COMPARISON OF MORNING AND EVENING HIGH-INTENSITY INTERVAL TRAINING (HIIT) ON SELECTED PARAMETERS IN BADMINTON PLAYERS

Muhammad Alamgir
Ph.D. Scholar, Department of Sports Sciences & Physical Education,
Gomal University, Dera Ismail Khan, Pakistan. Email: Alamgir2882@gmail.com

Gulshan Tahira
Lecturer, Department of Physical Education and Sports Sciences,
University of Gujrat, Pakistan. Email: Gulshantahira33@gmail.com

Dr. Muhammad Iftikhar
Assistant Professor, Health, Physical Education and Sports Sciences,
Health Services Academy, Islamabad, Pakistan. Email: efeawan@gmail.com

Abstract

In this study, we delve into the realm of high-intensity interval training (HIIT) and its impact on the performance of collegiate badminton players, emphasizing the importance of timing in implementing such training. A total of 45 male college badminton players, aged 18 to 21, regularly engaging in five days of exercise per week for at least one year, participated in the research conducted at Government Degree College (GDC), Qila Didar Singh, Gujranwala, Punjab, Pakistan. The participants exhibited a mean age of 19.48 ± 1.29 years, a height of 170.31 ± 7.15 cm, a weight of 64.37 ± 6.59 kg, and a BMI of 22.22 ± 2.12. The research protocols comprised a ten-minute warm-up followed by ten minutes of HIIT, with measurements taken during the morning (09:30-10:30 a.m.) and evening (05:00-06:00 p.m.) sessions. Evaluation of aerobic fitness, speed, and agility utilized the 20m shuttle run test, Sprint time over 20m, and SEMO agility test. Results revealed significant differences in scores between morning and evening HIIT programs ($p < .05$). However, no significant disparities were noted in the performance times of these tests between the two time frames ($p > .05$). In conclusion, this study suggests that HIIT training can enhance badminton players' performance, irrespective of whether it is conducted in the morning or evening.

Keywords: HIIT; Aerobic Fitness; Speed; Agility; Badminton Players.

Introduction

Brief recoveries occur in badminton between longer rallies (aerobic system) and shorter, high-intensity rallies (anaerobic system) (Jeyaraman, District & Nadu, 2012). Researchers have observed that badminton players obtain 60-70% of their energy from the aerobic system and 30% is from the anaerobes system (Phomsoupha & Laffaye, 2015; Van-Lieshout & Lombard, 2003). The period of a badminton match is between 15-90 minutes depending on the player’s performance and the number of rallies played (Manrique & Gonzalez-Badillo, 2003). Badminton players require high levels of aerobic energy to maintain performance for a duration of half an hour or more. Hence, the competitive badminton players’ training should concentrate on improving their ability to repeat high-intensity activities and faster recovery after that. Therefore, aerobic fitness improvement should be included in badminton training as part of physical exercise (Smith et al., 2013).

A combination of anaerobic and aerobic fitness, speed, power, agility, strength, and technical and tactical skills are needed for badminton players (Phomsoupha & Laffaye, 2015; Lees, 2003). The employment of traditional methods (long slow distance, fartlek, etc.) improving aerobic fitness is common among badminton coaches. Therefore, it is necessary to form a training that involves all of these fitness components (Raman & Nageswaran, 2013). Functional training has become well-known worldwide and has been combined with high-intensity interval training (Feito et al., 2018; Mercer, 2022). Functional training refers to specific training coordinated with the athletes’ need to increase their performance in sport (Kong & Liu, 2013). Previous studies have combined high-intensity functional training with cross-fit training, which is based on the concept of improving work capacity over time by using weight training such as push-ups and squats ((Feito et al., 2018). Nevertheless, in this study, badminton skills will be paired with aerobic exercise. Therefore, this study aimed to examine the effects of high-intensity interval functional training on the aerobic fitness, speed, and agility of young badminton players.

Objectives

1. To evaluate how morning high-intensity interval training (HIIT) affects badminton players' performance metrics.
2. To evaluate how evening time high-intensity interval training (HIIT) affects badminton players' performance metrics.
3. To analyze the significant difference in the effects of HIIT in morning versus evening on the performance parameters of badminton players.

Materials and Methods

Workplace Location and Facilities

The study was conducted at the Government Degree College for Boys in

Gujranwala, Punjab, Pakistan, at Qila Didar Singh. The researchers believe that all the required facilities including ground for exercise, running tracks for speed and agility tests, stopwatches, and assistance are available at this college. All these facilities helped the researcher to conduct the study successfully.

The research design used to carry out any research project is described in the methodology section. Since the current study used a cause-and-effect methodology and the researcher needed to gather numerical data, quantitative methodology was used to gather data on research variables both before and after the intervention.

Treatment Studied

For eight weeks, high-intensity interval training (HIIT) was administered to experimental groups A and B while the control group was free to engage in their regular activities. There was no control group provided for the HIIT programs. The training session was set for the morning, from 9:30 to 10:30, and the evening, from 4:00 to 5:00. The researchers monitored the training programs closely. To obtain precise and genuine findings, proper attendance was recorded on a certain register.

The training programs were held at Qila Didar Singh, Gujranwala, Central Ground Government Degree College for Boys. The researcher, working with an assistant, will oversee the proper implementation of the HIIT program under personal supervision.

Measurements

The present study aims to examine the effects of HIIT performed at various times a day on aerobic fitness, speed, and agility of college badminton players. The following tests/instruments were used to collect data on the proposed dependent variable.

i. Height: The height of the subjects was measured through a studio-meter, and this measurement was taken in feet.
ii. Weight: The weight of the subject was measured through a weight meter and these measurements were taken in Kg.
iii. Body Mass Index (BMI): For the measurement of BMI, the researchers measured the height and weight of each respondent. The formula of BMI is (BMI = kg/m2) where kg is a person's weight in kilograms and m2 is their height in meters squared.

Performance Parameters

i. **Aerobic Fitness:** Aerobic Fitness (20m shuttle run test) was used to measure the aerobic fitness of the subjects.

ii. **Speed:** The individuals were measured for sprint time over a distance of 20 meters, using split times for the 5 and 10-meter distances.

iii. **Agility:** SEMO agility test was applied to assess the agility of the subjects.

Methods of Data Collection

All the subjects completed the familiarization phase before data collection by attending a session in which they practiced all HIIT exercises and test conditions. The researchers recruited volunteers to conduct HIIT activities in a single group. Additionally, during the practice session, participants were informed that the study would be completed in two different periods: in the morning (09.00-10.00) and in the evening (04.00-05.00). The body weight was determined using an electronic scale with a 0.1-kilogram accuracy (kg). The participants' height was determined during the measurement using a stadiometer with an accuracy of 0.01 meters (m). Using an electronic scale, the body mass index and body fat ratios of all subjects were determined and recorded. After HIIT, the participants' 30 m sprint and T-line agility performance were assessed at two different durations throughout the day (starting at 9.00 a.m. and 4.00 p.m.). Three trials were performed for each measurement, and the highest value of the three trials was used for each variable. After the T-test and 30 m speed test tracks, a two-door photocell electronic chronometer system measuring with 0.01-second precision was placed at the start and finish lines of the tracks. Three trials were taken for each variable (a remaining interval of 1 min after each trial for the T-test and 30 s after each trial for the 30 m sprint test), and the highest value for the three trials was utilized for analysis.

Sampling Technique and Procedure

Forty-five male volunteers between the ages of 18 and 21, who had exercised consistently three days a week for at least three years and are studying at Government Degree College for Boys, Qila Didar Singh, Gujranwala, participated in the study. To be included in the study, the badminton players had to fulfill the following requirements: (a) they had to be playing hockey for at least three years; (b) they had to be free of medical histories that could have an impact on the study's findings; (c) they had to guarantee consistent participation in the study; and (d) they had to obey the researchers' instructions throughout the entire study.

All athletes were given all of the essential information regarding the study's requirements and risks, and they were required to sign an informed consent form indicating that they volunteered to participate. The players were instructed to maintain their usual level of physical activity and abstain from intense activities for 24 hours before the study. Additionally, they were forbidden from using stimulants (e.g. caffeine) or depressants (e.g. alcohol) before the study. Before starting the study, necessary approval was received from the Directorate of Academics, Gomal University, Dera Ismail Khan.

Results

Table 1. Anthropometric Measures of the Participants

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Age (years)	45	18.00	21.00	19.4889	1.29021	1.665
Height (cm)	45	159.00	184.00	170.3169	7.15671	51.218
Weight (kg) pre	45	56.00	82.00	64.3778	6.59989	43.559
Weight (kg) post	45	53.00	78.00	59.3778	5.62579	31.649
Body Mass Index in Pre-test	45	18.90	28.31	22.2202	2.12380	4.511
Body Mass Index in Posttest	45	16.54	26.93	20.1520	2.44563	5.981

Table 1 presents the descriptive statistics of various anthropometric measures of 45 college-level badminton players. The measures include age, height, weight before and after training, and body mass index (BMI) before and after the training. The average age of players was 19.49 years, with a range of 3 years between the youngest and oldest players. The average height was 170.32 cm, with a range of 25 cm. The average weight before training was 64.38 kg, with a range of 26 kg, while the average weight after training was 59.38 kg, with a range of 25 kg. The average BMI before training was 22.22, with a range of 9.41, and the average BMI after training was 20.15, with a range of 10.39. The variance in BMI was relatively high compared to other measures. The descriptive statistics indicate that the badminton players had a relatively narrow age range and height range, but a wide range of weight and BMI before training. After training, there was a decrease in weight and BMI, indicating a positive effect of the training on the players' physical fitness.

Table 2. Tests of Between-Subjects Effects (Aerobic Fitness (Shuttle Run test)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	69.399[a]	3	23.133	41.429	.000	.752
Intercept	24.011	1	24.011	43.001	.000	.512
Aerobic Fitness pretest	4.666	1	4.666	8.357	.006	.169
Groups	64.127	2	32.063	57.422	.000	.737
Error	22.894	41	.558			
Total	6541.130	45				

Corrected Total	92.292	44

a. R Squared = .752 (Adjusted R Squared = .734)

The ANOVA results show that there is a significant main effect of the intervention, F (2, 41) = 57.422, p < .001, with a large effect size (partial eta squared = .737). This indicates that there are significant differences in aerobic fitness between the three groups after the intervention. The table also shows that the model is significant, F (3, 41) = 41.429, p < .001, and explains a large amount of the variance in the post-test scores (R squared = .752). The Intercept row represents the mean post-test score of the control group, which is significantly different from zero (p < .001). The AFP row represents the effect of the pretest scores on the posttest scores, which is significant (p = .006) but has a relatively small effect size (partial eta squared = .169).

Table 3. Between-Subject Effects (Dependent Variable: Speed (Sprint time over 20 meters)

Source	**Type III Sum of Squares**	**df**
Corrected Model	24.001[a]	3
Intercept	1.082	1
SPPRE	2.013	1
Grp	23.575	2
Error	6.486	41
Total	610.882	45
Corrected Total	30.487	44

a. R Squared = .787 (Adjusted R Squared = .772)

Table 3 reports the results of the statistical analysis of the data using a Type III Sum of Squares. The corrected model shows that the independent variables, SPPRE (pretest sprint time) and Grp (group type), have a significant effect on the dependent variable, Speed. The F-value (50.574) is significant (p < .001), which indicates that the model is a good fit for the data. The partial eta-squared value (0.787) suggests that the independent variables explain a large proportion of the variance in the dependent variable. The intercept variable represents the mean score for the control group (the group that did not receive HIIT training). The intercept variable is significant (p = .012), suggesting that there is a difference between the control group and the experimental groups. The SPPRE variable represents the pretest sprint time and is also significant (p = .001), indicating that the pretest scores influence the posttest scores. The Grp variable, representing the type of training (morning vs. evening), has the most significant effect on the dependent variable (Speed). The F-value for Grp (74.516) is very high, and the p-value is significant ($p < .001$), indicating that the type of training has a

significant effect on the sprint time of the badminton players. The R-squared value (0.787) indicates that 78.7% of the variance in the dependent variable (Speed) can be explained by the independent variables (Speed and Group). The adjusted R-squared value (0.772) suggests that the model is robust and not overfitting the data.

Table 4. Tests of Between-Subjects Effects (Dependent Variable: Agility (SEMO Agility Test)

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	119.219[a]	3	39.740	84.822	.000	.861
Intercept	9.026	1	9.026	19.266	.000	.320
AGPRE	7.402	1	7.402	15.799	.000	.278
Grp	109.656	2	54.828	117.028	.000	.851
Error	19.209	41	.469			
Total	6375.940	45				
Corrected Total	138.428	44				

a. R Squared = .861 (Adjusted R Squared = .851)

The results show that the corrected model is statistically significant (Sig. < .001), indicating that the independent variables collectively have a significant effect on the dependent variable. The Partial Eta Squared value of .861 indicates that the independent variables explain 86.1% of the variance in the dependent variable. The Intercept variable has a statistically significant effect on the dependent variable (Sig. < .001), indicating that the mean agility score is significantly different from zero. The AGPRE variable also has a statistically significant effect on the dependent variable (Sig. < .001), indicating that the pretest agility score is a significant predictor of the posttest agility score. The Grp variable has a statistically significant effect on the dependent variable (Sig. < .001), indicating that the type of training (morning or evening) has a significant effect on the post-test agility score.

Discussion

The purpose of the current study was to evaluate how high-intensity interval training (HIIT) in the morning and evening affected the badminton players' aerobic fitness, speed, and agility. It was hypothesized that high-intensity interval training (HIIT) conducted in the morning and evening would improve badminton players' aerobic fitness, speed, and agility. The majority of the literature in this field has likewise corroborated the results of the current investigation. The data analysis revealed a significantly higher sum of squares of 64.732 degrees of freedom of 2, and a mean square of 32.366 when testing the first hypothesis. This led to an F-value of 49.324 with a significance level of.000. Additionally, the data analysis revealed a noteworthy distinction in the average sprint time of 20 meters among the three cohorts ($F = 54.332$, $p < .001$). With an F-statistic of 88.241 and a p-value of less than 0.001, the data analysis did, however, show a significant difference in mean agility scores between the control group and the two experimental groups. In conclusion, the findings imply that college-level badminton players can enhance their agility with both morning and evening HIIT and that there is no discernible difference in the efficacy of morning versus evening HIIT. It is important to highlight that the Bonferroni procedure was used to correct these results for multiple comparisons, lowering the possibility of false positives in hypothesis testing. Previous studies in this field have also been carried out; a summary of their findings is provided below. Kilit and Arslan (2019) conducted a study whereby they examined several significant characteristics of juvenile tennis players following six weeks of high-intensity interval training (HIIT) against six weeks of on-court tennis training (OTT). Technical scores, performance responses, and psychophysiological reactions made up these metrics. Based on their results, sprint and jump performance significantly improved with both training regimes from the pre- to the post-testing phases. In terms of agility and technical ratings, the OTT group's responses were noticeably better than those of the HIIT group. In a different study, Arslan, Orer, and Clemente (2020) examined the impact on young football players' psychophysiological responses and technical skills of five weeks of run-based HIIT versus small-sided game training (SSG). According to their findings, SSG exercise outperformed HIIT in terms of improving agility and technical test performance. In contrast, the HIIT group performed noticeably better in the repeated sprint tests and the 1000-meter run. To find out how HIIT affected Taekwondo athletes, one more study was done. There were two groups: high-intensity continuous running (HICR) and high-intensity interval training (HIIT) with a rest time. According to the results, both groups considerably raised the Taekwondo athletes' sit-up and T-test scores (Monks et al., 2017). Using a range of work-to-rest ratios, Seo et al. (2019) examine the impact of high-intensity interval training (HIIT) on athletes' athletic performance. Tests of athletic performance conducted before and after included the Wingate anaerobic, agility T-test, vertical jump, and VO2 max. Following four weeks of 10 HIIT sessions with the 1:4 group, the program's effectiveness in boosting anaerobic and aerobic capacity was assessed. Váczi et al. (2013) sought to determine how power, agility, and knee extensor strength were affected by a brief in-season plyometric training program. The results of the study demonstrate that plyometric training, which included high-impact unilateral and bilateral exercises, greatly increased maximal knee extensor strength and lower limb power but had less of an influence on agility specific to football. Gokkurt and Kivrak's (2021) goal was to find out how eight weeks of high-intensity interval training affected the players' under-19 (U19) football players' speed, agility, and acceleration. The speed and acceleration characteristics of the football players in the experimental group were compared before and after the test, and it was found that the post-test values were noticeably greater. Suppiah et al.'s (2020) goal was to ascertain how young badminton players' sprint performance, agility, and aerobic fitness were affected by high-intensity functional interval training. The findings show that the experimental group (EG) and the control group differed significantly in terms of 20 m Multistage Fitness and Four Corner Agility, respectively.

Conclusion

The current study compared the effects of morning and evening high-intensity interval training (HIIT) on a few key badminton player performance characteristics and discovered that both training schedules significantly improved the performance metrics. The results showed that high-intensity interval training (HIIT) can improve badminton players' aerobic fitness, speed, and agility regardless of the time of day. The results showed that the morning and evening training groups' total improvements did not differ significantly from one another. Similar improvements were seen by both groups in all assessed performance metrics. This shows that the overall efficiency of HIIT for enhancing these particular performance characteristics is not considerably affected by the timing of the training session. It is interesting to note, nonetheless, that individuals in the morning training group felt less exerted during the training sessions than those in the evening training group. According to this subjective measure, training in the morning may be seen as less physically taxing, which could have an impact on motivation and program adherence. For this reason, trainers and athletes should take into account each player's unique preferences, daily schedules, energy levels, and motivation while creating training plans for badminton players. Based on these considerations, training schedules can be chosen, since the study shows that training sessions in the morning and the evening can both result in comparable gains in performance. In the end, whatever the precise schedule selected, the most important thing is to emphasize regularity and commitment to the exercise regimen. Further investigation into these and other variables, such as Chronotype (individual differences in circadian cycles) and certain badminton performance metrics, may determine whether morning or evening training is more beneficial. Furthermore, researching the long-term impact of morning versus evening HIIT on recovery and performance may yield insightful information for improving badminton and other sports training regimens.

This study contains several restrictions. The current study did not involve participants of either gender, and the volunteers' body and muscle temperatures were not used to evaluate the outcomes. Increasing the sample size while keeping gender quantification in mind will allow future research to be duplicated. Furthermore, considering the participants' circadian rhythms, distinct training regimens based on individual awareness can be used to assess performance metrics at various times of the day. In the end, this will lead to recommendations for planning more accurate participants.

Recommendations

i. Since both morning and evening training sessions were found to be equally effective, it is important to consider individual preferences and chronotypes when scheduling training. Some players may naturally perform better or feel more energized during specific times of the day. Coaches should communicate with athletes to understand their preferences and optimize training schedules accordingly.

ii. Athletes must be encouraged to assess their personal energy levels at different times of the day. If an athlete consistently feels more energized and motivated in the morning, morning training may be more suitable for them. Conversely, if an athlete feels sluggish in the morning but more alert and energetic in the evening, an evening training session may be more beneficial.

iii. Although there were no significant differences in overall performance improvements between the morning and evening training groups, the study revealed that participants in the morning group reported lower perceived exertion levels. Coaches should consider this when planning training sessions, as lower perceived exertion, may positively impact motivation and adherence to the program.

References

1. Ahmed, S., Akter, R., Saraswat, A., & Esht, V. (2019). Core stability and its impact on upper extremity function in racket sports: a narrative review. Saudi J Sports Med, 19(2), 31. https://doi.org/10.4103/sjsm.sjsm_15_19
2. Ahmed, S., Saraswat, A., & Esht, V. (2022). Correlation of core stability with balance, agility and upper limb power in badminton players: a cross-sectional study. Sport Sciences for Health, 18(1), 165–169. https://doi.org/10.1007/S11332-021-00789-W/TABLES/2
3. Appukutty, M., Shyam, S., Choo, Z. Y., Tan, S. S., Chong, H. Z. M., & Choong, A. (2023). Effects of n-3 long-chain polyunsaturated fatty acid supplementation on the omega-3 index and exercise performance among Malaysian football players: a randomized controlled trial. British Food Journal, 125(6), 2019–2036. https://doi.org/10.1108/BFJ-11-2021-1250/FULL/XML
4. Barreira, J., Chiminazzo, J. G. C., & Fernandes, P. T. (2016). Analysis of point difference established by winners and losers in games of badminton. International Journal of Performance Analysis in Sport, 16(2), 687–694. https://doi.org/10.1080/24748668.2016.11868916
5. Bezodis, N. E., Willwacher, S., & Salo, A. I. T. (2019). The Biomechanics of Track and Field Sprint Start: A Narrative Review. Sports Medicine, 49(9), 1345–1364. https://doi.org/10.1007/S40279-019-01138-1
6. Buldú, J. M., Gómez, M. Á., Herrera-Diestra, J. L., & Martínez, J. H. (2021). Editorial: Nonlinear dynamics and networks in sports. Chaos, Solitons and Fractals, 142. https://doi.org/10.1016/j.chaos.2020.110518
7. Carboch, J., & Smocek, P. (2020). Serve and Return in Badminton: Gender Differences of Elite Badminton Players. International Journal of Physical

Education, Fitness and Sports, 44–48. https://doi.org/10.34256/IJPEFS2014

8. Charest, J., & Grandner, M. A. (2022). Sleep and athletic performance: impacts on physical performance, mental performance, injury risk and recovery, and mental health: an update. Sleep Med Clin, 17(2), 263–282. https://doi.org/10.1016/j.jsmc.2022.03.006

9. Chiou, S. S., Hsu, Y., Chiu, Y. H., Chou, C. C., Gill, D. L., & Lu, F. J. (2020). Seeking positive strengths in buffering athletes' life stress–burnout relationship: the moderating roles of athletic mental energy. Front Psychol, 10, 3007. https://doi.org/10.3389/fpsyg.2019.03007

10. De França Bahia Loureiro, L., Costa Dias, M. O., Cremasco, F. C., Da Silva, M. G., & De Freitas, P. B. (2017). Assessment of Specificity of the Badcamp Agility Test for Badminton Players. Journal of Human Kinetics, 57(1), 191–198. https://doi.org/10.1515/HUKIN-2017-0060

11. Fukuoka, Y., Iihoshi, M., Nazunin, J. T., Abe, D., & Fukuba, Y. (2017). Dynamic characteristics of ventilatory and gas exchange during sinusoidal walking in humans. PLoS ONE, 12(1). https://doi.org/10.1371/JOURNAL.PONE.0168517

12. Fullagar, H. H. K., Vincent, G. E., McCullough, M., Halson, S., & Fowler, P. (2023). Sleep and Sport Performance. Journal of Clinical Neurophysiology, 40(5), 408–416. https://doi.org/10.1097/WNP.0000000000000638

13. Gabbett, T. J. (2020). Debunking myths about training load, injury, and performance: empirical evidence, hot topics and recommendations for practitioners. British Journal of Sports Medicine, 54(1), 58–66. https://doi.org/10.1136/BJSPORTS-2018-099784

14. Gasuma, S., Abcd, R., Kunta, S., Abcd, P., Santoso, S., & Abcd, S. (2023). Differences in the effect of high and low maximum oxygen consumption capacity on the increase in lactic acid after exercise at night. Health Technologies, 1(2), 31–39. https://doi.org/10.58962/HT.2023.1.2.31-39

15. Gholamalizadeh, M., Mirsadeghi, N. A., Rastgoo, S., Abbas Torki, S., Bourbour, F., Kalantari, N., Shafaei, H., Teymoori, Z., Alizadeh, A., Mosavi Jarrahi, A., &

Doaei, S. (2022). Association of body mass index and dietary fat intake with autism in children: a case-control study. Nutrition and Food Science. https://doi.org/10.1108/NFS-12-2021-0366/FULL/HTML

16. Gomez, M. Á., Rivas, F., Connor, J. D., & Leicht, A. S. (2019). Performance differences of temporal parameters and point outcomes between elite men's and women's badminton players according to match-related contexts. International Journal of Environmental Research and Public Health, 16(21). https://doi.org/10.3390/IJERPH16214057
17. Hamed Ibrahim Hassan, I. (2017). The Effect of Core Stability Training on Dynamic Balance and Smash Stroke Performance in Badminton Players. International Journal of Sports Science and Physical Education, 2(3), 44. https://doi.org/10.11648/J.IJSSPE.20170203.12
18. Jaworski, J., Lech, G., Żak, M., Witkowski, K., & Piepiora, P. (2023). Relationships between selected indices of postural stability and sports performance in elite badminton players: Pilot study. Frontiers in Psychology, 14, 1110164. https://doi.org/10.3389/FPSYG.2023.1110164/BIBTEX
19. Kelly, D. T., Tobin, C., Egan, B., McCarren, A., O'Connor, P. L., Mccaffrey, N., & Moyna, N. M. (2018). Comparison of sprint interval and endurance training in team sport athletes. Journal of Strength and Conditioning Research, 32(11), 3051–3058. https://doi.org/10.1519/JSC.0000000000002374
20. Knief, U., & Forstmeier, W. (2021). Violating the normality assumption may be the lesser of two evils. Behav Res Methods, 53(6), 2576–2590. https://doi.org/10.3758/s13428-021-01587-5
21. Koral, J., Oranchuk, D. J., Herrera, R., & Millet, G. Y. (2018). Six sessions of sprint interval training improve running performance in trained athletes. Journal of Strength and Conditioning Research, 32(3), 617–623. https://doi.org/10.1519/JSC.0000000000002286
22. Kosack, M. H., Staiano, W., Folino, R., Hansen, M. B., & Lønbro, S. (2020). The acute effect of mental fatigue on badminton performance in elite players. International Journal of Sports Physiology and Performance, 15(5), 632–

638. https://doi.org/10.1123/IJSPP.2019-0361

23. Kryeziu, A., Begu, B., Asllani, İ., & Iseni, A. (2019). Effects of the 4-week plyometric training program on explosive strength and agility for basketball players. Turkish Journal of Kinesiology, 5(3), 110–116. https://doi.org/10.31459/TURKJKIN.553453
24. Lastella, M., Roach, G. D., Halson, S. L., & Sargent, C. (2016). The chronotype of elite athletes. Journal of Human Kinetics, 54(1), 219–225. https://doi.org/10.1515/HUKIN-2016-0049
25. Lim, S. T., Kim, D. Y., Kwon, H. T., & Lee, E. (2021). Sleep quality and athletic performance according to chronotype. BMC Sports Sci Med Rehabil, 13(1), 2. https://doi.org/10.1186/s13102-020-00228-2
26. Litwic-Kaminska, K., & Kotysko, M. (2020). Sleep quality of student-athletes and non-athletes - the role of chronotype, stress, and life satisfaction. Sleep Sci (Sao Paulo, Brazil), 13(4), 249–255. https://doi.org/10.5935/1984-0063.20190153
27. Liu, H., Leng, B., Li, Q., Liu, Y., Bao, D., & Cui, Y. (2021). The Effect of Eight-Week Sprint Interval Training on Aerobic Performance of Elite Badminton Players. International Journal of Environmental Research and Public Health, 2021, Vol. 18, Page 638, 18(2), 638. https://doi.org/10.3390/IJERPH18020638
28. Lunn, W. R., & Axtell, R. S. (2021). Validity and Reliability of the Lode Excalibur Sport Cycle Ergometer for the Wingate Anaerobic Test. Journal of Strength and Conditioning Research, 35(10), 2894–2901. https://doi.org/10.1519/JSC.0000000000003211
29. Maksum, A., & Indahwati, N. (2023). Personality traits, environment, and career stages of top athletes: An evidence from outstanding badminton players of Indonesia. Heliyon, 9, e13779. https://doi.org/10.1016/j.heliyon.2023.e13779
30. Malhotra, R. K. (2017). Sleep, recovery, and performance in sports. Neurol Clin, 35(3), 547–557. https://doi.org/10.1016/j.ncl.2017.03.002
31. Ozmen, T., & Aydogmus, M. (2016). Effect of core strength training on dynamic balance and agility in adolescent badminton players. Journal of Bodywork

and Movement Therapies, 20(3), 565–570.

32. Panda, M., Rizvi, M. R., Sharma, A., Sethi, P., Ahmad, I., & Kumari, S. (2022). Effects of electromyostimulation and plyometric training on sports-specific parameters in badminton players. Sports Medicine and Health Science, 4(4), 280–286. https://doi.org/10.1016/J.SMHS.2022.08.002
33. Phomsoupha, M., & Laffaye, G. (2015). The Science of Badminton: Game Characteristics, Anthropometry, Physiology, Visual Fitness and Biomechanics. Sports Medicine, 45(4), 473–495. https://doi.org/10.1007/S40279-014-0287-2
34. Ramasamy, Y., Usman, J., Sundar, V., Towler, H., & King, M. (2021). Kinetic and kinematic determinants of shuttlecock speed in the forehand jump smash performed by elite male Malaysian badminton players. Sports Biomechanics, 1–16. https://doi.org/10.1080/14763141.2021.1877336
35. Roden, L., Rudner, T., & Rae, D. (2017). Impact of chronotypes on athletic performance: current perspectives. Chrono Physiol Ther, 7, 1–6. https://doi.org/10.2147/cpt.s99804
36. Slimani, M., Chamari, K., Miarka, B., Del Vecchio, F. B., & Chéour, F. (2016). Effects of Plyometric Training on Physical Fitness in Team Sport Athletes: A Systematic Review. Journal of Human Kinetics, 53(1), 231–247. https://doi.org/10.1515/HUKIN-2016-0026
37. Sonoda, T., Tashiro, Y., Suzuki, Y., Kajiwara, Y., Zeidan, H., Yokota, Y., Kawagoe, M., Nakayama, Y., Bito, T., Shimoura, K., Tatsumi, M., Nakai, K., Nishida, Y., Yoshimi, S., & Aoyama, T. (2018). Relationship between agility and lower limb muscle strength, targeting university badminton players. J Phys Ther Sci, 30(2), 320–323. https://doi.org/10.1589/jpts.30.320
38. Stojanović, E., Stojiljković, N., Scanlan, A. T., Dalbo, V. J., Berkelmans, D. M., & Milanović, Z. (2018). The Activity Demands and Physiological Responses Encountered During Basketball Match-Play: A Systematic Review. Sports Medicine, 48(1), 111–135. https://doi.org/10.1007/s40279-017-0794-z
39. Suchomel, T. J., Nimphius, S., & Stone, M. H. (2016). The Importance of

Muscular Strength in Athletic Performance. Sports Medicine (Auckland, N.Z.), 46(10), 1419–1449. https://doi.org/10.1007/S40279-016-0486-0

40. Tan, C., Lu, J., Wang, J., An, Y., Cao, G., Zhao, D., & Qiu, J. (2023). Chronotype characteristics of professional athletes in China: a comprehensive descriptive study. Journal of Physiological Anthropology, 42(1), 1–13. Doi: https://doi.org/10.1186/S40101-023-00343-2/TABLES/4

41. Wang, J., Qiu, J., Yi, L., Hou, Z., Benardot, D., & Cao, W. (2019). Effect of sodium bicarbonate ingestion during 6 weeks of HIIT on anaerobic performance of college students. Journal of the International Society of Sports Nutrition, 16(1). https://doi.org/10.1186/S12970-019-0285-8

This is an open-access article distributed under the Creative Commons Attribution License 4.0