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Abstract

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Material and Method: The analysis involved football players aged 12 to 16 with 4–8 years of training experience, involved in a program called "wave periodization". Two tests were performed each year, one in June (Test A) and the other one in December (Test B). Maximal Aerobic Speed (MAS) and Velocity Intermittent Fitness Test (V_{IFT}) indicators were measured using the Intermittent Fitness Test 30–15 by M. Buchheit.

Results: Tests conducted after a 6-month training cycle in subsequent years statistically significantly increased the MAS ($Z = 14.45$; $p < 0.001$) and V_{IFT} ($Z = 13.11$; $p < 0.001$) values. The importance of MAS ($F = 206.31$; $p < 0.001$) and V_{IFT} ($F = 209.11$; $p < 0.001$) increased in both tests in subsequent years of training. The player's position on the pitch does not correlate with the results of endurance tests. However, there is a relationship between players' age and endurance.

Conclusions: The training based on the wave periodization model significantly increased the endurance of the RKS Raków Częstochowa Academy players. The research shows that in each year between 2018 and 2022, the training intervention increased the tested players' MAS and V_{IFT} values. The tested players' position on the pitch does not correlate with the results of endurance tests. The recorded positive correlation between age and endurance confirms the current knowledge.

Keywords

soccer, endurence, periodization, tactical periodization, Maximal Aerobic Speed, Velocity Intermittent Fitness Test, small-sided games

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Article

Adaptive changes in young football players working in a modified tactical periodization model based on the example of endurance

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Keywords: soccer, endurance, priodization, tactical periodization, Maximal Aerobic Speed, velocity Intermittent Fitness Test, small-sided games.

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1. Introduction

A high level of endurance in soccer is essential for players to maintain the intensity and pace of play throughout the match. This is crucial to the success of the entire team. During football matches, players cover a total distance of approximately 7–13 km, repeating short, high-intensity running exercises [1]. This is a reason for the growing physical demands on players. Clubs are increasingly looking for players who have a high ability to perform repeated, intense match events [2]. Therefore, measuring and assessing this ability is an important element in determining the preparation of these football players for sports competitions.

Currently, in research on players' endurance, scientists focus, among others, on aerobic endurance, i.e. the body's ability to withstand medium-intensity exercise for a long time, which is crucial during sports competitions where football players perform hundreds of different activities (actions) [3–5], as well as anaerobic endurance, i.e. the ability to withstand short-term but intense effort, which is especially important during feints, changes of direction, sprints, jumps and other explosive movements that can deceive or dominate the opponent in the game [6, 7].

One of the factors influencing the level of football players' physical fitness, including endurance, is an adequately selected training program [8–10]. One such program is working with footballers based on the so-called tactical periodization [11]. This program is used to train players in the context of the tactical realities of the match. The wave periodization model is a dedicated component responsible for shaping the player's motor features in accordance with the principles determining the process of long-term development of a football player. Wave periodization (cyclicality) is an advanced training planning system in sports [12]. It involves a repeated division of the training period into a series of periods of different intensities, tasks, and planned goals. Each set, called a wave, has a specific duration and is focused on different aspects of training (tactical indications) to optimize the team's overall athletic performance [13]. The idea of the wave periodization model is based on an understanding that the body responds to training in phases, and a single approach to training may lead to decreased performance, excessive load, or injury. Unlike the classic system, it does not include preparatory, competitive and post-competitive periods (transition–detraining).

The motor preparation model at the RKS Raków Częstochowa Academy is based on a modified tactical periodization model, whose additional goal is long-term development of children and youth [29]. Its unique character can be illustrated by describing one example of a training mesocycle. A training mesocycle (e.g., 28 days) consisting of four microcycles: 1 – capacity (7 days); 2 – explosiveness (7 days); 3 – mixed (7 days); and 4 – regenerative (7 days). The wave system of microcycles is implemented throughout the season. Unlike the classic method, it does not consider preparatory, competitive and post-competitive periods (transition–detraining). The time structure of training does not change during the round, except for the regeneration microcycle, in which the games aim to regenerate the muscular system and the mental area. The terminology used in relation to microcycles is characteristic of the analysed environment of the Football Academy and was created as a language of internal communication.

The nature of the microcycle is subordinated to tactical and technical assumptions, which include actions in specific phases of the game (attack, defence, transition from attack to defence and from defence to attack); zones (low, medium, and high); and sectors (side, centre). In the work concept described above, endurance training was carried out in various types of games (fragments created considering match events called small, medium and large) and in isolated runs at a specific, individualized MAS speed (from the test results A and B).

The main training highlights using the abovementioned games took place as scheduled match day +3 days (MD+3) and match day -3 days (MD-3) schedules. On the MD+3 training day, small-sided games (SSG) were combined with runs based on a parameter called maximal aerobic speed (MAS). The forms of the games depended on the number of players participating in the training. All games were closely connected to tactical tasks in a specific micro-cycle. Authors dealing with the subject of small, one-sided games used in football pay more and more attention to tactical goals through which the players' physical parameters are shaped. Small matches reflect match conditions, thus shaping anaerobic and aerobic endurance. The type of developed skill is influenced by variables (number of players, playing field area, game duration, rest break and additional rules) [33]. The results of the authors' research [34] show that the game's period in a specific phase significantly affects the player's external and external load. The day on which this type of training exercise occurs is also an important aspect. They must be adjusted to the match day so that the regeneration time is optimal in relation to the expected match peak. Table 1 is a representative example of the work pattern on days MD+3 and MD-3.

Table 1. Schedule of training sessions to develop players' endurance (example).

Day	Type of training	Capacity	Explosiveness	Mixed	Regenerative
Tuesday MD+3	Games	4 × 4 – 5 × 5	1 × 1 – 3 × 3	3 × 3 – 5 × 5	Fragments of games (corrections of match errors)
	MAS	3 series × 3 reps 30s work: 30 s rest 100%	3 series x 3 reps 15s work: 45s rest 130%	3 series × 2 reps 30s work: 45s rest 110–120%	no runs
Wednesday MD-3	Games	8 × 8 (+N) – 10 × 10	6 × 6 – 8 × 8 (+N)	7 × 7 – 10 × 10	8 × 8 – 10 × 10

MAS = Maximal Aerobic Speed, MD+3 = Match Day + 3 days; MD-3 = Match Day -3 days, N – neutral/additional player (in either form, an additional goalkeeper may appear – coach's decision).

Maintaining and cyclically developing an appropriate level of endurance and preventing its large fluctuations is a key element of success in football. It influences the team's sports results at both professional and amateur levels. Its development and optimization require the involvement of both players and coaches, and knowledge from scientific research can contribute to more effective and evidence-based training programs.

This work aims to evaluate training based on a modified wave periodization model on the endurance of players aged 12 to 16 at the RKS Raków Academy in 2018–2022. The following research questions were asked: How did the training change the results of endurance tests, and what is the correlation between the tests and the players' age and playing position?

2. Materials and Methods

2.1. Subject

The analysis covered football players of the RKS Raków Częstochowa Academy (Poland), aged 12 to 16, with 4–8 years of training experience. The tested players trained six times a week (4 team training units, one formation training, 1 match). The training load consisted of 90 minutes of training in the gym, 370 minutes of exercise on the pitch and 45–90 minutes of match play. All of them were included in the modified wave periodization model program.

2.2. Protocol

Two tests were performed each year, one in June (Test A) and the other one in December (Test B). Each test took place after a specific microcycle's start round, following a systematic testing protocol. The tests were always carried out in the capacity microcycle on MD+3 (the third day after the match) relative to the match. The day before the tests, regeneration training took place. All tests took place in the same place, i.e. in a sports hall where the surface and temperature did not change.

2.3. Work model

Study participants worked according to the following scheme: MD+1 Day Off; MD+2 Recovery training; MD+3 Small Games; MD -3 Medium Games/Large Games; MD -2 Day Off, MD -1 Pre-match preparation.

2.4. Measurement

The Maximal Aerobic Speed (MAS) and Velocity Intermittent Fitness Test (V_{IFT}) indexes were measured using the Intermittent Fitness Test 30-15 according to Buchheit's assumptions [14]. The test is characterized by 30-second shuttle runs performed at increasing speeds over a distance of 40 m, with 15-second active recovery periods between them. All competitors started the test at a rate of 10 km/h.

2.5. Ethics

All participants were thoroughly informed about the content of the study, its goals, possible risks and benefits. The tasks and tests performed in this study were exercises typically performed during training (sprints and jumps). All participants had a federation license, thanks to which their parents signed a document at the beginning of the season authorizing them to participate in the club's football activities. This type of intervention does not alter standard football training or involve motor activities different from typical training and matches; therefore, the intervention never posed an additional risk beyond that associated with everyday football practice. Moreover, all participants underwent medical examinations before the start of the season, and the tests were carried out without any injuries or physical discomfort. The study complied with the requirements of the Declaration of Helsinki. The tests were part of the routinely conducted testing process (or assessment of physical fitness level) in the hall.

2.6. Statistical Analysis

The mean, median and standard deviation values were calculated for all designated indicators. The normality of distribution was checked using the Shapiro-Wilk test. Due to the lack of normality of distribution, differences between the compared groups were assessed based on Wilcoxon and Friedman ANOVA tests. Spearman's rank correlation coefficients were calculated for selected indicators. Statistical significance was assumed at $p < 0.05$. All calculations were performed using Statistica 13.

3. Results

Table 2 summarizes the descriptive statistics for the Maximal Aerobic Speed (MAS) test and the Velocity Intermittent Fitness Test (V_{IFT}). Figure 1 graphically shows the differences in average values of the tests performed for tests A and B. It can be seen that the tests performed after a 6-month training cycle statistically significantly higher values for MAS ($Z = 14.45$; $p < 0.001$) and V_{IFT} ($Z = 13.11$; $p < 0.001$). Figure 2 shows average changes in the tests carried out over the subsequent years 2018–2022. It can be observed that in both tests, the values of Maximal Aerobic Speed ($F = 206.31$; $p < 0.001$) and Velocity Intermittent Fitness Test ($F = 209.11$; $p < 0.001$) increase in subsequent years of training. Table 3 lists Spearman's correlation coefficients between the year of research, the player's age, the player's position on the pitch, and the tests performed. It can be seen that the player's position on the pitch has no connection with the results of endurance tests. However, there is a relationship between age and endurance, but there is a weak relationship between the year of research and the test performed.

Table 2. Descriptive statistics of recorded variables.

Test	Variable	Mean	Median	Minimum	Maximum	SD
A (June)	MAS [m/s]	4.464	4.400	3.400	5.400	0.332
	V_{IFT} [km/h]	19.569	19.500	15.000	23.500	1.462
B (December)	MAS [m/s]	4.623	4.700	3.800	5.400	0.319
	V_{IFT} [km/h]	20.272	20.500	16.500	23.500	1.398

MAS – Maximal Aerobic Speed; V_{IFT} – Velocity Intermittent Fitness Test

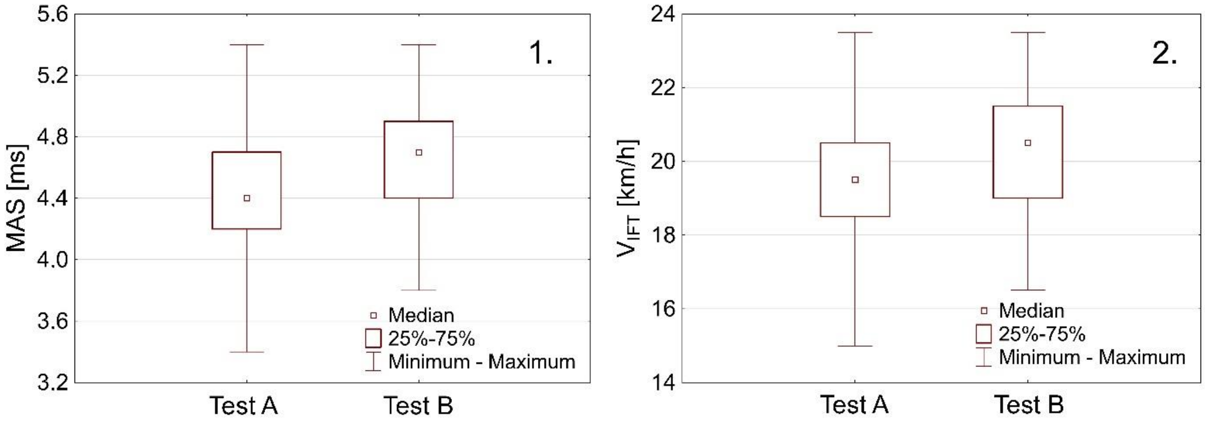

Figure 1. Average values of tests performed in June (Test A) and December (Test B): 1. MAS – Maximal Aerobic Speed (Z = 14.45; $p < 0.001$), 2. V_{IFT} – Velocity Intermittent Fitness Test (Z = 13.11; $p < 0.001$) depending on the test date.

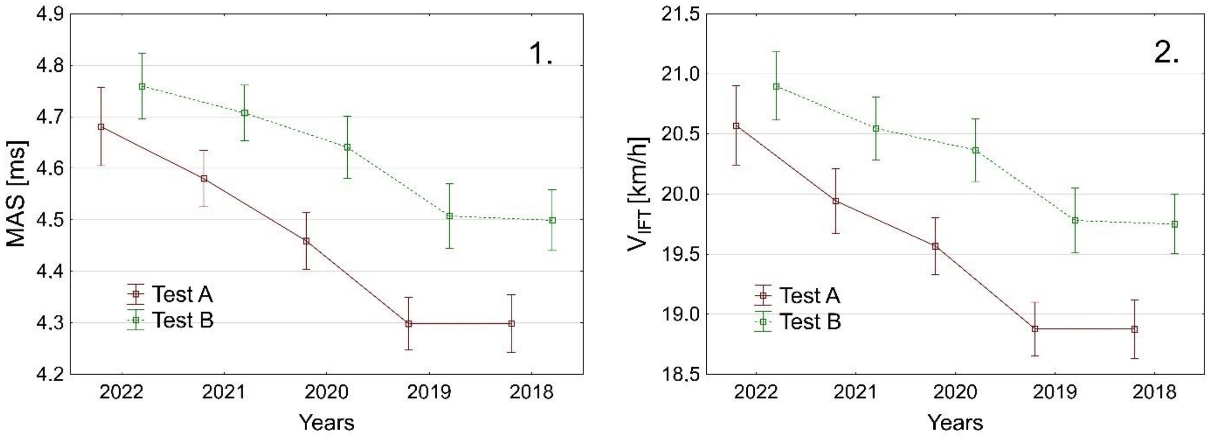

Figure 2. Average values of tests performed in June (Test A) and December (Test B): 1. MAS – Maximal Aerobic Speed (F = 206.31; $p < 0.001$), 2. V_{IFT} – Velocity Intermittent Fitness Test (F = 209.11; $p < 0.001$) in subsequent years of training.

Table 3. Spearman rank correlation table of selected variable.

Variable	V_{IFT} A	MAS A	V_{IFT} B	MAS B
Year of research	0.43*	0.45*	0.31*	0.32*
Player’s age	0.55*	0.53*	0.53*	0.52*
Player’s position on the pitch	0.08	0.09	0.05	0.05

* $p < 0.05$; MAS – Maximal Aerobic Speed; V_{IFT} – Velocity Intermittent Fitness Test; A – Test A (in June); B – Test B (in December)

4. Discussion

Based on the performed analysis, it can be assumed that the applied training based on the wave periodization model significantly increased the endurance of the RKS Raków Częstochowa Academy players. The recorded average test results show that the players improved their fitness capabilities over the period under study. The research shows that in each year between 2018 and 2022, the training intervention increased the Maximal Aerobic Speed and Velocity Intermittent Fitness Test values of the surveyed players. Therefore, the use of Small-Sided Games confirms an improvement in technical and tactical skills and fitness abilities [15]. In the long-term development of young football players, using both intensive and extensive patterns in small games is beneficial [33]. That is why they are trendy and widely used in periodization. Studies that evaluated the combination of SSG and high-intensity running-based exercise have shown significant benefits on aerobic capacity [30,31]. Additionally, research by other authors confirms an improvement in VO_{2max} in athletes who already have a good level of aerobic capacity after using intermittent interval exercises [16].

Current research reports that soccer players need a well-developed ability to perform repeated short, high-intensity running activities over two 45-minute periods, which can be viewed as intermittent endurance capacity [17, 18]. Therefore, it is believed that the importance of endurance in football is very important [19], which in match practice is of great importance and may affect the final result of the entire team or club. It can be seen that the position of the tested players on the pitch is not related to the results of endurance tests. The recorded positive correlation between age and endurance confirms the current knowledge that the biological development of the tested athletes influences their physical fitness, which is consistent with the results of other studies. [20, 21]. However, it is worth noting that the topic of reactions to aerobic training in children and adolescents is controversial and strongly depends on the type of training program [22]. Therefore, there is a clear need for research that examines the relationship between maturation and training through carefully monitored programs [23–25].

Another important aspect is the standardization of areas for variable game formats. Thanks to this, appropriate additional regulations (rules) can be used to shape the selected type of endurance in the game [34]. Additionally, it can be noticed that the tasks performed by players on the pitch or their position do not affect the results of the tests conducted in the analysed group. This does not mean that this pattern persists in senior football. Studies on the specialization of a player in particular positions show significant differences in the generated pitch parameters that correlate with the level of endurance [32]. This aspect should be observed when working with young players, and correctly determining the moment of specialization may prove crucial in the long run.

To sum up, it can be said that using training based on the wave periodization model is an effective method of long-term planning and development of endurance in football players. This may result, among others, from the players' full commitment not only in the physical area but also in many others [11].

This article may expand knowledge regarding the influence of a modified training periodization model on shaping the endurance of players involved in a long-term development program. This may contribute to achieving better sports results on the pitch. The conducted research is in line with the analyses of coaches and researchers which confirm the need to monitor players' progress [26–28].

The authors hope to fill the gap in knowledge regarding the long-term observation of young football players in a leading football club in Poland with an analysis of the impact of training based on tactical periodization.

Study Limitations

Due to the type of analysis undertaken and its long observation period, it should be noted that the analysis is general in nature and does not consider areas of individual influence, e.g. players' regeneration, diet, and sleep quality. The mentioned components (data) could influence reactions and adaptations in the muscular and physiological systems.

Practical Aspect

The applied physical preparation program combined with tactical and technical preparation can be effective in the long-term and multi-dimensional development of the endurance of young players. The idea of using the tactical periodization model (wave periodization) is undoubtedly transferable to other team games in terms of players' motor preparation and shaping motor features in relation to the requirements of a given position and type of game.

Direction of Further Research

Analysing the latest literature, the authors want to add GPS analysis to the games used in order to influence the training process even more precisely, increase work efficiency, and limit injuries and overload states of young football players. Additional data can allow creating an optimization model and effectively influence each player's individual needs. This may have a direct impact on the effectiveness of the entire team in league competition.

5. Conclusions

1. The study showed that the use of a modified wave periodization model significantly improved the aerobic endurance of soccer players, which was proven by an increase in the values of MAS (Maximum Aerobic Speed) and VIFT (Interrupted Endurance Test Index) in tests conducted twice during the year.
2. The analysis showed no direct relationship between a player's position on the pitch and his results in endurance tests. This finding emphasises that all soccer players can benefit from wave periodization training regardless of their position.
3. The study results highlight how crucial endurance is in football and its impact on athletic performance. The authors indicate the need for further research in this area, especially in developing and adapting training programs, including the potential use of GPS analysis, to increase training effectiveness and minimize the risk of injuries and overload in young athletes.

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