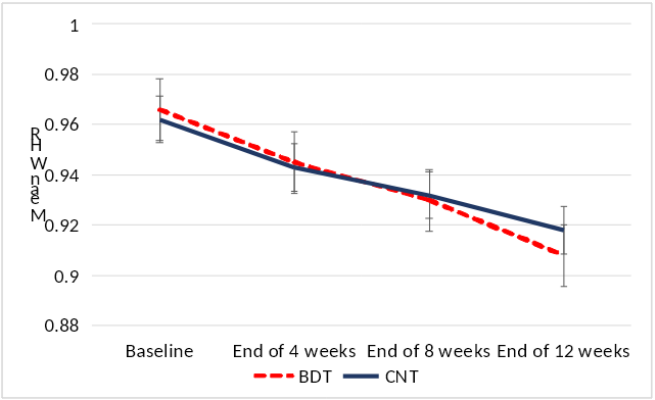

Figure 9. Mean WHR of BDT and CNT group across time
Note: The figure shows the mean value of WHR plotted against various time points. WHR, Waist hip ratio; BDT, Badminton intervention group; CNT, Control group

WHR

No significant difference was observed in WHR between the groups at baseline (p = 0.740). The BDT group had a mean WHR of 0.97, while the CNT group had a similar value of 0.96 (Table 8). Over the 12 weeks, both groups demonstrated reductions in WHR, with the BDT group decreasing from 0.97 to 0.91, and the CNT group decreasing from 0.96 to 0.92 (Table 8). Though both groups WHR significantly reduced over time, MANOVA showed greater improvements in the BDT group as indexed by time, time-by-group and overall main effect of treatment analysis (all p's <0.001) (Figure 9).

The BDT group were more compliant with the training program; The participants could complete 96.67% of all the sessions prescribed to them. Meanwhile, the CNT group had a compliance rate of 92.23%. Adherence was significantly higher in the BDT group with participants missing 1.23 +/- 0.19 sessions per month while the CNT group missed 1.94 +/- 0.34 sessions (p<0.001).

DISCUSSION

This RCT investigated the effect of badminton on HRV and body composition in overweight and obese amateur badminton players. The results demonstrated significant improvements in HRV indices and body composition among participants in both the BDT and CNT groups. However, the badminton intervention led to more pronounced improvements, particularly in HRV markers like RMSSD and SDNN, as well as BMI) and TBF%. These findings suggest that structured badminton training is effective in improving autonomic regulation and body composition among overweight individuals.

Heart Rate Variability Improvements

The increase in HRV indices, such as RMSSD and SDNN, in the BDT group is consistent with other studies that have examined the effects of physical exercise

on autonomic function. HRV reflects the balance between sympathetic and parasympathetic nervous system activity, with higher values indicating better cardiovascular health (Rastović et al., 2019; Shaffer & Ginsberg, 2017). Previous research supports the association between physical activity and improved HRV, particularly in overweight individuals (Dias et al., 2022; Guimarães et al., 2024; Godfrey et al., 2019; Dias et al., 2021; Plaza-Florido, 2019). A study by Songsorn et al. showed that HIIT increased HRV in overweight individuals, aligning with our findings on the efficacy of badminton, a high-intensity, intermittent sport, in promoting autonomic regulation (Songsorn et al., 2022).

Furthermore, this study corroborates the results of Kim et al., which demonstrated significant improvements in HRV following a 12-week circuit training intervention in obese female adults with metabolic syndrome (Kim et al., 2018). The badminton group's improvements in RMSSD and SDNN may reflect the sport's unique demands, involving rapid bursts of movement followed by short recovery periods, which likely contribute to improved vagal tone and autonomic adaptability (Hoffmann et al., 2024).

Body Composition Changes

In terms of body composition, both the badminton and control groups experienced reductions in BMI and TBF%. However, the more pronounced changes observed in the badminton group suggest that this form of intervention offers superior benefits compared to conventional aerobic and resistance training. This finding is consistent with the work of Boutcher, which emphasized that high-intensity intermittent exercises like badminton are particularly effective at reducing fat mass while preserving lean muscle mass (Boutcher, 2011). The badminton intervention in our study resulted in a significant reduction in BMI (from 26.81 to 24.27) and TBF% (from 24.79% to 20.63%), supporting the hypothesis that badminton as a sport when given as a structured intervention improves fat metabolism (Martínez-Rodríguez et al., 2021). The intermittent nature of the sport likely promotes both caloric expenditure and metabolic adaptations that support fat loss (Martínez-Rodríguez et al., 2021).

Superiority of badminton training

While both the intervention and control groups showed significant improvements, the badminton group outperformed the control group in terms of HRV and body composition improvements. This suggests that badminton, as a sport, may offer unique benefits beyond those associated with traditional forms of exercise, such as gym-based aerobic and resistance training. The moderate-intensity aerobic and resistance training performed by the control group led to notable, but comparatively smaller, changes in HRV and body composition. The greater improvements in RMSSD and SDNN in the badminton group are also indicative of enhanced parasympathetic activity, which is a critical marker of cardiovascular health (Dias et al., 2021). The control group's improvements were likely the result of increased overall physical activity and energy expenditure, but the unique structure of badminton training, involving short bursts of high-intensity activity followed by rest, appears to offer superior benefits for autonomic regulation.

Autonomic dysfunction is common in obesity, increasing cardiovascular risks and hindering recovery from physical activity. Our findings align with several recent studies that have examined the effects of different exercise modalities on HRV and body composition in overweight populations. Wewege et al. found that HIIT was more effective than moderate- intensity continuous training (MICT) at improving HRV and reducing body fat in overweight adults (Wewege et al., 2017).

Similarly, our study found that badminton, which mirrors the intermittent nature of HIIT, outperformed traditional aerobic and resistance training in improving both HRV and body composition.

Additionally, Liu et al. demonstrated that racquet sports, including badminton, were associated with greater improvements in cardiorespiratory fitness and metabolic health compared to non-specific physical activity (Liu et al., 2024). This supports the idea that the unique demands of badminton, including rapid acceleration, deceleration, and changes in direction, may be particularly effective at stimulating metabolic and autonomic adaptations that enhance health outcomes in overweight individuals. Moreover, a study by Spring et al. (2020) showed that long-term participation in sports with intermittent activity patterns, like badminton and tennis, was associated with greater reductions in cardiovascular risk factors, including visceral fat, compared to more sustained forms of exercise like jogging or cycling. The intermittent nature of badminton, as highlighted in our study, likely provides a metabolic stimulus that leads to superior reductions in fat mass and improvements in autonomic regulation.

Implications for Practice

The findings from this study have significant implications for the design of physical activity programs aimed at improving autonomic regulation and body composition in overweight and obese individuals. Given the superior improvements observed in the badminton group, sports-based interventions that combine high-intensity activity with short recovery periods should be considered as an effective alternative to traditional exercise programs for this population.

Furthermore, our study adds to the growing body of evidence that sports like badminton can be integrated into weight management programs to provide both physical and psychological benefits, as the enjoyment and

engagement associated with playing a sport may enhance adherence to physical activity recommendations.

Limitations and Future Research

While this study provides valuable insights into the benefits of badminton for overweight and obese individuals, several limitations should be acknowledged. The relatively short duration of the intervention (12 weeks) limits our ability to assess the long-term effects of badminton on HRV and body composition. Future research should explore the sustainability of these improvements over longer periods and investigate whether badminton can lead to more permanent changes in autonomic function and body composition.

Additionally, the study focused exclusively on overweight and obese individuals, limiting the generalizability of the findings to other populations. Future studies should explore the effects of badminton on HRV and body composition in different age groups, fitness levels, and individuals with comorbidities such as diabetes or cardiovascular disease.

CONCLUSIONS

The study demonstrates that both the BDT and CNT groups exhibited improvements in HRV and body composition over the 12 weeks, with the BDT group showing more substantial gains. Increases in RMSSD and SDNN in the BDT group suggest enhanced parasympathetic activity and overall heart rate variability, which may contribute to improved autonomic regulation. The more pronounced reduction in the LF/HF ratio in the BDT group indicates a shift towards parasympathetic dominance, further underscoring the effectiveness of the badminton training intervention.

Additionally, the BDT group experienced greater reductions in BMI and TBF% compared to the CNT group, reflecting more significant improvements in body composition. The higher adherence rate in the BDT group further highlights the feasibility and potential of the intervention. Overall, these findings suggest that badminton training can lead to meaningful improvements in autonomic function and body composition, offering potential long-term health benefits. Future research could focus on exploring the long-term effects of BDT on HRV and body composition, as well as examining the underlying mechanisms driving these improvements.

ADDITIONAL INFORMATION

Disclosures

Human subjects: Consent was obtained or waived by all participants in this study. Saveetha Medical College and Hospital Institutional Ethics Committee issued approval 014/05/23/IEC/SMCH. Ethical approval was obtained from the Saveetha Medical College and Hospital Institutional Ethics Committee (Ref. No. 014/05/23/IEC/SMCH) prior to the commencement of the study. All participants were provided with an information sheet detailing the study, after which they signed informed consent forms, confirming their voluntary participation. Participants were not involved in the design, conduct, reporting, or dissemination of the research. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue.

Conflicts of interest

In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/ services info:** This is a Badminton World Federation funded research project. The project grant was availed for the year 2022-2023. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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