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ORIGINAL ARTICLE

Analysis of external load and internal load in AirBadminton: A new healthy and recreational sports modality

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ABSTRACT

The aim of this study was to compare internal load and external load between AirBadminton and traditional indoor badminton. The research was conducted with 8 badminton players from the Alicante Technification Centre, including both men and women. The study was carried out based on the recommendations and guidelines of the International Badminton Federation. The procedure included competitions in both 1vs1 and 2vs2 formats, first on sand and then on hard court. Various variables related to players' internal and external load were analysed, using devices such as WIMU PRO for external load and Polar H7 transmitters for internal load. Data analysis was performed using statistical tests such as T-Student and Wilcoxon. Results showed significant differences between indoor badminton and AirBadminton in terms of internal and external load. In the 1vs1 format, indoor badminton was found to be more demanding, with higher intensity efforts, greater distance covered, and higher heart rate compared to AirBadminton. Similar results were observed in the 2vs2 format, confirming that indoor badminton involves greater effort. AirBadminton may be a healthier and more accessible alternative, suitable for different age groups, as it is less explosive and lighter in terms of internal and external load. Future research should focus on technical, tactical, and full-match duration aspects of this new modality.
Keywords: Health, External load, Internal load, Badminton, AirBadminton.

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INTRODUCTION

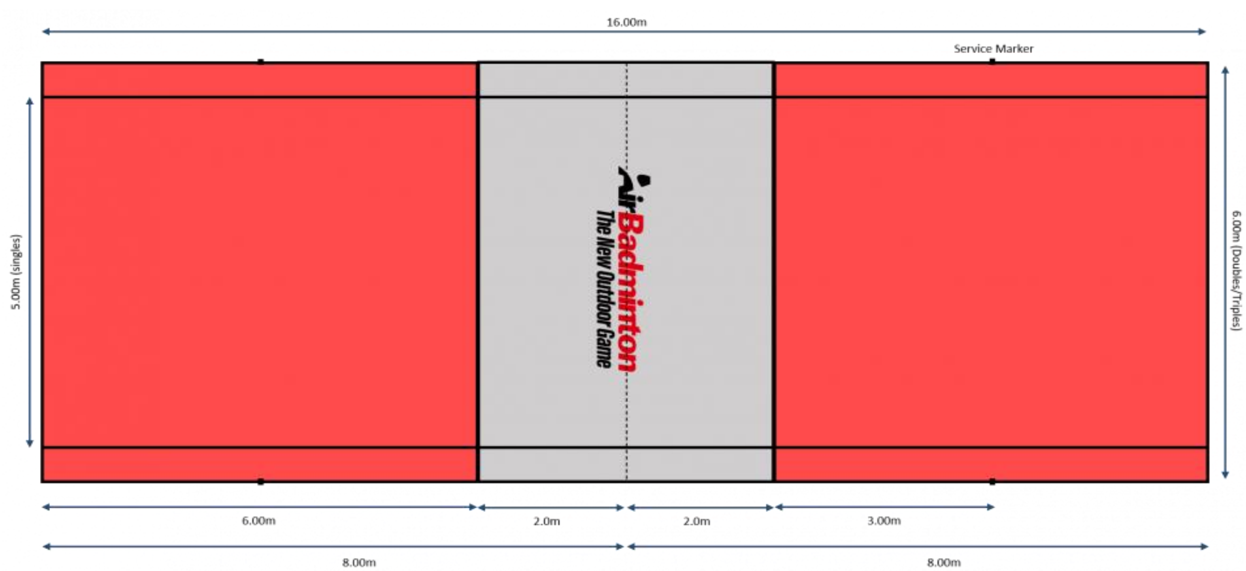
Currently, badminton has a limited number of federation licenses, making it a minority sport compared to other racket sports like tennis, despite its growth in recent years (Gómez-Rodríguez et al., 2022).

Nevertheless, numerous studies have found badminton to be a social game, which is not only taught in schools as a sports modality within Physical Education classes due to its physical and coordinative benefits (Wong et al., 2019), but also contributes to overall well-being, improving individuals' health levels (Rampichini et al., 2018; Cabello-Manrique et al., 2022; Lizuka et al., 2020).

However, the scientific community, particularly researchers from European and Asian countries (Blanca-Torres et al., 2020), has focused on various types of studies, including those related to performance and training parameters (Edel et al., 2023; Schneider et al., 2020; Abián-Vicént et al., 2021), medical and rehabilitation parameters (Hoskin et al., 2023; Maldoddi & Gella, 2022; Herbaut & Delannoy, 2020), and even competition parameters at technical-tactical levels (Valldecabres et al., 2020; Valldecabres et al., 2023), with the latter being the least studied in recent years (Blanca-Torres et al., 2020).

On the other hand, the Badminton World Federation (BWF), in its commitment to society as a sports entity, and to fulfil its educational and sports promotion purposes, presented a new sports modality derived from traditional badminton, known as AirBadminton, to all national federations at the Annual General Meeting held in May 2019 in Nanning, China (Sheng, 2019).

AirBadminton was created with the aim of promoting the sport and making it even more inclusive, providing guidelines for outdoor practice regardless of location or playing surface (Retrieved from BWF 30-11-2023).



Source: BWF

Figure 1. Official Air-badminton dimensions.

The rules governing this sport are established by the Badminton World Federation, which, after initiating the development project in 2013, finalized a set of regulations, along with specific court dimensions -as shown in figure 1- and a shuttlecock, designed and patented to address the uncertainties and uncontrollable elements of outdoor play (BWF). Lastly, in addition to maintaining traditional badminton match formats such as singles -1vs1- and doubles -2vs2-, this new sports modality introduces a new competitive format where two teams of 3 players compete -3vs3- with variations in specific rules for this competitive format. In March 2020, the BWF introduced the AirShuttle to the global market as the official shuttlecock for this modality (BWF).

Given the recent emergence of this sports modality, there is a scarcity of scientific research aimed at studying it. Many avenues of research are opening up in this new sport, providing an opportunity for its analysis and better understanding as a sports modality. In this case, the present study aims to analyse the load imposed by this sports modality, specifically comparing the internal and external load between AirBadminton, a new modality, and traditional badminton - indoor court.

METHOD

Data collection for the research was carried out on October 12, 2019, Saturday. The investigation into the elements of internal and external load was structured as follows:

First, competitions were held in both 1vs1 and 2vs2 formats of outdoor badminton on a sand surface.

Subsequently, the competitions were replicated in both order and participants, but on the usual playing surface (hard court).

To ensure the proper conduct of Air badminton competitions, the recommendations established by the BWF - Badminton World Federation - were taken into account. Similarly, both the rules and playing space were determined based on the proposal and guidelines established by the International Badminton Federation at the Congress held in May 2019 in China, where the proposal for AirBadminton as an emerging and alternative modality was developed.

Participants

Participants in the study were intentionally selected by the National Badminton Federation. A total of 8 badminton players from the Alicante training centre, including 4 men (age: 20.75 ± 0.88 years; height: 180.00 ± 03.0 cm; weight: 76.35 ± 2.73 kg; and BMI: 23.60 ± 0.74) and 4 women (age: 20.50 ± 1.19 years; height: 173.50 ± 6.4 cm; weight: 65.30 ± 2.34 kg; and BMI: 21.77 ± 1.51), participated voluntarily in this research.

The participants were required to belong to the Alicante training centre and have no previous experience playing badminton on sand.

Anthropometric measurements of weight and height were taken using a validated bioimpedance scale InBody 270 (Biospace, California, USA) and a stadiometer (SECA, model 213, Hamburg, Germany), respectively.

Both the technical staff of the training centre and the participating players were informed in advance about the details of the research by the federation. The study was conducted following the ethical provisions established by the Belmont Report (1979) and the Helsinki Declaration (WMA, 2021).

Procedure

The study was conducted over a single day, during which 4 matches were played in the 1vs1 format on the sand surface, followed by another 4 matches on the hard court surface. After all the matches in the first format (a total of 8 matches) were completed, the 2vs2 format matches were played, maintaining the same competition structure on the respective surfaces, i.e., first matches were played on the sand (4 matches), followed by matches on the usual court (4 matches).

The matches were organized by gender, with 2 matches played in the male category and 2 matches played in the female category for each format.

Variables analysed for Internal and External Load

For each participant in this research, the external load of matches in different formats and surfaces was analysed using the following variables: Total distance covered (Distance), Distance covered per minute (Distancemin), Meters covered between 0 and 6 km/h (MetersSpd06), Meters covered between 6 and 12 km/h (MetersSpd612), Meters covered between 12 and 18 km/h (MetersSpd1218), Meters covered between 18 and 21 km/h (MetersSpd1821), Total accelerations (Accelerations), Total decelerations (Decelerations), Accelerations per minute (Accmin), Decelerations per minute (Decmin), Distance of accelerations (DistanceAcc), Distance of decelerations (DistanceDec), Maximum Speed Sprint (MaxSS), Total steps taken (TotalSteps), Steps per minute (Stepsmin), Total jumps performed (TotalJumps), and Jumps per minute (Jumpsmin).

The linear accelerations during the competition were obtained from speed variations detected by the GNSS sensor included in the inertial device used in this research, with speed increases considered as accelerations and speed decreases considered as decelerations. The WIMU PRO inertial device was used for data acquisition related to external load. This device is equipped with GPS technology validated for both collective and individual sports (Bastida-Castillo et al., 2018; Molina-Carmona et al., 2018; Gómez-Carmona et al., 2020), which integrates a 10 Hz GPS receiver and a 100 Hz triaxial accelerometer, gyroscope, and magnetometer. It weighs approximately 70 grams and has a recording capacity of 1 Hz (one record per second) for displacement data, athlete speed, volume, and training loads. This instrument allows the design and evaluation of training programs, as well as the prescription of recovery exercises to ensure adaptation and adjustment to the subject.

The analysis of internal load (average heart rate, maximum heart rate, and kilocalories consumed) was conducted using Polar H7 transmitters, as well as the Polar Team application for iPad. The use of the Polar H7 device allows researchers to obtain device records on-site through the connection established between the Polar team application on iPad and the device via Bluetooth.

Variables

The variables established as components of external load are Total distance covered (Distance), Distance covered per minute (Distancemin), Meters covered between 0 and 6 km/h (MetersSpd06), Meters covered between 6 and 12 km/h (MetersSpd612), Meters covered between 12 and 18 km/h (MetersSpd1218), Meters covered between 18 and 21 km/h (MetersSpd1821), Total accelerations (Accelerations), Total decelerations (Decelerations), Accelerations per minute (Accmin), Decelerations per minute (Decmin), Distance of accelerations (DistanceAcc), Distance of decelerations (DistanceDec), Maximum Speed Sprint (MaxSS), Total steps taken (TotalSteps), Steps per minute (Stepsmin), Total jumps performed (TotalJumps), and Jumps per minute (Jumpsmin).

The variables established as components of internal load are Maximum heart rate (HRmax) and Average heart rate (AVGHR).

It is worth noting that for subsequent data analysis, all variables are identified in the AirBadminton modality by adding the letter "*A*" to the end of each variable name, while the variables corresponding to the court modality have the letter "*P*" added at the end of their names.

Data analysis

To address the objective of this research, a descriptive analysis was carried out, where the data obtained in the different categories studied are presented as mean and standard deviation (mean ± SD) to describe all the demands in the matches played on different playing surfaces.

To determine the normality of both internal and external load variables, the Shapiro-Wilk test was performed according to the game modes played - 1vs1 and 2vs2. Subsequently, two types of analyses were conducted based on the results of the normality test. For those variables with normal distribution, the Student's t-test for related samples was used to compare the differences between variables. Similarly, for those variables that did not follow a normal distribution, a non-parametric test for related samples, specifically the Wilcoxon test, was performed for the same purpose.

These statistical analyses were conducted using SPSS software version 22.00.

RESULTS

To address the objective outlined, normality tests were first conducted for each of the variables studied according to the game mode played - sand or court - to determine if the data obtained followed a normal distribution. Based on this, either a parametric test - Student's t-test - or a non-parametric test - Wilcoxon test - was applied.

According to the normality analysis of the variables studied, the results indicate that the variables MetersSpd06, Accelerations, Decelerations, MaxSpeedSprint – MaxSS –, TotalJumps, and Jumpsmin do not follow a normal distribution, while the rest of the variables do follow a normal distribution in the 1vs1 mode - see Table 1.

Table 1. Results of the normality test for the 1vs1 mode, sand, and track.

	Kolmogorov-Smirnova			**Shapiro-Wilk**		
	Statistic	gl	Sig.	Statistic	gl	Sig.
DistanceA	.230	8	.200*	.891	8	.237
DistanceP	.188	8	.200*	.894	8	.257
DistanceminA	.224	8	.200*	.921	8	.434
DistanceminP	.244	8	.176	.859	8	.118
MetersSpd06A	.309	8	.023	.794	8	.025
MetersSpd06P	.219	8	.200*	.853	8	.101
MetersSpd612A	.211	8	.200*	.917	8	.405
MetersSpd612P	.195	8	.200*	.921	8	.437
MetersSpd1218P	.224	8	.200*	.922	8	.444
AccelerationsA	.349	8	.005	.755	8	.009
AccelerationsP	.209	8	.200*	.872	8	.159
DecelerationsA	.361	8	.003	.753	8	.009
DecelerationsP	.232	8	.200*	.869	8	.149
AccminA	.132	8	.200*	.987	8	.988
AccminP	.156	8	.200*	.942	8	.636
DecminA	.169	8	.200*	.965	8	.855
DecminP	.153	8	.200*	.974	8	.927

DistanceAccA	.170	8	.200*	.925	8	.473
DistanceAccP	.222	8	.200*	.854	8	.106
DistanceDecA	.151	8	.200*	.960	8	.806
DistanceDecP	.235	8	.200*	.906	8	.328
MaxSSA	.455	8	.000	.591	8	.000
MaxSSP	.234	8	.200*	.949	8	.697
HRmaxA	.181	8	.200*	.921	8	.439
HRmaxP	.189	8	.200*	.875	8	.168
AVGHRA	.187	8	.200*	.951	8	.717
AVGHRP	.205	8	.200*	.893	8	.251
TotalStepsA	.249	8	.155	.913	8	.379
TotalStepsP	.204	8	.200*	.921	8	.435
StepsminA	.227	8	.200*	.891	8	.237
StepsminP	.159	8	.200*	.972	8	.917
TotalJumpsA	.300	8	.033	.798	8	.027
TotalJumpsP	.186	8	.200*	.940	8	.614
JumpsminA	.313	8	.020	.787	8	.021
JumpsminP	.134	8	.200*	.950	8	.716

Referring to the results of the normality test of the variables in the 2vs2 mode, Table 2 presents the results obtained from this analysis. It can be observed that all the variables studied exhibit a normal distribution except for the variables Accelerations, TotalJumps, and Jumpsmin, which do not.

Table 2. Results of the normality test for the 2vs2 mode, sand, and track.

	Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
	Statistic	gl	Sig.	Statistic	gl	Sig.
DistanceA	.138	8	.200*	.984	8	.978
DistanceP	.220	8	.200*	.883	8	.202
DistanceminA	.172	8	.200*	.959	8	.803
DistanceminP	.215	8	.200*	.921	8	.437
MetersSpd06A	.157	8	.200*	.938	8	.588
MetersSpd06P	.275	8	.075	.828	8	.057
MetersSpd612A	.224	8	.200*	.902	8	.299
MetersSpd612P	.226	8	.200*	.922	8	.450
MetersSpd1218A	.513	8	.000	.418	8	.000
MetersSpd1218P	.513	8	.000	.418	8	.000
AccelerationsA	.240	8	.194	.816	8	.042
AccelerationsP	.270	8	.090	.826	8	.054
DecelerationsA	.244	8	.178	.830	8	.059
DecelerationsP	.253	8	.140	.846	8	.088
AccminA	.270	8	.089	.861	8	.124
AccminP	.156	8	.200*	.971	8	.906
DecminA	.265	8	.102	.858	8	.115
DecminP	.142	8	.200*	.977	8	.947
DistanceAccA	.204	8	.200*	.856	8	.109
DistanceAccP	.155	8	.200*	.971	8	.908
DistanceDecA	.222	8	.200*	.894	8	.252
DistanceDecP	.218	8	.200*	.838	8	.071
MaxSSA	.266	8	.102	.847	8	.088
MaxSSP	.253	8	.141	.915	8	.390
HRmaxA	.270	8	.088	.884	8	.204
HRmaxP	.160	8	.200*	.969	8	.891
AVGHRA	.266	8	.100	.865	8	.135
AVGHRP	.150	8	.200*	.955	8	.764
TotalStepsA	.201	8	.200*	.972	8	.911

TotalStepsP	.141	8	.200*	.989	8	.993
StepsminA	.130	8	.200*	.975	8	.932
StepsminP	.190	8	.200*	.926	8	.482
TotalJumpsA	.391	8	.001	.641	8	.000
TotalJumpsP	.280	8	.065	.807	8	.034
JumpsminA	.387	8	.001	.705	8	.003
JumpsminP	.212	8	.200*	.913	8	.374

Considering the normal variables, the T-Student test, for each of the studied modes that exhibit a normal distribution, shows significant results in all comparisons between variables -Table 3- in the 1vs1 mode. Meanwhile, in the 2vs2 mode, significant results are observed in the comparison between the variables Distance, Distancemin, DistanceAcc, DistanceDec, HRMax, AVGHR, TotalSteps, and Stepsmin, depending on the surface where the competition takes place (sand or hard court).

Table 3. Results of the t-student test for the 1vs1 modality.

	Paired differences					**t**	**gl**	**Sig. (bilateral)**
	Media	Standard deviation	Standard error mean	95% confidence interval of the difference				
				Lower	Upper			
DistanceA - DistanceP	-95.808	29.382	10.388	-120.372	-71.244	-9.223	7	.000
DistanceminA - DistanceminP	-13.295	4.326	1.529	-16.911	-9.679	-8.693	7	.000
MetersSpd612A - MetersSpd612P	-42.562	20.954	7.408	-60.080	-25.044	-5.745	7	.001
MetersSpd1218A - MetersSpd1218P	-1.571	1.401	0.495	-2.742	-0.399	-3.171	7	.016
AccminA - AccminP	-2.525	2.483	0.878	-4.602	-0.448	-2.875	7	.024
DecminA - DecminP	-2.346	2.161	0.764	-4.153	-0.539	-3.070	7	.018
DistanceAccA - DistanceAccP	-44.686	10.087	3.566	-53.119	-36.254	-12.531	7	.000
DistanceDecA - DistanceDecP	-34.969	6.206	2.194	-40.157	-29.781	-15.938	7	.000
HRmaxA - HRmaxP	-26.750	14.636	5.175	-38.986	-14.514	-5.169	7	.001
AVGHRA - AVGHRP	-37.125	27.305	9.654	-59.952	-14.298	-3.846	7	.006
TotalStepsA - TotalStepsP	-164.750	41.897	14.813	-199.777	-129.723	-11.122	7	.000
StepsminA - StepsminP	-23.967	6.057	2.142	-29.032	-18.903	-11.191	7	.000

Table 4. Results of the t-student test for the 2vs2 modality.

	Paired differences					**t**	**gl**	**Sig. (bilateral)**
	Media	Standard deviation	Standard error mean	95% confidence interval of the difference				
				Lower	Lower			
DistanceA - DistanceP	-60.703	38.954	13.772	-93.268	-28.137	-4.408	7	.003
DistanceminA - DistanceminP	-9.730	3.461	1.223	-12.623	-6.837	-7.953	7	.000
MetersSpd612A - MetersSpd612P	-11.256	17.173	6.072	-25.614	3.101	-1.854	7	.106
AccminA - AccminP	-1.065	3.340	1.181	-3.857	1.727	-0.902	7	.397
DecminA - DecminP	-1.144	3.338	1.180	-3.935	1.648	-0.969	7	.365
DistanceAccA - DistanceAccP	-18.599	9.728	3.440	-26.732	-10.466	-5.407	7	.001
DistanceDecA - DistanceDecP	-11.776	10.581	3.741	-20.623	-2.930	-3.148	7	.016
HRmaxA - HRmaxP	-33.000	16.656	5.889	-46.925	-19.075	-5.604	7	.001
AVGHRA - AVGHRP	-32.250	19.492	6.891	-48.546	-15.954	-4.680	7	.002
TotalStepsA - TotalStepsP	-121.625	63.028	22.284	-174.318	-68.932	-5.458	7	.001
StepsminA - StepsminP	-17.420	6.238	2.205	-22.635	-12.205	-7.899	7	.000
DecelerationsA - DecelerationsP	0.875	51.607	18.246	-42.269	44.019	0.048	7	.963
MaxSSA - MaxSSP	-1.404	4.343	1.535	-5.035	2.227	-0.914	7	.391

On the other hand, for those variables that do not follow a normal distribution, the non-parametric Wilcoxon test for related samples shows significant differences between the analysed variables in the 1vs1 mode -Table 5- except for the variable Decelerations. Regarding the 2vs2 mode, significant differences were found in the analysis of the Wilcoxon test -Table 6- when comparing the variables corresponding to total jumps -TotalJumps- and jumps per minute -Jumpsmin-.

Table 5. Wilcoxon Test Results for 1vs1 Modality.

	AccelerationsP - AccelerationsA	TotalJumpsP - TotalJumpsA	JumpsminP - JumpsminA	MetersSpd06P - MetersSpd06A	DecelerationsP - DecelerationsA	MaxSSP - MaxSSA
Z	-1.960	-2.375	-2.524	-2.521	-1.820	-2.521
Sig. asymptotic (bilateral)	.050	.018	.012	.012	.069	.012

Table 6. Wilcoxon Test Results for 2vs2 Modality.

	MetersSpd1218P - MetersSpd1218A	AccelerationsP - AccelerationsA	TotalJumpsP - TotalJumpsA	JumpsminP - JumpsminA
Z	-.447	.000	-2.207	-2.371
Sig. asymptotic (bilateral)	.655	1.000	.027	.018

DISCUSSION

The main findings in this research show the differences between the studied sports modalities, AirBadminton and traditional indoor badminton.

Regarding the analysis in the competitive practice of 1vs1, the results indicate significant differences between the modalities, where it is observed that badminton played indoors, both in the study of external load variables and internal load variables, is higher compared to that obtained in the AirBadminton modality. These results concerning badminton's conditional level imply greater effort for the practitioner in all facets, particularly highlighting a higher number of high-intensity efforts (accelerations, decelerations, jumps, and sprints), as well as a longer distance covered. These differences in actions and values of external load also imply variations and differences in the analysis of internal load, with indoor badminton being much more intense than AirBadminton, with higher maximum and mean heart rates in the former compared to the latter. These results are consistent with those achieved by Manrique and Badillo (2003) in their analysis of internal and external load in competitive badminton.

Regarding the results obtained in the 2vs2 modality, considering the surface where the game takes place, either sand or indoor court, it can be observed that, at the conditional level, indoor badminton implies greater effort for the practitioner in all facets, similar to what was observed in the 1vs1 modality. Additionally, these results regarding this modality are in line with those obtained by Gawin et al. (2015) in their study with professional Badminton players in both singles and doubles.

These findings demonstrate how AirBadminton entails a lower physical demand, a characteristic that aligns with other alternative sports that are established as sports modalities themselves, such as Beach Volleyball and Beach Handball, which are currently the leaders in recreational sports practice (Bělka et al., 2015).

CONCLUSIONS

The objective of this research has been to identify the similarities and differences between traditional badminton and AirBadminton, a new sports modality practiced on a sand surface (beach), in terms of both external and internal load.

The conclusions reached after the analyses conducted, which address the objectives set, are as follows:

- In terms of external load, AirBadminton appears to be a less explosive, lighter, and less demanding sports modality in terms of total distance covered, as well as in executing a lower number of accelerations and decelerations compared to traditional badminton.
- Regarding internal load, AirBadminton shows lower mean heart rate levels than traditional badminton, as well as lower maximum heart rates. This makes AirBadminton a sport with a more aerobic profile compared to indoor badminton, which is much more explosive and demanding.

This type of sports modality emerges as an alternative to traditional badminton practice with a healthier and more popular character, allowing for a wide age range of participants. Furthermore, pending further research depth into this sports modality, it can be asserted that this outdoor modality played on sand encourages stroke execution that is less common in traditional badminton and can serve as a resource for injury rehabilitation phases.

Future research lines are focused on delving into the study of this sport in terms of spatial occupation and performance on the court, technical-tactical aspects, as well as studying the full duration of matches and the tactics developed by players with more experience in this new sports modality.

AUTHOR CONTRIBUTIONS

All authors have contributed to the recording and analysis of data, as well as to the design of the research and the drafting of the document and conclusions of the work.

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No potential conflict of interest was reported by the authors.

REFERENCES

Abián-Vicén J, Bravo-Sánchez A & Abián P (2021) AIR-BT, a new badminton-specific incremental easy-to-use test. PLoS ONE 16(9): e0257124. https://doi.org/10.1371/journal.pone.0257124

Bělka, J., Hůlka, K., Šafář, M., Weisser, R., & Chadimova, J. (2015). Beach handball and beach volleyball as means leading to increasing physical activity of recreational sportspeople-Pilot study. Journal of Sports Science, 3(4), 165-170. https://doi.org/10.17265/2332-7839/2015.04.002

Blanca-Torres, J.C., Ortega, E., Nikolaidis, P.T., & Torres-Luque, G. (2020). Bibliometric analysis of scientific production in badminton. Journal of Human Sport and Exercise, 15(2), 267-282. https://doi.org/10.14198/jhse.2020.152.03

Blanca-Torres, J.C., Ortega, E., Nikolaidis, P.T., & Torres-Luque, G. (2020). Bibliometric analysis of scientific production in badminton. Journal of Human Sport and Exercise, 15(2), 267-282. https://doi.org/10.14198/jhse.2020.152.03

Cabello-Manrique, D., Lorente, J. A., Padial-Ruz, R., & Puga-González, E. (2022). Play badminton forever: A systematic review of health benefits. International Journal of Environmental Research and Public Health, 19(15), 9077. https://doi.org/10.3390/ijerph19159077

Edel A, Weis J-L, Ferrauti A & Wiewelhove T (2023), Training drills in high performance badminton-effects of interval duration on internal and external loads. Front. Physiol. 14:1189688. https://doi.org/10.3389/fphys.2023.1189688

Gawin, W., Beyer, C., & Seidler, M. (2015). A competition analysis of the single and double disciplines in world-class badminton. International Journal of Performance Analysis in Sport, 15(3), 997-1006. https://doi.org/10.1080/24748668.2015.11868846

Gómez Rodríguez, J., Cabello Manrique, D., & Gómez Píriz, P. T. (2022). Evolución y desarrollo del bádminton español 2000-2019. Retos: nuevas tendencias en educación física, deporte y recreación, 44, 335-345. https://doi.org/10.47197/retos.v44i0.90491

Gomez-Carmona, C. D., Bastida-Castillo, A., Gonzalez-Custodio, A., Olcina, G., & Pino-Ortega, J. (2020). Using an inertial device (WIMU PRO) to quantify neuromuscular load in running: Reliability, convergent validity, and influence of type of surface and device location. The Journal of Strength & Conditioning Research, 34(2), 365-373. https://doi.org/10.1519/JSC.0000000000003106

Herbaut, A., & Delannoy, J. (2020). Fatigue increases ankle sprain risk in badminton players: A biomechanical study. Journal of Sports Sciences, 38(13), 1560-1565. https://doi.org/10.1080/02640414.2020.1748337

Hoskin, A. K., Watson, S., & Kamalden, T. A. (2022). Badminton-related eye injuries: a systematic review. Injury prevention. https://doi.org/10.1136/ip-2022-044564

Iizuka, T., Ohiwa, N., Atomi, T., Shimizu, M., & Atomi, Y. (2020). Morning heart rate variability as an indication of fatigue status in badminton players during a training camp. Sports, 8(11), 147. https://doi.org/10.3390/sports8110147

Manrique, D. C. (2008). Análisis de las características del juego en el bádminton de competición. Su aplicación al entrenamiento.(2000). Tesis doctorales, (15).

Molina-Carmona, I., Gómez-Carmona, C., Bastida-Castillo, A., & Pino-Ortega, J. (2018). Validez del dispositivo inercial WIMU PRO para el registro de la frecuencia cardiaca en un test de campo. SPORT TK-Revista EuroAmericana de Ciencias del Deporte, 7(1), 81-86. https://doi.org/10.6018/321921

Rakesh Maldoddi & Laxmi Gella (2022) Eye injuries in badminton - players' perspective toward the usage of personal protective equipment, The Physician and Sportsmedicine. https://doi.org/10.1080/00913847.2022.2159564

Rampichini, S., Limonta, E., Pugliese, L., Cè, E., Bisconti, A. V., Gianfelici, A., ... & Esposito, F. (2018). Heart rate and pulmonary oxygen uptake response in professional badminton players: comparison between on-court game simulation and laboratory exercise testing. European journal of applied physiology, 118, 2339-2347. https://doi.org/10.1007/s00421-018-3960-6

Schneider C, Wiewelhove T, McLaren SJ, Ro¨leke L, Ka¨sbauer H, Hecksteden A, et al. (2020) Monitoring training and recovery responses with heart rate measures during standardized warm-up in elite badminton players. PLoS ONE 15(12): e0244412. https://doi.org/10.1371/journal.pone.0244412

Sheng, L. (2019). Beach badminton development-based on the promotion of badminton. Acad. J. Humanit. Soc. Sci, 2, 143-150.

Valldecabres R, Casal CA, Chiminazzo JGC & de Benito AM (2020) Players' On-Court Movements and Contextual Variables in Badminton World Championship. Front. Psychol. 11:1567. https://doi.org/10.3389/fpsyg.2020.01567

Valldecabres, R., de Benito, A.M., Losada, J.L., & Casal, C.A. (2022). Badminton World Championship stress zones and performance factors: The key to success through log-linear analysis. Journal of Human Sport and Exercise, 17(1), 10-21. https://doi.org/10.14198/jhse.2022.171.02

Wong, Towel K.K. BSca; Ma, Ada W.W. PhDb; Liu, Karen P.Y. OT, PhDc; Chung, Louisa M.Y. DHScb; Bae, Young-Hyeon PT, PhDd; Fong, Shirley S.M. PT, PhDa,b,∗; Ganesan, Balasankar OT, PhDa,e,f; Wang, Hsing-Kuo PT, PhDg,h. (2019). Balance control, agility, eye-hand coordination, and sport performance of amateur badminton players: A cross-sectional study. Medicine 98(2):p e14134. https://doi.org/10.1097/MD.0000000000014134